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Raspberry Pi

Official Magazine
#152 | April 2025

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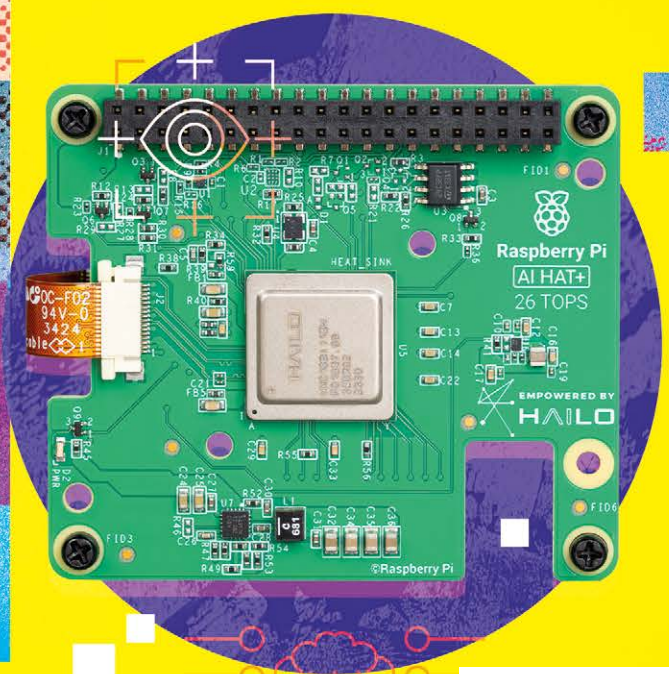

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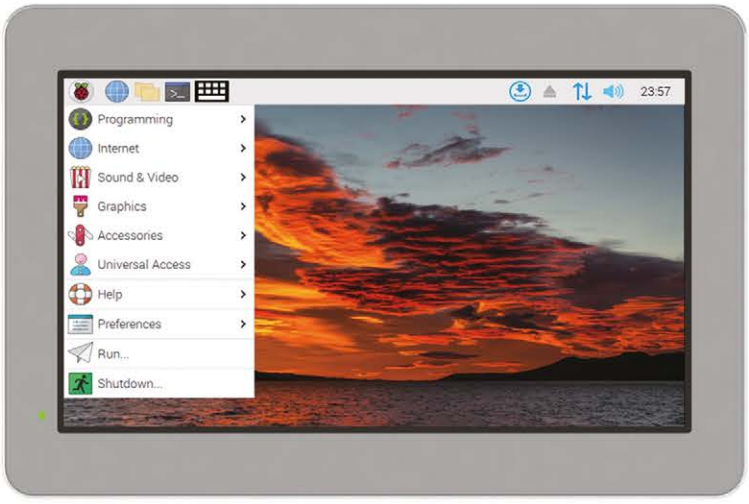
Industrial Raspberry Pi

ComfilePi



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The ComfilePi is a touch panel PC designed with high-tolerant components and no moving parts for industrial applications. It features a water-resistant front panel, touchscreen, color LCD (available in various sizes), RS-232, RS-485, Ethernet, USB, I2C, SPI, digital IO, battery-backed RTC (real-time clock), and piezo buzzer.

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COMFILE TECHNOLOGY

Welcome to Raspberry Pi Official Magazine

Editor
Lucy Hattersley
Lucy is trying to coax a virtual environment with a swapfile to install a frankly ludicrously large model and is loving every minute of it.

rpimag.co

Artificial intelligence is at the heart of the modern tech industry. Through cyclical processes of training and inference, this remarkable technology helps us understand masses of data, make decisions much faster and at scale (if not necessarily better), and make our devices smarter and more intuitive.

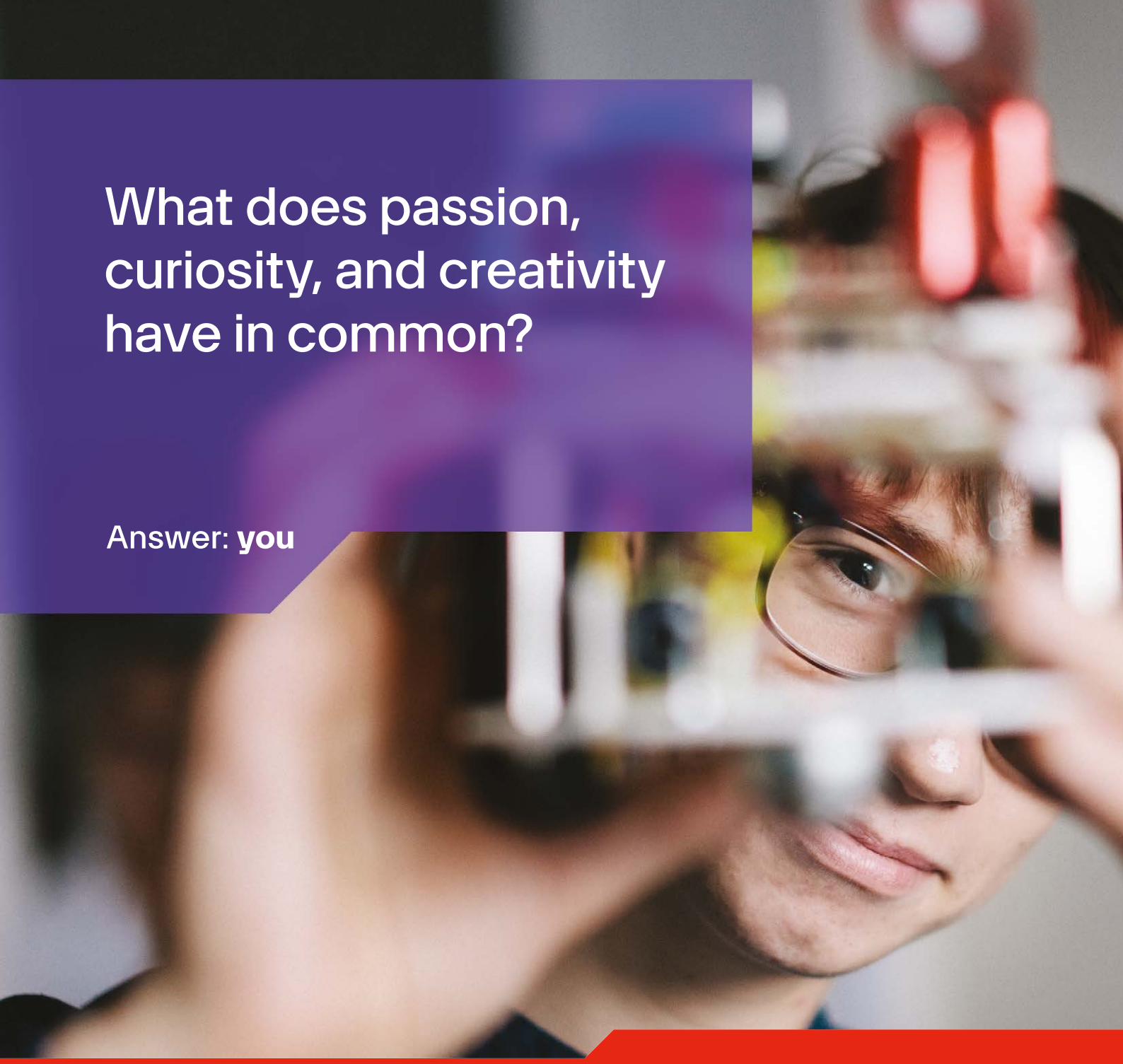
The engineers at Raspberry Pi have been busy helping our favourite computer get ready for this remarkable new generation of technology. Alongside a bulkier 16GB Raspberry Pi 5 model with extra RAM to contain larger AI models, we have custom accelerator hardware like AI HAT+ and Raspberry Pi AI Camera with Sony IMX500 Intelligent Vision Sensor.

This month we've been building the ultimate Raspberry Pi AI hardware stack and putting it to work with AI models. We're using this to understand the underlying principles of training models, and using them to make inference decisions. Then we're looking at practical projects you can deploy to your Raspberry Pi today.

AI isn't everything, though. If you prefer your technology more analogue, KG has created an amazing CRT emulation console, Nicola is looking at soap making, and Rob has written the A to Z of Raspberry Pi.

This magazine is incredible fun to create. Just like AI: challenging at times but with a lot of rewards. I hope you enjoy reading it as much as we enjoyed writing it.

Lucy Hattersley – Editor



What does passion, curiosity, and creativity have in common?

Answer: **you**

Whatever you call yourself (Maker, Student, Tinkerer, Hobbyist, Tech-Wizard...) you embody the spirit of invention–and that spirit is what creates a better world for us all.

If you can dream it up, we'll help you build it at digikey.co.uk

DigiKey

we get technical

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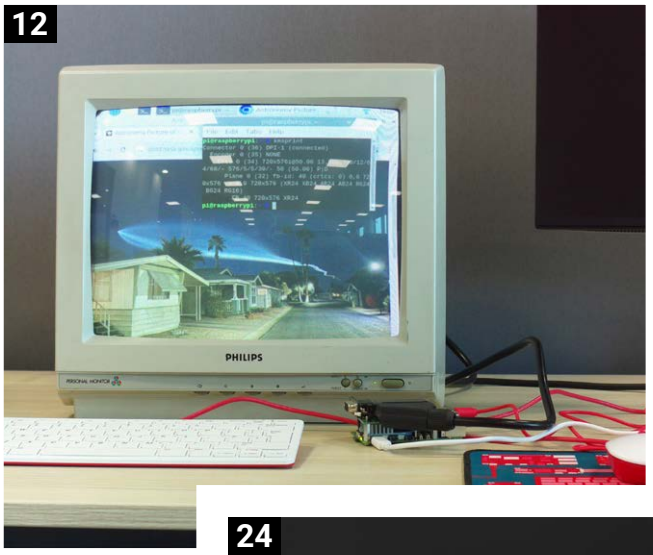

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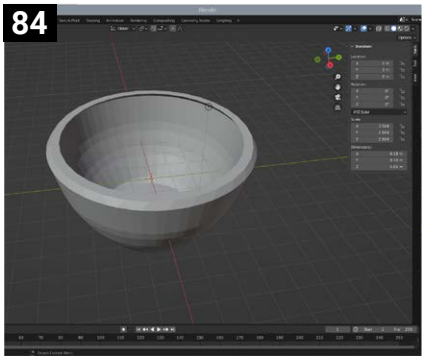

Top Projects

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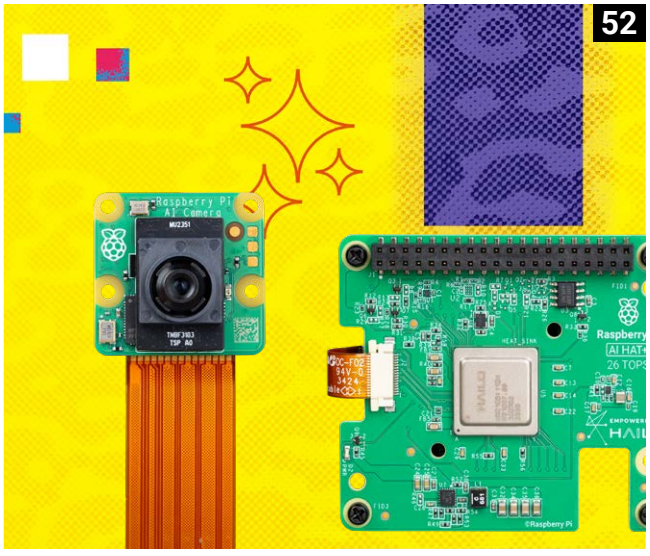

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Feature

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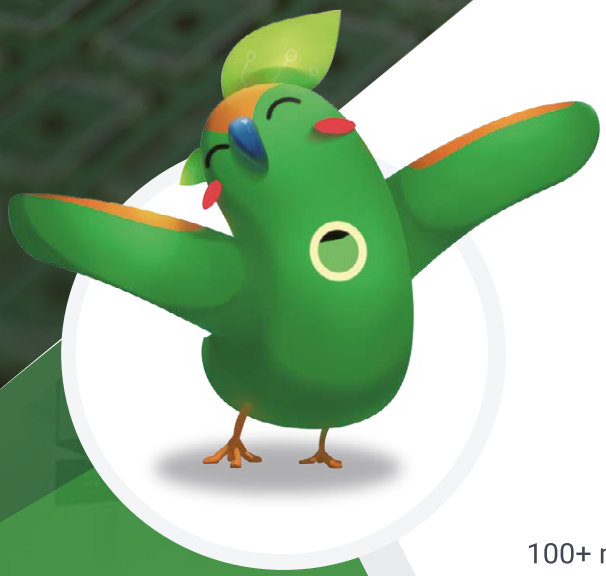

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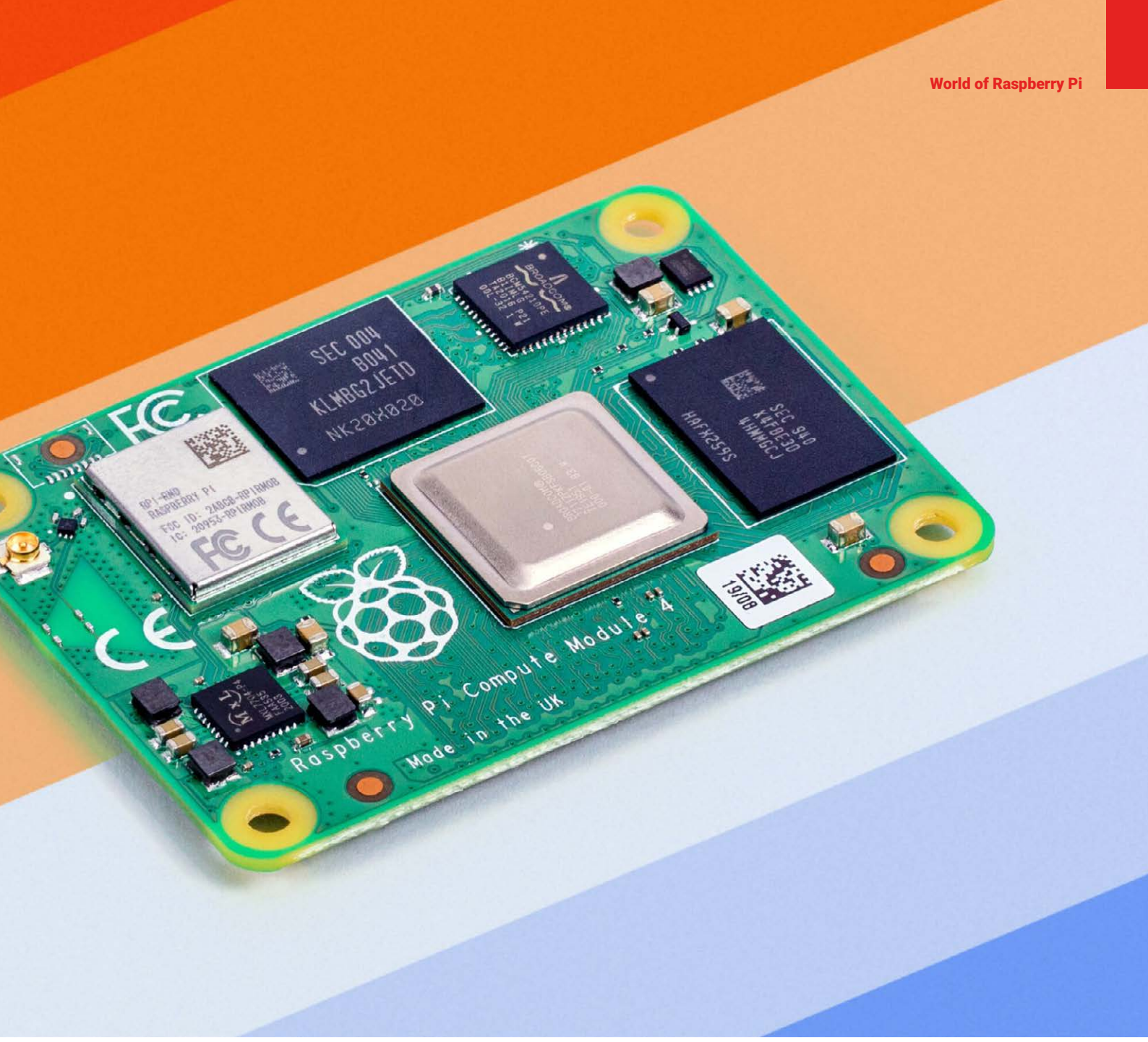
Extended temperature range for Compute Module 4

Sturdy CM4 capable of operating in extreme environments. By **Lucy Hattersley**

Raspberry Pi Compute Module 4 – the deep embedded version of Raspberry Pi 4 – has a new, sturdy, update that enables it to operate in extreme temperature environments.

Raspberry Pi computers have been deployed in a wide array of challenging environments, ranging from desert robots (**rpimag.co/deserteye**) to an Antarctic ice camera (**rpimag.co/antarcticpicam**). Now, a number of Compute Module 4 variants come with an extended temperature range of -40°C to +85°C, ideal for handling applications in more extreme indoor and outdoor environments.

> *Our products need to perform flawlessly in harsh environments*



"Our products need to perform flawlessly in harsh environments," says Eben Upton, Raspberry Pi CEO and co-founder, even when "subject to extremes of temperature or pressure, or running unattended for years on end in remote or inaccessible locations."

The new variants integrate extended-temperature-range SDRAM and eMMC parts from Raspberry Pi's partner Samsung, explains Eben: "All other components on the board are already qualified to the broader temperature range.

"We are offering variants with and without wireless connectivity, and with a range of SDRAM and eMMC densities," adds Eben. "A core subset of these variants is available to purchase from stock from our network of Raspberry Pi Approved Resellers (**rpimag.co/resellers**), while others can be built to order, subject to a minimum order quantity."

You can find a full list of variants, including their prices, in the Raspberry Pi Compute Module 4 product brief at **rpimag.co/cm4productbrief**.

▲ Raspberry Pi Compute Module 4 with extended temperature range

With Raspberry Pi technology already providing high-quality, low-cost compute everywhere from the ocean floor (**rpimag.co/nous**) to low Earth orbit (**rpimag.co/cubesat**), "we've seen a fair few exotic deployments," says Eben, "but we suspect our customers will build things with Compute Module 4 (**rpimag.co/cm4**) extended temperature variants that will nevertheless surprise us!"

How we added interlaced video to Raspberry Pi 5 DPI

It can now output to a classic CRT TV.

By **Nick Hollinghurst**

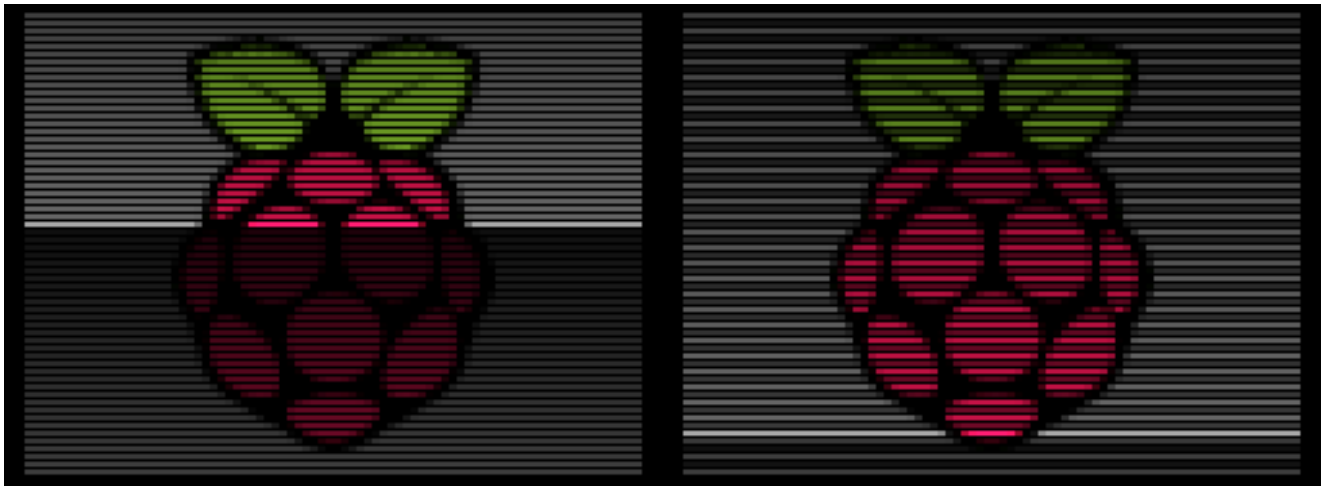
▲ TV output, now with interlace

The very first Raspberry Pi had a composite video output, and all models with a 40-pin header have a display parallel interface (DPI) output. With some external components, DPI can be converted to VGA or RGB/SCART video. Those analogue interfaces are still in demand for retro media and gaming.

Raspberry Pi 5 was a big step up in processing power, but unlike previous models, its DPI block didn't support interlaced video (which isn't really part of the DPI standard), so it couldn't send full-resolution RGB to a CRT television. Until now.

Early TV systems worked by scanning the image from (usually) left to right, top to bottom. There were tradeoffs between frame rate, resolution, and radio bandwidth demands. With interlace, the frame is divided into odd and even lines. The odd lines are scanned from top to bottom, followed by the even ones. This reduces flicker and improves smoothness without increasing bandwidth. The two parts of each frame are called 'fields'.

We hope this helps people to enjoy an authentic retro experience



▲ Illustration of progressive and interlaced scanning

Analogue TVs don't need to do anything special to tell which field is which. Provided the horizontal scanning rate is an odd multiple of half the vertical rate, the scan-lines will fall into the right places on the screen. A key feature of interlaced video is that vertical synchronisation pulses can occur in two different phases, relative to the horizontal ones.

The problem to solve

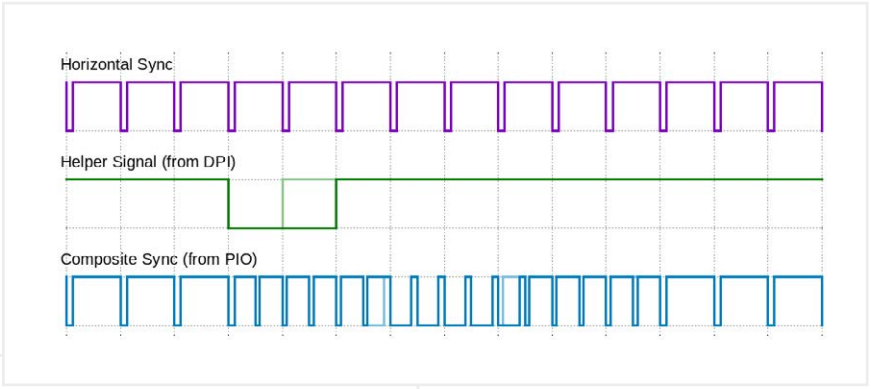
To generate interlaced video, we had to do three things:

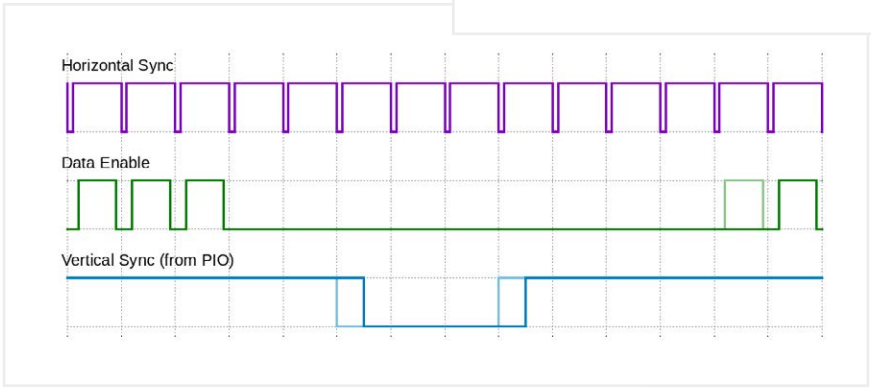
- Get DPI to emit fields (even or odd lines of a frame buffer) instead of frames
- Time those signals so that they will be in the proper arrangement for interlace
- Generate appropriate sync pulses

The first part is easy. By changing an address and doubling the 'stride' between lines, we can arrange for DPI to read and display just the even or odd lines of a frame-buffer. We use an interrupt to switch back and forth between even and odd fields, 50 or 60 times a second.

The second problem is solved by hacking the DPI peripheral. If we time it just right, we can change its configuration on the fly, so that every second frame – every second field, I should say – gets one extra blank line at the end. The extra line should come after an upper field and before a lower one.

The third problem is harder. RP1's DPI has no way to make vertical sync pulses start midway through a line.





▲ PIO uses HSync and a 'helper signal' (modified VSync) to make interlaced CSync
◀ PIO snoops on HSync and DE to generate VSync; the odd field is shown by fainter waveforms

PIO to the rescue

Like our RP2040 (**rpimag.co/rp2040**) and upgraded RP2350 (**rpimag.co/rp2350**) microcontrollers, the RP1 chip has a Programmable Input/Output (PIO) block. It can generate many kinds of real-time waveforms. We recently added PIO support to our version of the Linux kernel, exposing it to device drivers and user programs.

PIO snoops on DPI's horizontal sync (HSync) and data enable (DE) pins to generate vertical sync (VSync). You can see the PIO code here: **rpimag.co/rp1dpigit**. Two of PIO's four state machines (SMs) are used: one SM serves as a timer, generating an 'interrupt' at the start and middle of each line. The other SM finds the start of the vertical blanking interval (the first line without DE), then counts half-lines to work out when to start and end the VSync pulse. Finally, it samples DE again to detect the extra blank line, to ensure it has the correct field-phase for next time.

There are some gotchas: the DE signal must be output on GPIO1, whether it's used or not. PIO is not synchronised to the DPI clock and its VSync output can jitter up to ±5ns. That isn't significant at standard-definition TV rates, but it could be a problem at higher resolutions! Finally, the sync fix-up consumes most of RP1's PIO instruction memory, so PIO can't be used for other cool things (**rpimag.co/piolib**) at the same time as generating interlaced DPI.

config.txt

> Language: **Bash**

```
001. dtoverlay=vc4-kms-dpi-generic
002. dtparam=clock-frequency=13500000
003. dtparam=hactive=720,hfp=12,hsync=64,hbp=68
004. dtparam=vactive=576,vfp=5,vsync=5,vbp=39
005. dtparam=vsync-invert,hsync-invert
006. dtparam=interlaced
```

If you have a Raspberry Pi 5, a VGA666 HAT, and a VGA monitor that can run at 50Hz TV rates, you could test it by adding the listed code to **config.txt**.

Make sure you've upgraded to the latest Raspberry Pi OS. Note that the above configuration will output DPICLK (which isn't used) on GPIO0, and DE (which PIO needs to snoop on) on GPIO1, and precludes the use of I2C/DDC on those pins. Other HATs might need a custom overlay to enable DE output on GPIO1 (where safe to do so).

Composite sync too

VGA cables have separate wires for horizontal and vertical sync, but TVs combine everything in one signal (composite video). A halfway house, used in SCART, is 'composite sync', which multiplexes the two sync signals but keeps them separate from RGB.

Most existing SCART HATs have circuitry to generate composite sync, but PIO can do it too! To keep the code size down, it's not in the kernel driver; sample PIO code can be found here: **rpimag.co/dpicsyncc**. To test it you'll most likely need modified hardware, and this time you'll need a pin control that does not output DE on GPIO1. Select an interlaced video mode, then run the example PIO program with `sudo` and a few parameters.

Remember that RP1's DPI can't generate VSync in interlaced modes. Instead, we get it to output a 'helper signal' that alternates between 1-line and 2-line pulses. PIO snoops on HSync and the helper signal to synthesize CSync (composite sync).

In progressive modes, DPI can generate a normal VSync, therefore PIO snoops on that instead.

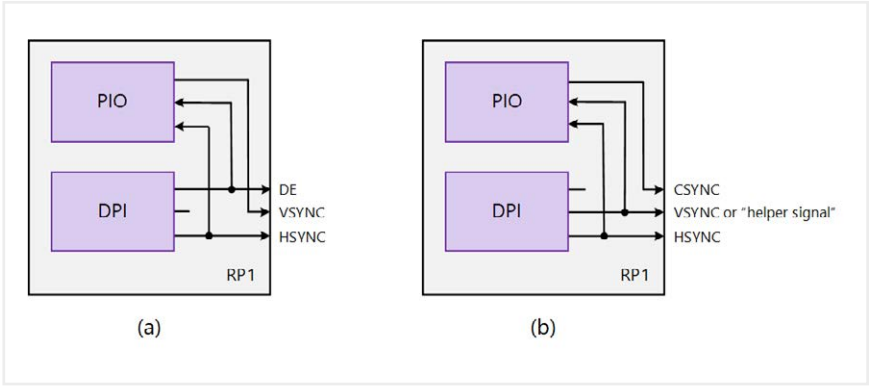
The ins and outs

You might be wondering why PIO can't completely replace DPI. It's mostly down to bandwidth and clocking. The DPI block has larger FIFOs and can transfer data across the PCIe link much more efficiently. DPI benefits from a dedicated clock, to generate arbitrary pixel rates. PIO would also struggle with some pixel format conversions.

Fortunately, DPI can take care of the pixels, leaving PIO to fix up the sync signals.

The two blocks can communicate only through GPIO pins – normally GPIOs 1, 2, and 3.

We hope this helps people to enjoy an authentic retro experience with their favourite television shows and games on a real CRT TV!



Two ways PIO can help DPI: (a) Fix up VSync for interlace; (b) Generate composite sync

RP2350 now available at JLCPCB

RP2350 microcontroller is available via JLCPCB's fantastic fast-turn PCB assembly service. By **Chris Boross**

RP2350 is Raspberry Pi's latest high-performance, secure microcontroller, offering unparalleled levels of processing and flexibility at its very affordable price point. Now that rapid assembly of RP2350-based boards is available from JLCPCB, prototyping and initial production of your designs is straightforward and speedy.

Before users submit a design to JLC, we're asking that they do the following:

- Read and follow our RP2350 hardware design guide here: **rpimag.co/rp2350hwdesign**
- Use the Abracon ABM8-272-T3 12MHz crystal oscillator: **rpimag.co/ABM8**
- If using the on-chip SMPS, use the custom Abracon polarised inductor: **rpimag.co/AOTA**
- Familiarise themselves with the RP2350 datasheet including chip errata: **rpimag.co/rp2350datasheet**

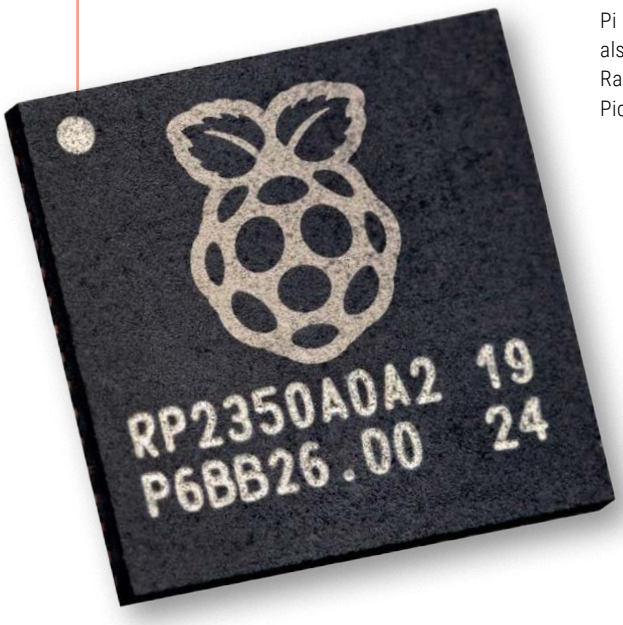
This is to help ensure the designs will function well across temperature and process variations. We also provide a helpful reference design in KiCad format (**rpimag.co/minikicad**, direct download).

We're huge fans of JLC's PCB services and it's been great working with them to bring RP2350 into the firm's inventory of processors. To learn more about its service, visit the JLCPCB website.

▼ Producing PCBs with Raspberry Pi RP2350

◀ JLCPCB's fast-turn PCB assembly service

Prototyping and initial production of your designs is straightforward



▼ Raspberry Pi RP2350 also powers Raspberry Pi Pico 2

Other resellers

Initially, the RP2350A and RP2350B package versions are available via JLCPCB. The RP2354A and RP2354B versions (the package versions with stacked flash) will be available at JLCPCB, as well as other distributors and authorised resellers, later this year.

Visit Raspberry Pi's RP2350 page (**rpimag.co/rp2350**) to learn more about the RP2350 family of microcontrollers.

Visit the JLCPCB website to learn more or submit a design to JLC's PCB service (**rpimag.co/jlcpcb**).

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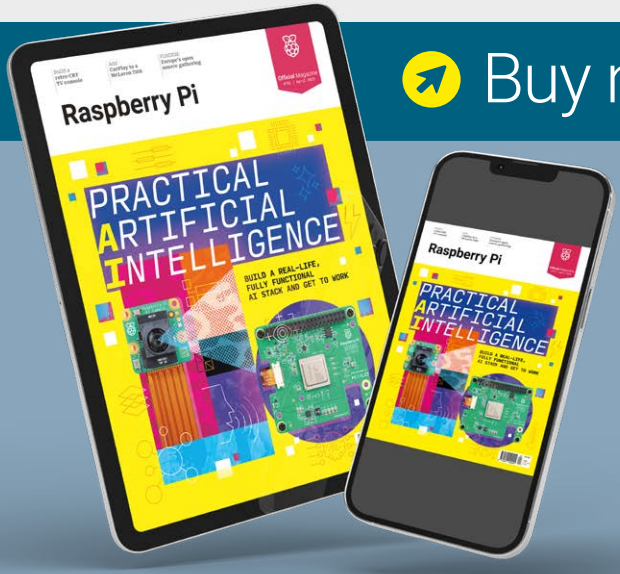

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McLaren 720S CarPlay/AirPlay

Not content with landing a fantasy supercar, this maker insisted on giving it a Raspberry Pi 5 audio makeover. **Rosie Hattersley** likes what she hears

Maker

Adam Bell

Adam is an Apple software specialist who focuses on interaction design, animations, gestures, and reverse engineering.

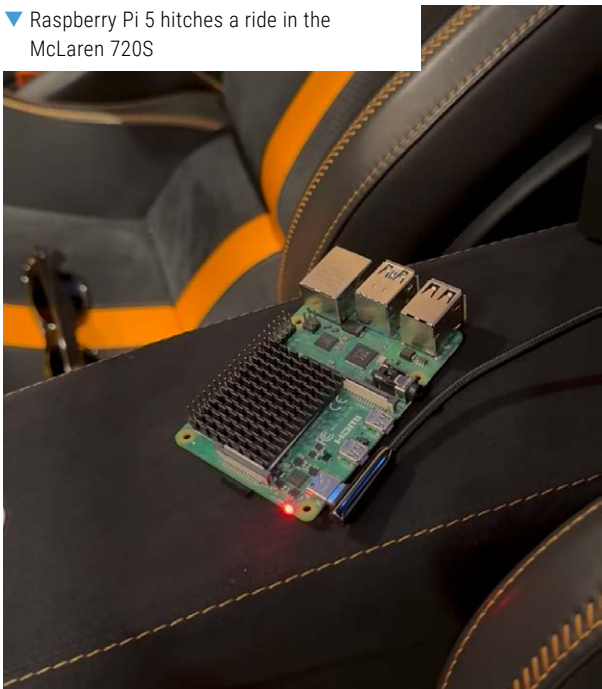
rpimag.co/mclarencarplay

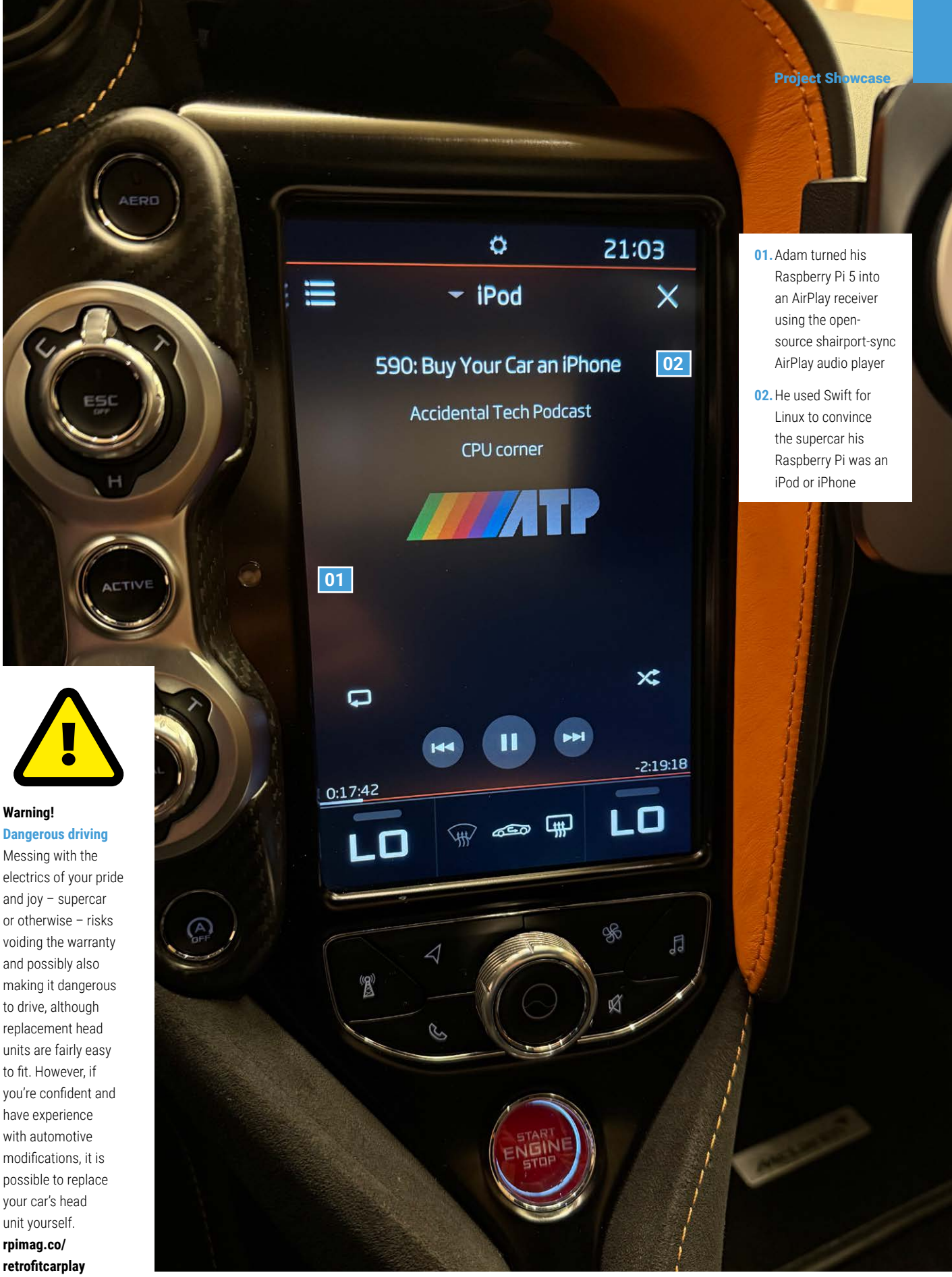
In a scenario that is somewhat outside our own range of experience, software engineer and car enthusiast Adam Bell recently became the brand-new owner of a McLaren 720S. The car is resplendent in McLaren Orange and "amazing in every single way… except for the lack of CarPlay", having launched (in 2017) just before the in-car entertainment system became prevalent.

Despite being the very proud owner of a supercar (and sufficiently skilful to handle the corkscrew at Laguna Seca), Adam missed the way CarPlay automatically connects and streams audio wirelessly from his iPhone, especially as he drives the car on his daily commute [sweet!]. The McLaren's integrated infotainment system does work with Bluetooth audio, but only the lossy AAC variety and wasn't quite the slick setup Adam had become accustomed to. High-quality audio can be streamed wirelessly and Adam decided using Raspberry Pi 5 as an AirPlay receiver would offer the best shot at kitting out the ultimate supercar with an exceptional audio setup. The resulting Raspberry Pi 5 AirPlay project ended up being something of a rollercoaster, a bit like the racing tracks Adam loves to throw his beloved McLaren around.

> *How to trick the car into thinking his Raspberry Pi was an iPhone*

▼ Raspberry Pi 5 hitches a ride in the McLaren 720S





01. Adam turned his Raspberry Pi 5 into an AirPlay receiver using the open-source shairport-sync AirPlay audio player

02. He used Swift for Linux to convince the supercar his Raspberry Pi was an iPod or iPhone

Warning!

Dangerous driving

Messing with the electrics of your pride and joy – supercar or otherwise – risks voiding the warranty and possibly also making it dangerous to drive, although replacement head units are fairly easy to fit. However, if you're confident and have experience with automotive modifications, it is possible to replace your car's head unit yourself.

rpimag.co/retrofitcarplay

▲ Adam's McLaren 720S burns rubber at the racetrack

Pulling a Swift one

Adam revels in reverse coding, mainly in iOS and macOS, but is also well versed in Linux, even giving talks on using the Swift general-purpose programming language on the open-source platform (**rpimag.co/adambelltalks**). He enjoys using Raspberry Pi "since it's a pretty lightweight yet powerful, Arm-based machine that you can sort of repurpose to do anything with" and realised it could be useful here since it could be powered from the car's USB port without draining the battery. He finds Swift on Linux extremely dependable: it was "a naturally easier language for me to use given I can share code between my iOS projects and my Linux ones". Adam's detailed knowledge of the iPhone operating system meant he could quickly visualise how to trick the car into thinking his Raspberry Pi was an iPhone, using code he wrote in Swift for Linux and cleverly reverse-engineering parts of Apple's iAP2 (iPod Accessory Protocol v2). "The client would set up an iAP2 session and stream audio from the shairport-sync receiver over USB to the car, making the car think an iPhone was providing audio over USB."

Full throttle

Adam began the CarPlay project using Raspberry Pi 4, but was delighted when Pi 5 launched, immediately relishing its significantly faster boot time – "roughly seven seconds with all of my code running, including the iPhone emulation layer and AirPlay network". This meant he could be listening to his favourite songs almost as soon as he'd strapped himself in to the driver's seat and pressed the ignition button. He even wrote his own iPhone app, Albums, to serve up tracks he particularly enjoyed.

Adam was less convinced about working on everything in place: "McLaren P1 racing seats are amazing for keeping your body secure in fast corners at the race track; however, the ergonomics for using a laptop while sitting in them is very hard on your back and neck." He worked out that the car had a JVC Kenwood infotainment system and ended up buying a very cheap JVC Kenwood aftermarket stereo that supported iPhone USB playback. He used this kit on his desk to do most of the reverse-engineering and testing. Some of this was guesswork since

▲ Cynthion can be used with proprietary devices to retrofit and revive them

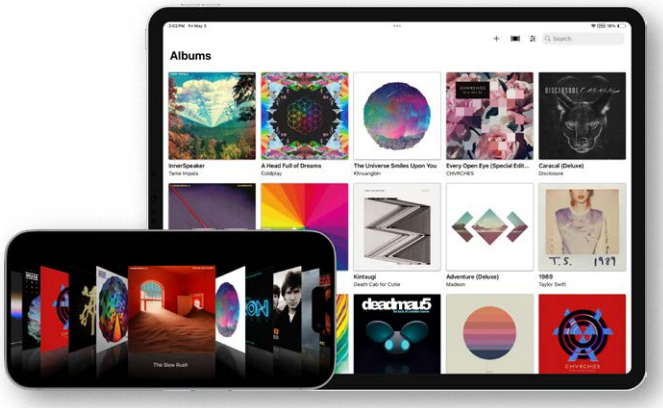
iAP2 is not publicly disclosed (you need to be a member of Apple's MFI program). Adam therefore spent "a lot of time throwing random things at the car's infotainment system to see what would happen, searching various corners of GitHub" to get ideas for missing things. Cynthion (**rpimag.co/cynthion**), a Wireshark-like USB protocol analyser and traffic sniffer, helped him understand iAP2's protocols, but there were still "a lot of nights spent sitting in my garage poking at my car's stereo and seeing it crash or reboot".

Nonetheless, Adam says "doing something end-to-end like this allows you to appreciate all the hard work that goes into building reliable embedded systems, and it's so satisfying once you get something you made working, no matter how ridiculous or over-engineered it ends up being!"

Quick FACTS

- Mike Brady's shairport-sync was an inspiration (**rpimag.co/shairport**)
- There was audible interference when connecting Raspberry Pi to the car stereo…
- This prompted Adam to choose the wireless iAP2 setup instead
- Long periods sitting in McLaren's P1 racing car seat can be uncomfortable…
- … and it convinced Adam to build a test rig in his house

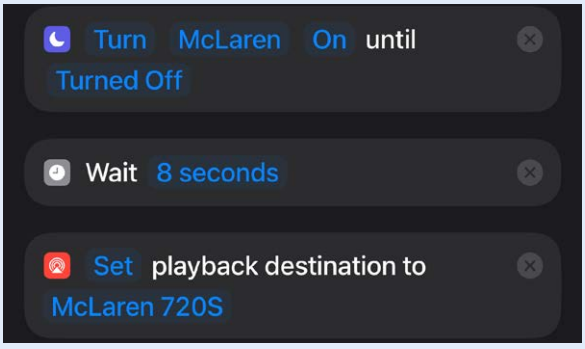
▼ Adam wrote an iOS app specifically to get to favourite songs faster



Hey Siri, play Fast Car

1. Adam's setup is unique to his model of car, but shairport-sync (**rpimag.co/shairport**) can be used to turn Raspberry Pi into an AirPlay receiver for old iPods and other players using Raspberry OS Lite and compiling Swift (**swift.org**).

2. Adam's version of iAP2 enabling his car stereo to communicate with Raspberry Pi masquerading as an iPod was based on wiomic's iap2 (**rpimag.co/iap2**) and handles authentication, media controls, and metadata.



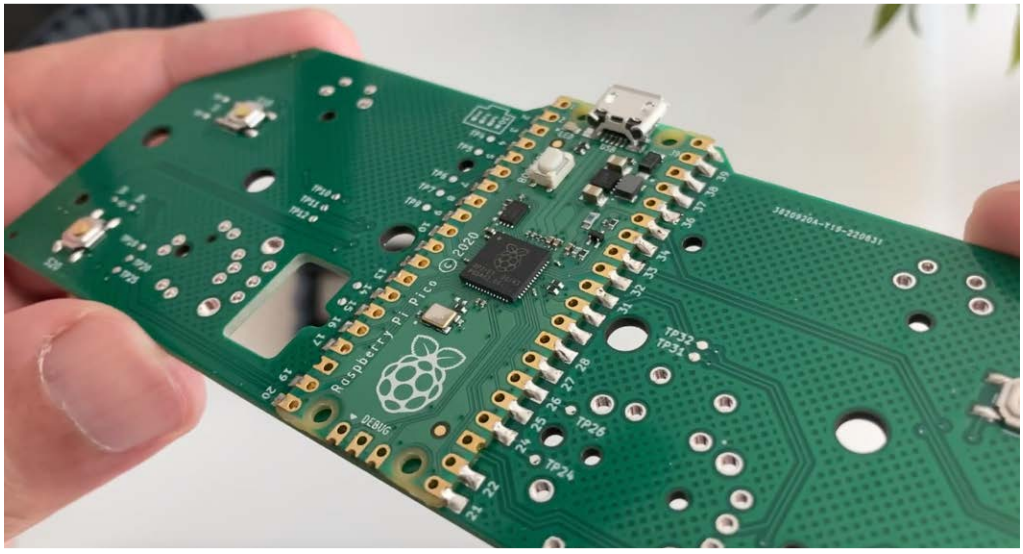
3. Configure shairport-sync to output using the USB audio device that the ipod-gadget project creates.

Alpakka v1.0 controller

RP2040 is used for the core module of this accessible controller, now with wireless functionality. By **Rosie Hattersley**

Makers
Michael Przybilski and Marcos Diaz
Finland-based software engineers Michael and Marcos regard firmware as their bread and butter.

inputlabs.io



▶ Raspberry Pico freshly soldered to the custom Alpakka printed circuit board

Software engineers Michael Przybilski and Marcos Diaz set up Input Labs in late 2022 with a mission of enabling "people with disabilities such as arthritis, who have difficulties holding and operating traditional pointing devices, such as computer mice, to comfortably work with computers". Now based at the renowned Maria 01 startup campus near Helsinki, Input Labs' founders are passionate about open-source hardware and the mutually supportive communities that help drive innovation and improvements. A year into their journey, Marcos and Michael announced a 3D-printable version of a traditional gaming controller that "enables the user to aim comfortably, with two hands, while making the interaction with the computer very precise". Alpakka v0, their two-handed reference design based around Raspberry Pi Pico, launched in late 2023 to an enthusiastic reception, and now the upgraded Alpakka v1 is available.

01. Alpakka is a 250MHz low-latency customisable input controller based around a Pico microcontroller

02. Two gyroscopes precisely track its location and compensate for input bias, making it a formidable games controller

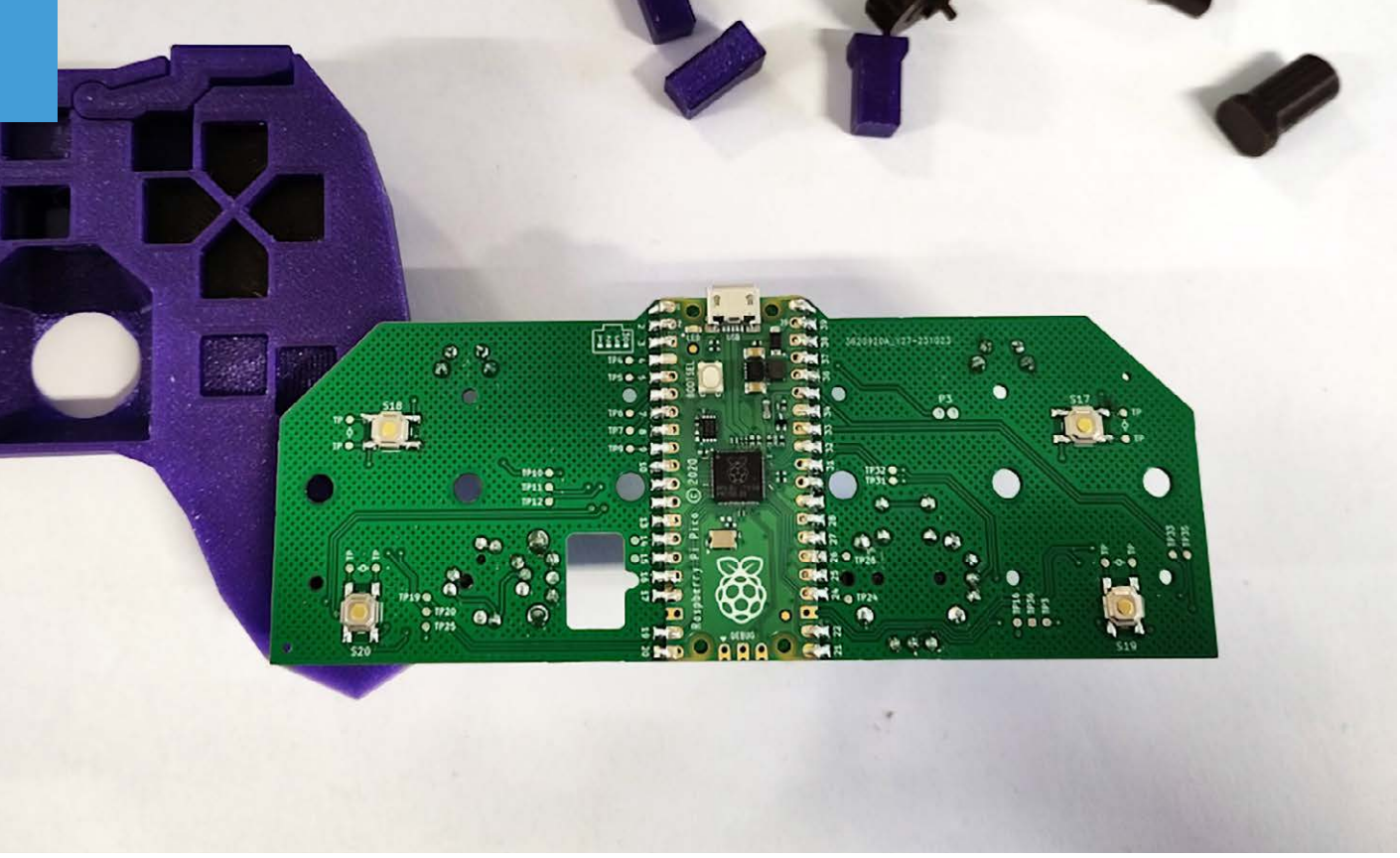
Alpakka's gyroscopes make it ideal for flick-stick gameplay in first-person shooters

Complete user control

Alpakka struck a chord with gamers keen on the customisable case design – the 3D-printable low-polygon housing could be remixed in Blender for a smoother one – and the precision provided by two IMUs (inertial measurement units) featuring gyroscopes. Precisely detecting movement of the handheld device significantly reduces drift and also compensates for individual bias, both of which are manna for gamers, explains Michael. Alpakka's gyroscopes also make it ideal for flick-stick gameplay in first-person shooters.

The pair were pleased with how well Raspberry Pico addressed their needs, with plenty of addressable GPIO pins for the various triggers and buttons alongside a quality ADC (analogue to digital converter) and solid documentation and developer community. "While Alpakka itself was designed from scratch, we took of course advantage of all the other things that work around us," says Michael. The 3D parts have low tolerances, as our own (*HackSpace*) review of the Alpakka v0 highlighted (**rpimag.co/alpakkareview**). The pair experimented with various hardware components, such as buttons, to find what level of required force would feel best for the triggers. To this end, they benefited from the invaluable input of a slew of eager testers, including a number with physical disabilities.

▼ Input Labs sells Alpakka in kit form, with a choice of colours



▲ *HackSpace* 3D-printed and tested Alpakka v0 and was suitably impressed

Michael says that it was a particular challenge to integrate the mechanical user interaction such as the triggers and buttons with the conductive touch area, but models from the likes of KiCad and Blender were helpful, as were Raspberry Pi's TinyUSB libraries. There is an accompanying 'Ctrl' app that allows users to configure aspects such as the gyroscope and button sensitivity. The 3D designs, PCB design, firmware, and Ctrl app can all be found in Input Labs' GitHub repositories (**github.com/inputlabs**).

Considered approach

The attention to detail certainly paid off. *HackSpace* magazine tested the original Alpakka controller kit and reported that, once 3D-printed and built, "it feels great in your hand. It's sturdy and just weighty enough to feel solid" with a gyroscope that means tilting the controller dictates mouse movements.

Such elements reflect Input Labs' recognition that the Alpakka controller is useful for those with particular adaptive needs, but it's the gaming community that will be the main customer base. Michael says their aim now is to make the best gaming controller around – "something that in gyro-gaming at least, we seem to be succeeding".

December 2024 saw Input Labs unveil a second reference design. As well as a second thumbstick variant, Alpakka v1.0 provides a much requested (but less than straightforward) feature: wireless gameplay. Michael and Marcos spent many months on a low-latency communications solution. This is provided via a dongle and a Marmota module with Raspberry Pi RP20240 alongside an Espressif ESP8684-MINI-1. The Alpakka v1.0 can also be recharged via a USB-C connection on the module.

Marcos and Michael have since launched the new wireless-enabled Alpakka v1.0 components in the online store along with a configurator for customers who prefer a ready-to-assemble kit. Iterations and improvements are ongoing as the pair seek to make good on their intention to design and market the very pinnacle of gaming and user-controlled input. Keeping close to their existing and future customers is a must, notes Michael. "Luckily, we have the pleasure of a very active and knowledgeable community," he adds. "Their expertise was, and still is, extremely valuable."

Quick FACTS

- Alpakka was initially designed for arthritis sufferers
- The original model brought in hundreds of customers
- It highlighted the need for quality adaptive input controllers
- Complete user configurability is a huge advantage
- Users can create and 3D-print custom models for their needs

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Whispering Wires

This landline phone reads poems aloud. **David Crookes** has a listen

Maker
Théo Z V Champion
Théo, who goes by the internet names tzvc and Rootkid, has a master's degree in computer science and says he has been tinkering with machines since the age of mythology.

rpimag.co/whisperwires

▶ Raspberry Pi Zero 2 W is connected to the two small 3 W amps and these components are housed in their own 3D-printed case which is then secured inside the phone

When Théo Z V Champion visited a vintage market in London, he noticed that shoppers were rather intrigued by a rotary phone – the type that needed callers to choose a number by inserting their fingers into the relevant holes of a dial before turning the wheel in order to initiate a telephone call. It was disconnected, but that didn't prevent many people – acting out of curiosity or feeling pangs of nostalgia – from lifting the handset and placing it against one of their ears.

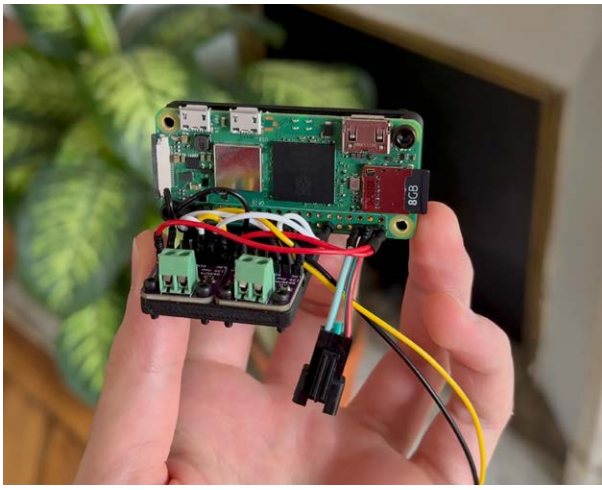
In each case, they were met with silence. They'd place the handset back on to the base, inevitably smile, and turn their attention to another retro device. But what if they had been able to listen to a voice? Would they have engaged with the phone for longer and potentially gained something more from the experience? With that thought in mind, Théo acquired an old landline phone of his own – albeit a push-button type – and he got to work on retrofitting it with a speaker.

The concept was that, upon lifting the handset, the user would hear a voice reading out a poem and this, he explains, would indulge a burning passion to mix technology with art. "I believe technology and engineering are underrepresented in art, so I create pieces that use technology as both the medium and the message to reveal the invisible world of engineering around us – be they algorithms, communications/surveillance tech, artificial intelligence, the internet and so on."

Listen up

Théo selected a vintage French Socotel S63 phone, opting for a model that was designed by the Centre national d'études des télécommunications in the 1980s as a standard-issue device for homes the length and breadth of France.

He then opened the housing and decided to make a Raspberry Pi Zero 2 W single-board computer the heart of his modernised device. Since Raspberry Pi Zero 2 W doesn't have an on-board audio amp, he connected it to a pair of



I believe technology and engineering are underrepresented in art

3W amplifier chips (MAX98357A). "This would drive audio to the phone earpieces via I2S," says Théo, who attached all of the components to a 3D-printed support and inserted it into the housing.

Raspberry Pi Zero 2 felt like a perfect fit and not simply because it was small enough to squeeze into the relatively cramped space within the phone. "I needed the phone to have internet access over Wi-Fi and to be able to play audio," he explains. "Being a software engineer, having a full Linux environment is also a blessing for me as opposed to more constrained environments such as ESP32, MicroPython, and so on. All the tools and packages I could think of are compatible with this single-board computer."

Finding inspiration

With the components sorted out and a switch hook connected so that, upon lifting the phone's handset, the Raspberry Pi would spring into action, Théo began to work on the software. He'd discovered the Poetry Foundation website (**poetryfoundation.org**), which contains large collection of poems, and was delighted to find that a good number of them included audio narrated by the author.

"I poked around the website code and was quickly able to find an open access to their database," he recalls. "I was able to download all the audio poems, but there was one issue: the poems contained an intro/outro by the author."

01. The project uses an old French push-button Socotel S63 phone which once came in a variety of colours. There were rotary dial versions too

02. No modifications were made to the housing, so it looks, to all intents and purposes, like an original phone albeit with a modern twist

Théo wanted the poem to sound like the poet was actually on the other side of the phone, not just a recording. “One of the main challenges was to clean up all the audio-narrated poems from their intro/outro to only have the actual poem play when the phone is picked up,” he says. “The solution involved transcribing all the poems and then using a large language model (LLM) to cut out irrelevant portions.”

AI for rhyme

To transcribe the audio poems, Théo used WhisperX (**rpimag.co/whisperx**), an advanced, fast automatic speech recognition model which is capable of transcribing audio with word-level timing. Building upon OpenAI’s Whisper model that has been trained on about 680,000 hours of diverse audio, it allowed Théo to get a handle on exactly when each word was spoken in an audio clip. He could then turn to Open AI’s LLM, GPT-4o-mini, to complete the next stage of the task.

“I passed the transcription into GPT-4o-mini, asking it to remove any intro/outro [material],” he explains. “I was left with a database of more than 3000 perfectly cut audio poems.” This method also meant that the device is ‘future-proof’, so to speak. “The database updates every day as new poems are uploaded to the Poetry Foundation website,” Théo reveals, and Whispering Wires is capable of playing them all.

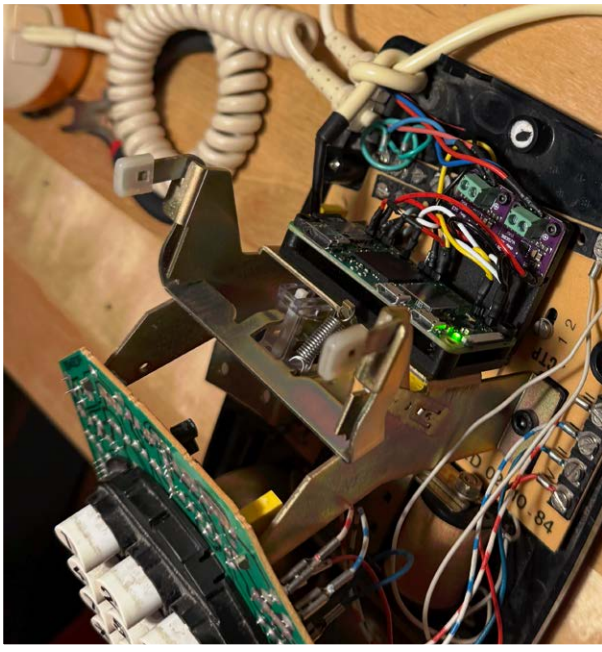
Of course, there are some ethical questions surrounding this move: is it right to remove the credit from the beginning of the audio simply to gain a seamless experience? Théo has already considered this and he says all of the information about the poets and the names of the poems is being saved and organised in a database. He plans to create some way to show the credits when the phone plays the poem and he’s currently looking for a small enough display.

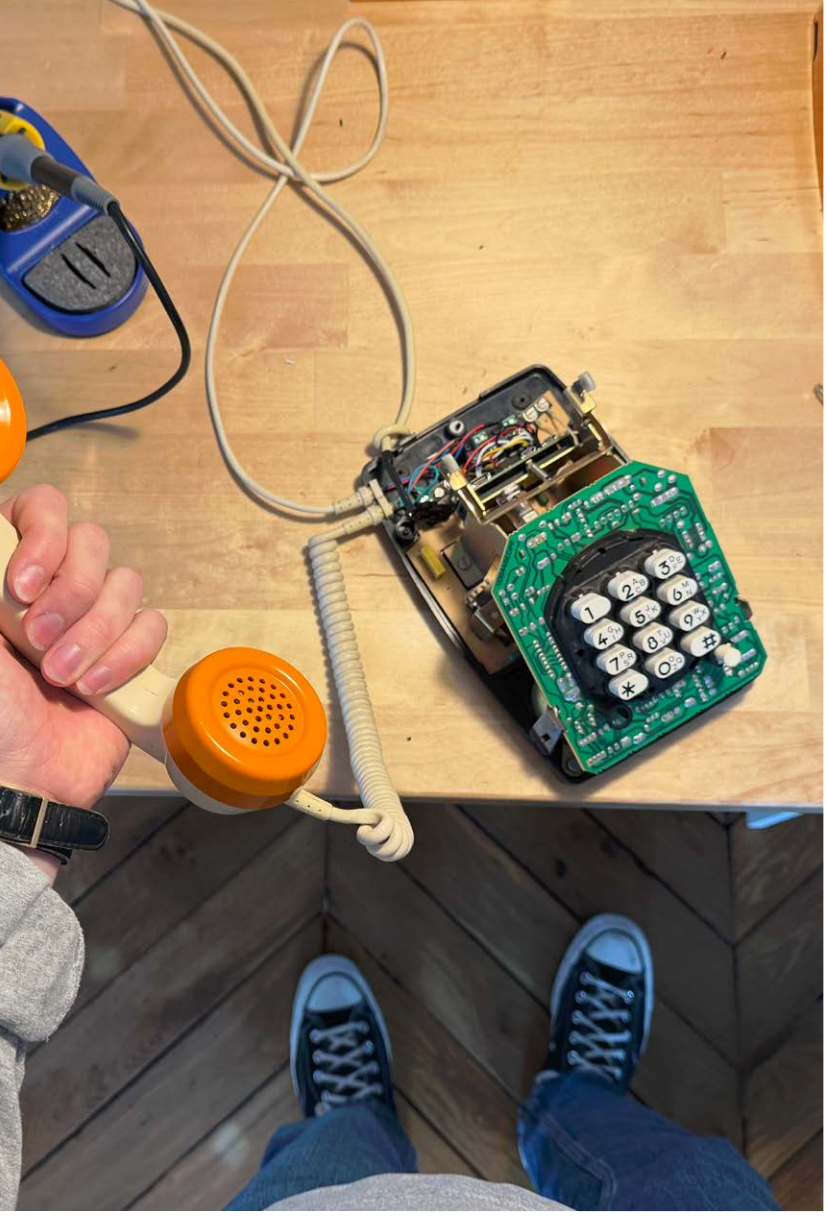
In the meantime, Théo has been working on making his project as authentic an experience as possible. Although sound comes out of both the handset speaker and an extra earpiece that allows two people to listen to the poems at the same time, Théo has ensured that the audio isn’t played with crystal-clear clarity but instead sounds just like the phones did when they were being used a few decades ago.

“To achieve the vintage phone audio quality, I researched what frequencies phones operated at back then and applied the same filter with code (300Hz to 3.4kHz band range at 8kHz sampling frequency) to get the authentic ‘phone grain’.” He’s also added a hang-up sound followed by a line-disconnect tone when a poem ends so that the listener has the feeling the poet has hung up. To that end, it’s shaped up well as a head-turning art piece and if the response from Théo’s YouTube video is anything to go by, it is certainly getting people talking.

Quick FACTS

- This project uses an old landline phone
- State-issued, it’s technically still the French government’s property
- It makes use of 68 hours’ worth of poems
- AI is used to edit the poem audio
- The project cost $60

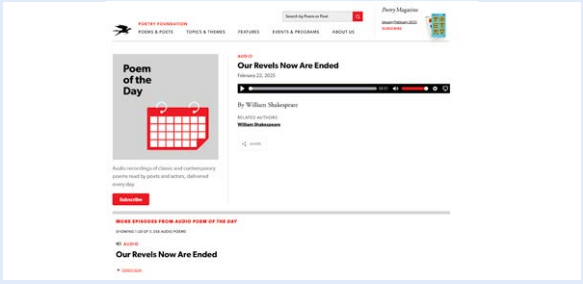




▲ The phone has a cache of a few gigabytes of poems for use offline, while audio is streamed when online with the phone directly connecting to the internet using Raspberry Pi's wireless LAN capabilities

◀ Rather than strip the phone internals, Théo has simply added the wires and modern electronics, which happen to fit neatly into the space towards the rear

Making poetry



1. A database created using artistic works pulls narrated poems from the Poetry Foundation website. An AI model called WhisperX creates word-level accurate transcriptions of those poems and a large language model strips them of any intros and outros.

2. When someone picks up the handset, the phone will automatically and immediately pull a random poem from the database. It will begin to play the audio through the earpiece, complete with an authentic phone audio grain for added nostalgia.

3. When the poem is finished, the poet 'hangs up' and this leaves the listener with a disconnect tone. All the listener has to do is put the handset back on the phone's base and pick it up again. The phone will then pull another random poem from the database.

Voltmeter Clock Boxes

A lifelong interest in electronics culminated in a precision project repurposing voltmeters as Raspberry Pi-controlled clock dials. Intriguing, thinks **Rosie Hattersley**

Maker

Finnley Dolfin

Finnley became an avid electronics fan and maker thanks to his Dad's interest in Heathkits and through TV shows such as *The Secret Life of Machines*.

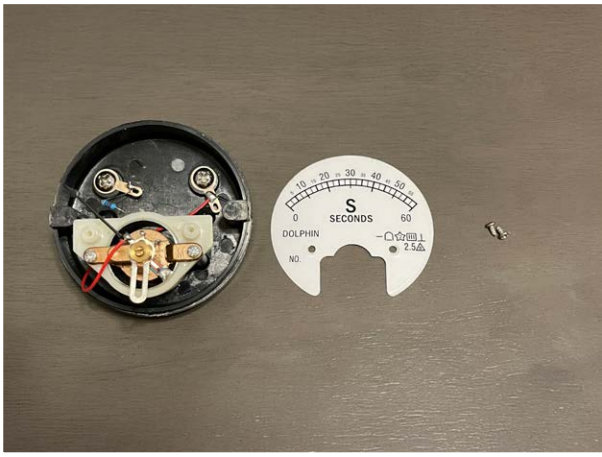
rpimag.co/rpiclock

Television has a lot to answer for! *Mr Wizard* was one of the earliest TV science shows, debuting in the US in 1951 and running until 1965.

The programmes comprised practical demonstrations to children using everyday objects. Presenter and educator Don Herbert (whose *Mr Wizard* shows can still be seen at **mrwizardstudios.com**) caught the imagination of children such as Finnley Dolfin. The maker credits the show and the influence of his electronics-mad father for sparking his own lifelong interest in how things worked. The Raspberry Pi Zero W-based Voltmeter Clock Boxes combine Finnley's interest in old electronics with modern components.

Sparking an interest

As he got older, Finnley experimented with making his own circuit boards, assembling various kits, and even built his first theremin from a Paia Electronics kit. "When single-board computers started hitting the scene, it felt like a natural evolution, combining my love for hardware tinkering with the endless possibilities of programmable systems like Raspberry Pi," says Finnley of his enthusiasm for all things Pi. Another of his Raspberry Pi projects is a Python-based RSS information display inspired by the old community channels from late 1980s and 1990s cable systems, featuring high-contrast colours, blocky text, and smooth jazz playing in the background. It pulls NOAA data from his own weather station.

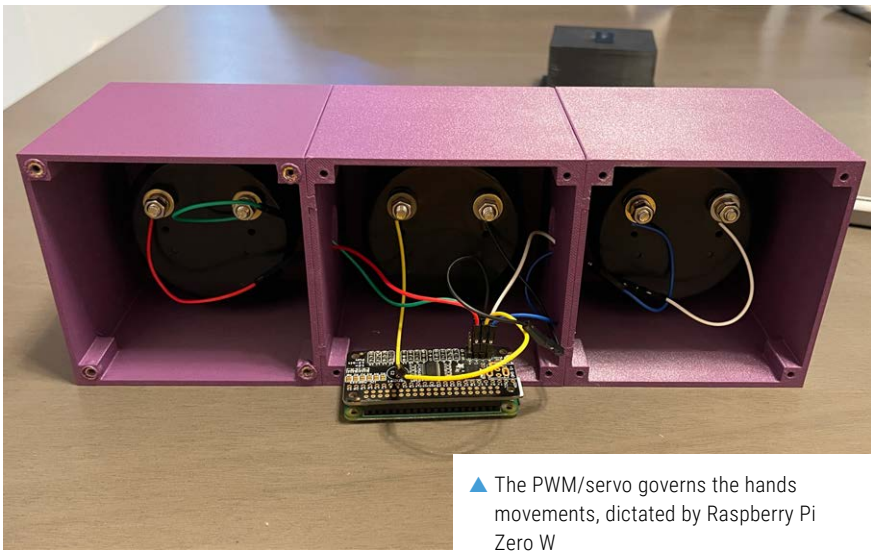


▲ The voltmeters' terminals were quite loose, so Finnley renovated them to improve accurate readings

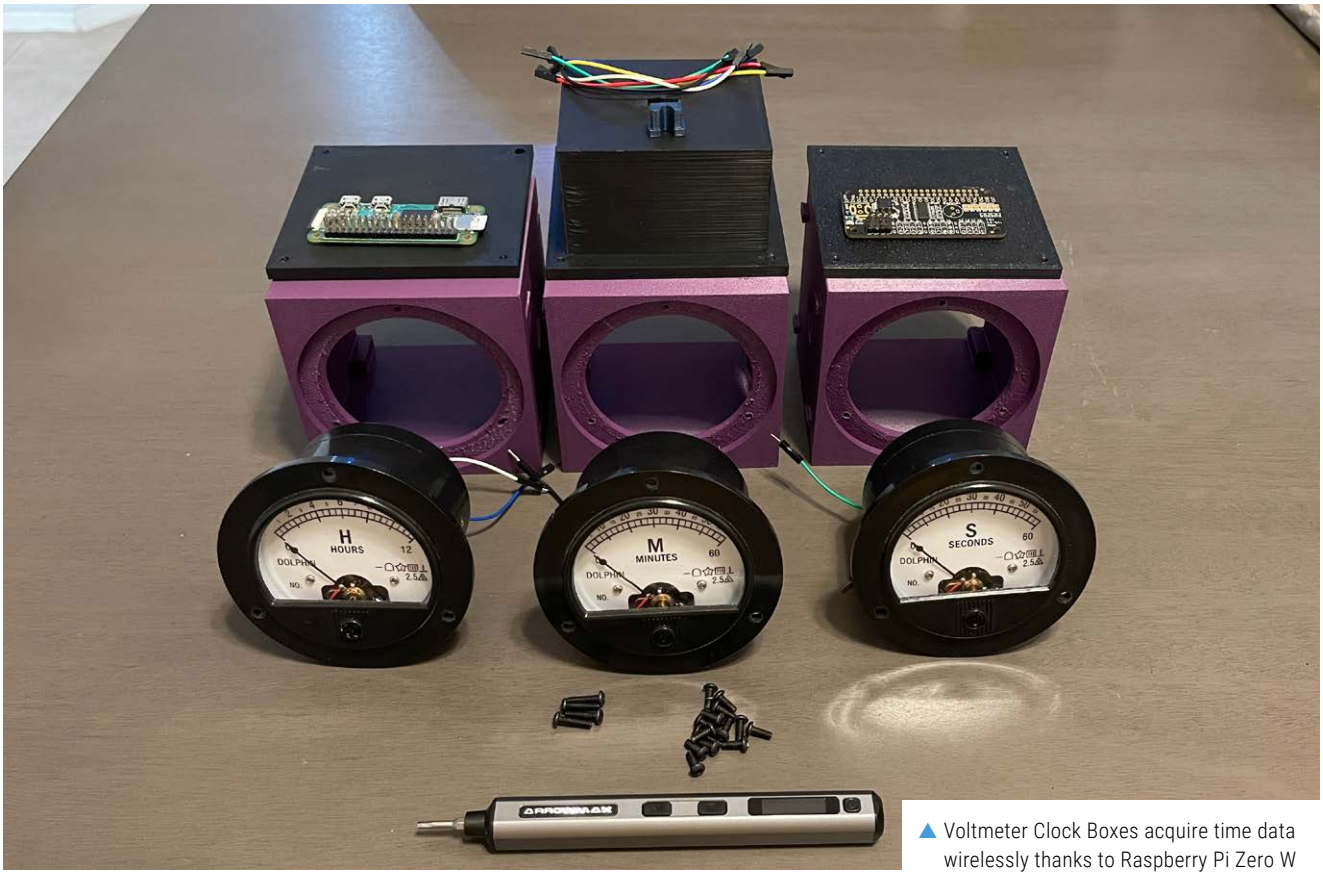
01. A trio of voltmeters were given clock faces indicating hour, minutes, and seconds, with an Arduino PCA9685 PWM/servo bonnet

02. Raspberry Pi Zero is used to control the voltmeter clock arms, syncing them wirelessly with the NPT clock. A PiSugar portable battery allows it to be used without mains power

Finnley experimented with making his own circuit boards, assembling various kits, and even built his first theremin



▲ The PWM/servo governs the hands movements, dictated by Raspberry Pi Zero W



▲ Voltmeter Clock Boxes acquire time data wirelessly thanks to Raspberry Pi Zero W

For the Voltmeter Clock Box, the idea was to have Raspberry Pi Zero W process the current time and drive the 16-channel PWM/servo controller signals so the voltmeter needles displaying the time move accurately and smoothly. "The concept isn't original – I first saw a similar project on Hackaday (**rpimag.co/currentmetertime**)," reveals Finnley. However, he was keen to use Raspberry Pi since he finds it easier to accomplish his goals. Raspberry Pi Zero W supports I2C and Wi-Fi and "its low power consumption makes it an efficient choice for continuous operation". He came up with various clock designs, including a six-segment binary one involving Arduino and WS2812 LEDs, but a panel meter clock with smooth sweeping motion instead of step movements was the version Finnley eventually settled on.

Ace face

When modifying the gauge faces to display the time rather than the voltage, Finnley collaborated with a friend who runs a sticker printing business: Wilde Prints. Finnley sketched clock faces and was very pleased with the resulting custom stickers which fit seamlessly over the meters' original gauge faces. By contrast, his original 3D printer "was not ideal for producing precise parts", even though Finnley initially designed a simple box to hold everything (STL files available at **rpimag.co/clockboxstl**). However, after upgrading to a Bambu Lab P1S 3D printer, he was able to create a much better housing. "The improved print quality and design flexibility motivated me to finalise the code and get everything working smoothly."

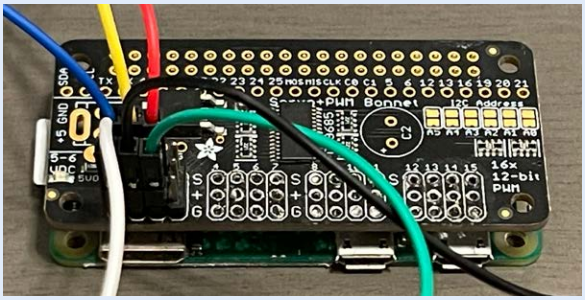
Having initially written code for the Arduino since he was using an Arduino PCA9685 PWM controller, Finnley needed to rewrite it for Raspberry Pi. The switch soon proved its worth since it simplified control of the analogue meters. Over the course of two years, he refined the setup to improve accuracy and ensure stable operation – Raspberry Pi OS support for a full Linux environment meant updates could be made easily without needing to reflash firmware or reprogram a microcontroller. He now plans to integrate an RTC module for better offline accuracy, ensuring the clock keeps time even without an internet connection. He also intends to put lights inside the voltmeter boxes so the time can be read more easily in low-light conditions.

▼ Early TV science show *Mr Wizard* inspired a young Finnley Dolfin

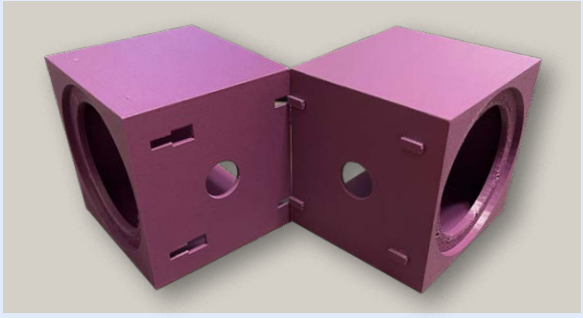
Quick FACTS

- Finnley rebuilt the analogue voltmeters…
- … Their loose terminal screws could have caused inaccurate readings
- He made use of the time-lapse camera feature on his smartphone…
- … This is used to check how smoothly the clock arms moved
- He is looking into how an offline model might work

Voltmeter time-telling



1. Three DC 62T2/65C5 3 V voltmeters were adapted with custom sticker clock faces. These were attached to an Arduino PWM/servo bonnet, which ensures the hands on each clock face are correctly aligned to indicate the current time.



2. Raspberry Pi Zero W running Raspberry Pi OS is I2C-enabled so it can communicate with the PWM/servo bonnet. It is placed inside the custom-built case.

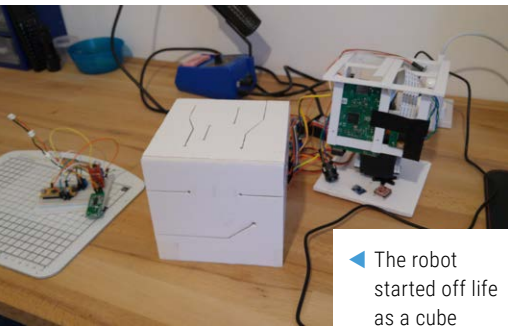
3. With the hardware installed, Raspberry Pi Zero W is set to run the Python clock script so it adjusts the frequency based on time. Finnley added a systemd service for automatic startup.

Bipedal companion robot

We all need a friend, whether they be human, furry, or long-term electronics project. **Rob Zwetsloot** befriends this bipedal pal

Maker
Dan Nicholson
A software engineer by day who has been building open-source robots for five years, logging the build process as he goes.

makerforge.tech



◀ The robot started off life as a cube

A robot companion is a bit like a pet, but without the muss or fuss as a Tom & Jerry cartoon once put it. While this one stands on two legs, it currently cannot walk; for maker Dan Nicholson, however, that wasn't the point of his long ongoing project.

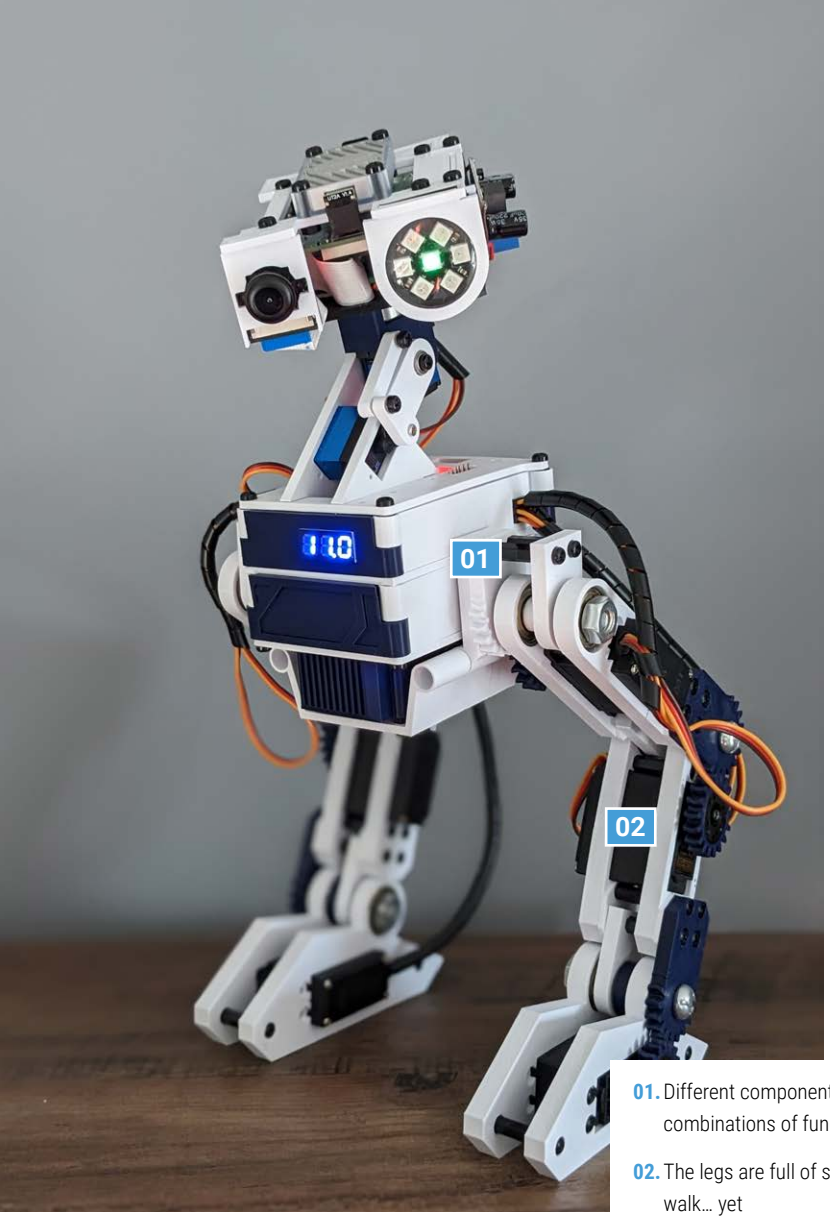
"It includes an easy-to-learn, custom software framework that supports functionality like object and face detection, animation, voice recognition, text-to-speech, AI integration, and much more," Dan explains. "I've focused heavily on documentation, and made design choices to keep the project accessible to as many people as possible. The goal is to make an autonomous desktop buddy that others can build, to inspire people to get involved in robotics and making."

He's been working on it since 2019, and has been featured on Raspberry Pi's blog with an earlier iteration of the robot (**rpimag.co/bipedalrobot**), although it started life as an animated cube before evolving via wood builds and 3D prints to the version today.

"During Covid lockdown, I was given a Raspberry Pi 3B+ and wanted to try building something with it," Dan tells us. "I had no idea what I could or couldn't do, and I only had a basic understanding of electronics, robotics, and 3D printing, so I thought a desktop companion would be a challenge... [And] it certainly was! Five years later, I'm still learning, building, and adding to the project."

Quick FACTS

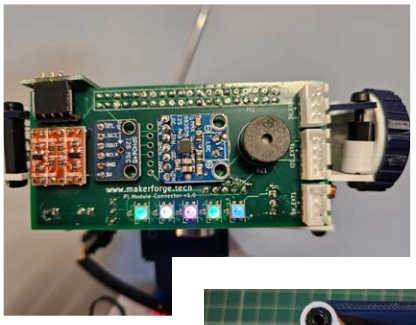
- All the components required are easy to obtain or make
- There have been three entirely separate 3D-printed chassis
- All the custom PCBs are open source, like the rest of the robot
- Other folks are adding wheeled legs so it can move
- Despite all the videos, Dan finds them tricky to make.



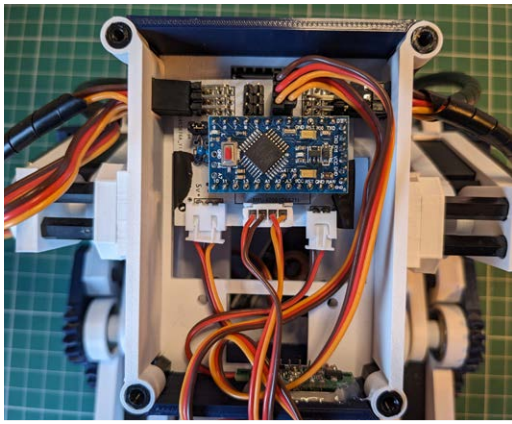
01. Different components allow for various combinations of functions

02. The legs are full of servos, but it cannot walk… yet

> *I've come to realise that the value of the project for me isn't just in having a robot, it's also in the learnings that I've taken away*



◀ There are many custom PCBs used in the build – all of which are open source



▲ An Arduino Pro Mini microcontroller also helps Raspberry Pi to control the robot

Tumultuous process

We often bang on about how taking part in a hobby is part of a process of learning and experimenting, and Dan has been learning all about it over the last few years, describing the experience of building the robot as "awful, and also loads of fun".

"I've come to realise that the value of the project for me isn't just in having a robot, it's also in the learnings that I've taken away from the years of trial and error," Dan says. "I haven't had any major disasters (yet!), but I have had a lot of things that haven't worked the way I wanted. But because I don't have a deadline and can take my time and try things out, my knowledge has become much stronger because of every experience, both good and bad."

As the project is ongoing, Dan reckons the functionality of the robot varies day-to-day, with a long list of features that can create "really interesting behaviours" when enabled in various combinations.

Always improving

As this is one of those projects that will never be completed, Dan has a long list of things he's contemplating adding or upgrading.

"I wish I had the time to do them all," he admits. "Right now I'm working on swapping Raspberry Pi 5 for Compute Module 5 and a custom carrier board. This will not only shrink the build and expand the existing functionality, but also allow other modules to be added easily for community variations. The great thing about this build is that, as new technology becomes available, the entire project direction can shift. A recent example is the Raspberry Pi AI Camera, which now handles object detection directly on the module and leaves the Raspberry Pi free to do other things. I'm excited to see what comes next."

He has managed to build a small community of folks around it too, who are doing their own changes and upgrades – including the ability for the robot to walk. Maybe we'll get it back in the magazine when it's mobile.

Inky Dashboard

This open-source e-ink dashboard will keep your life in order. By **David Crookes**

Maker
Jaeheon Shim
Jaeheon is a computer science student currently studying for his bachelor's degree at Georgia Tech. In his free time, he likes to make cool projects, both on the computer and in the real world!

rpimag.co/inkydashboard

If you've got a busy schedule, then it's all too easy to become overwhelmed. Without a good system in place, you'll find deadlines slip, appointments are missed, and you're constantly playing catch-up. It's why there are so many calendar and task management apps on the market and, crucially, why Jaeheon Shim decided to take his scheduling to another level.

"As a student, staying organised is crucial for keeping up with the demands of college life," he says. "I found myself relying on productivity apps like Google Calendar, Todoist, and Notion, but they weren't enough. Instead, I wanted my calendar to be physically present at my workspace, updating in real time to accommodate last-minute events. I also wanted it to be aesthetically pleasing – something that would perfectly complement my workspace while being as informative as possible."

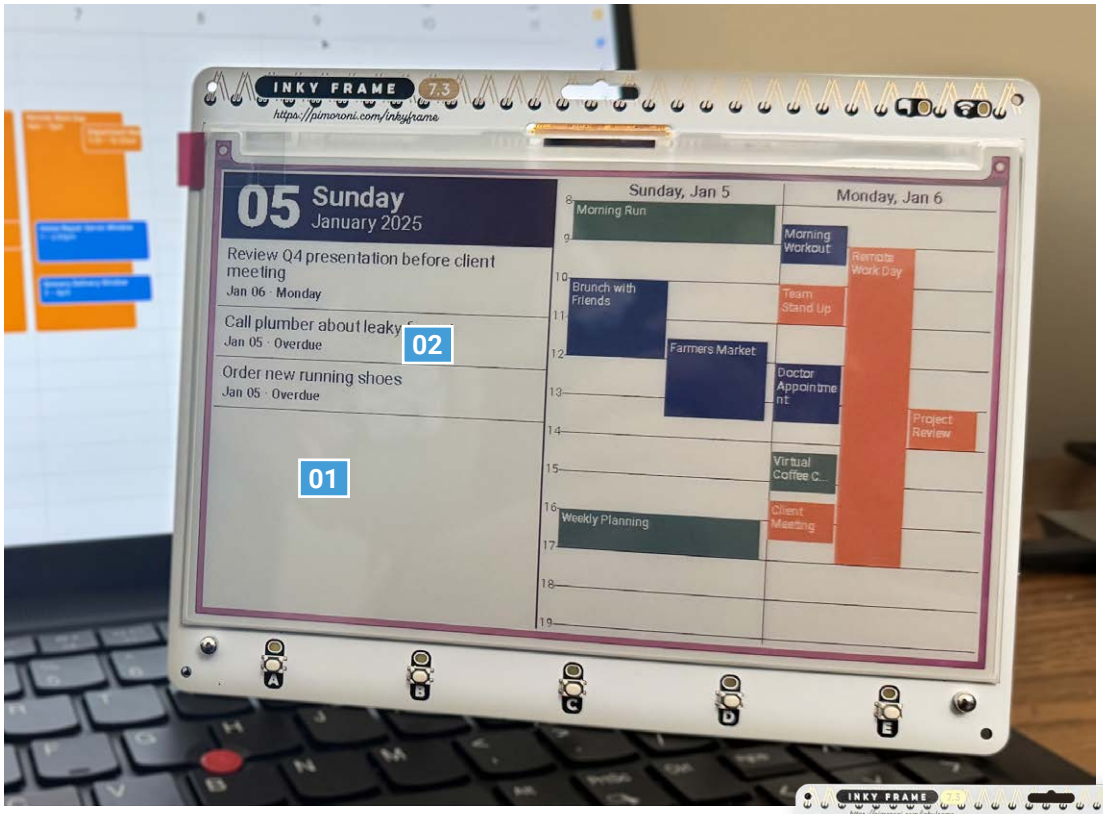
> *Working with a Raspberry Pi Pico W presented a learning curve*

Task master

To that end, Jaeheon devised the Inky Dashboard – effectively an e-ink display connected to a Raspberry Pi Pico W microcontroller running a bespoke UI. "I think e-ink displays are awesome. There's just something about their crisp, paper-like quality that makes them so uniquely satisfying to look at," he says. "I also wanted something that could sit on my desk without being a distraction; something that I could occasionally glance at but was otherwise running quietly in the background."

At its core, Jaeheon wanted a week-by-week calendar, where daily events would be laid out in a chronological column. "That way, I could visualise my week 'at a glance' and mentally prepare for the upcoming days of the week," he says, deciding to integrate his data from iCal.

▶ A Raspberry Pi Pico W is already surface-mounted to the back of the display. This project is all about the software



01. The Inky Dashboard uses Pimoroni's 7.3-inch e-ink Inky Frame which supports seven colours

02. LVGL is intended for touchscreen displays, but Jaeheon says it works great with a static screen

▼ The dashboard displays iCal and Todoist, but it can also handle syncing with Google Calendar or Microsoft Outlook

But when he later opted to integrate tasks from the Todoist app as well, to help him stay on top of his assignments and projects, he knew that he needed to compromise. "I had to shrink the calendar to only two days wide to make space for the to-do list, but in my experience being able to see today and tomorrow is enough for almost all purposes," he adds.

Quick FACTS

- The dashboard remains in a low-power state
- It's woken up by the Pico's on-board RTC
- Data is drawn from a custom server
- It will update every 30 minutes or so
- The project is entirely open source

To-do list

Working with a Raspberry Pi Pico W presented a learning curve for Jaeheon. "I'd never seriously worked with embedded programming before," he says. It took numerous attempts to create the UI he wanted, having tried libraries provided by Pimoroni and developing his own UI library. "Ultimately, I ended up settling on Light and Versatile Graphics Library (LVGL) and it took about a week to figure out how to port LVGL to Pico and Pimoroni's Inky Frame."

In the process, he figured out how to lay out overlapping events – "that was a fun, algorithm design challenge," he says. He also needed to create a server to retrieve the latest information because Pico isn't powerful enough to fetch it on its own. But, since the Pico connects periodically ("no more than every 30 minutes or so") and displays information on an e-ink screen, the project is power-efficient. It's also rather flexible.

"The data displayed on the calendar is presented in an agnostic format by the server, so I can always choose to add different sources by editing the Python code on the server (which is way easier to work with than the C++ running the display!)," Jaeheon says. "There are also many more features I want to add, such as a widget to show a basic weather forecast. The possibilities are endless!"


PROJECTS FOR MAKERS & HACKERS
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- FULL OF PROJECTS PERFECT FOR AN HOUR, AFTERNOON, OR WEEKEND OF MAKING

rpimag.co/BookOfMaking2025

Chop saw tape dispenser

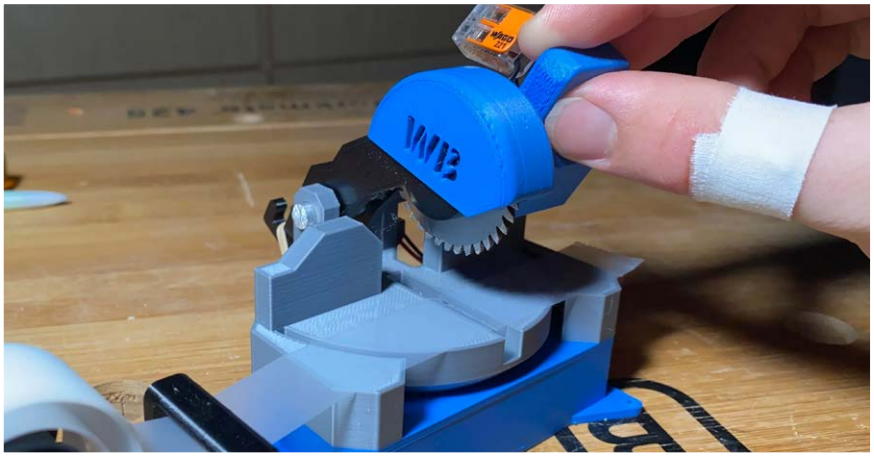
By Bunchowills

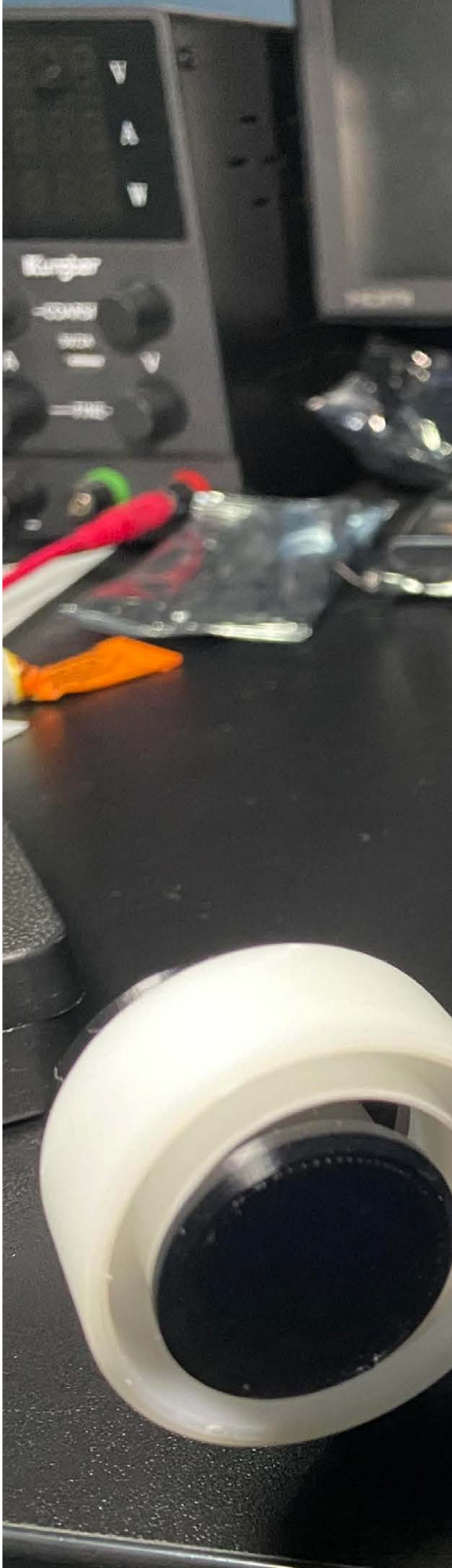
rpimag.co/TinyChopSaw

Much as we love a simple, elegant solution to an everyday problem, we're also big fans of people reinventing the wheel. Why tell the time with the clock on your smartphone, or the one in the top-right of your computer screen, when you could build a device that uses 3D-printed widgets and obsolete electronics to do the same job? Why buy a laptop off the shelf when you could build something that does the same job but in a wildly impractical form factor? Why use any mundane tool when you could use something far more awesome that you've made yourself?

It's in this spirit that Bunchowills has made the world's smallest chop saw that is also a tape dispenser. Yes, the spinny 3D-printed blade won't give you the same clean edge as a pair of scissors, but it looks considerably more awesome, and that's the whole point.

This mostly 3D-printed build runs on a pair of AA batteries, and can technically be used for woodworking projects as well as stationery management (its maker claims it can cut through toothpicks). Download the STL files, fire up your printer, and make one today for the woodworker with everything in your life.





Warning!
Moving parts
Be careful when handling this project because it has moving parts. Children should be supervised.

▲ A serrated circular saw blade isn't the best choice for clean Sellotape cuts, but it does look jolly impressive

F/A-18C Right Console

By ValeNoxBona

rpimag.co/FA18C

To many readers, 'F/A-18C Right Console' will look like a bunch of letters and numbers thrown together. To aviation enthusiasts, though, those letters and numbers clearly refer to the McDonnell Douglas F/A-18 Hornet, a fighter plane developed in the 1970s for the US Marines and US Navy. This replica control console by ValeNoxBona was apparently the maker's first ever build using the Arduino microcontroller, which is used to control the addressable RGB LEDs that light this project. The build uses a 3D-printed enclosure with a laser-cut and engraved acrylic top, backlit with WS2812 addressable RGB LEDs mounted on a custom PCB and controlled by the Arduino. The lettering is engraved into the acrylic, which makes the material thin enough for the lights underneath to shine through. Apart from the time involved, the biggest cost in building this was the switches, made by NKK of Scottsdale, Arizona.

▶ The F/A part of this project's name indicates that the aeroplane in question is intended as both a fighter (F) and an attack (A) aircraft


ELEC
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R GEN
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CABIN PRESS
NORM
DUMP
RAM/DU
ECS
ANTI ICE
PITOT
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AUTO
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WARN/CAUT
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CHART
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NVG
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STBY
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LTD/R
ARM
SAFE
LST/NFLR
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INS
RADAR
STBY
OPR
PULL
EMERG
OFF
SNSR
NORM
GND
CV
NAV
IFA
OFF
GYRO
TEST
GB

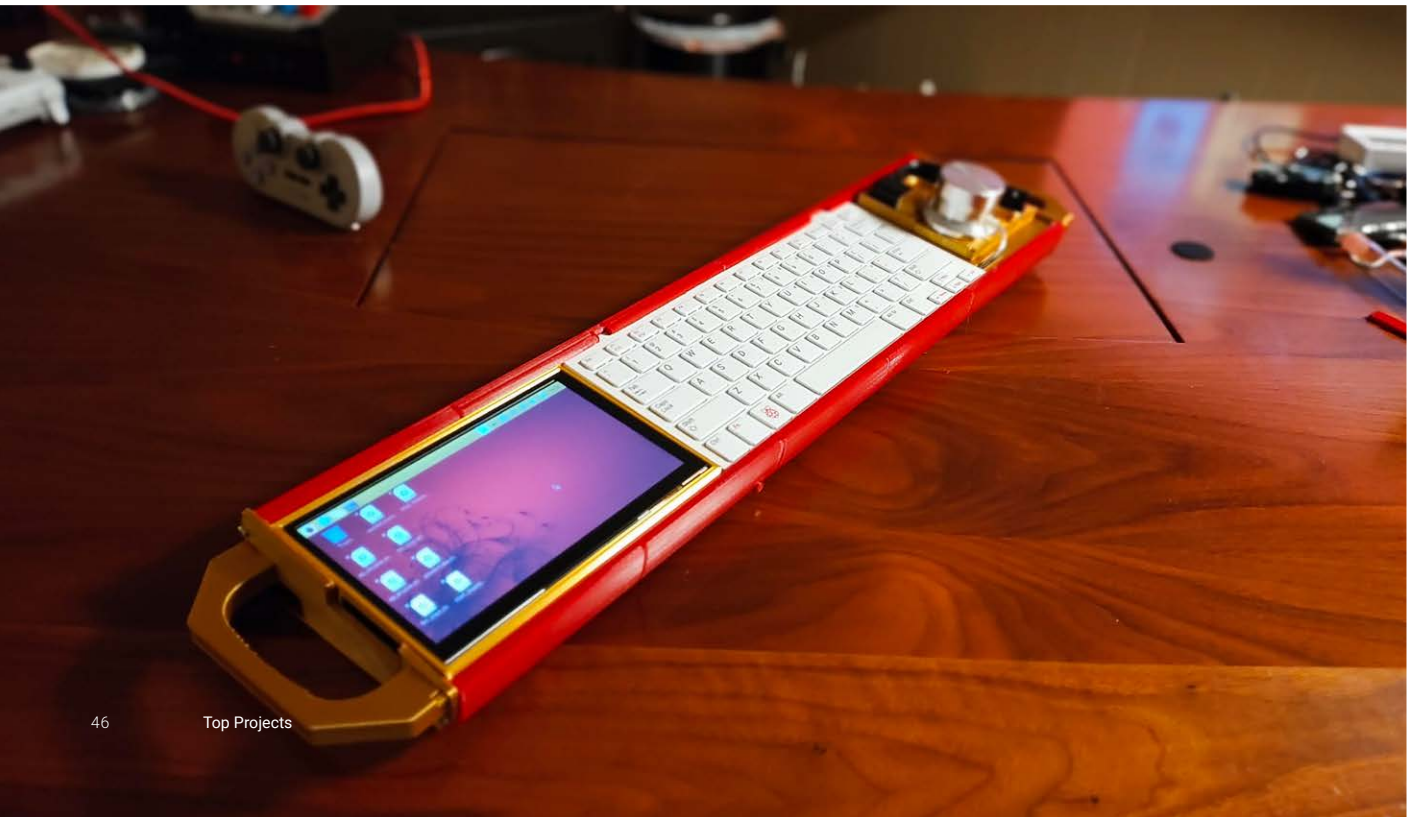
Apocolypse Later

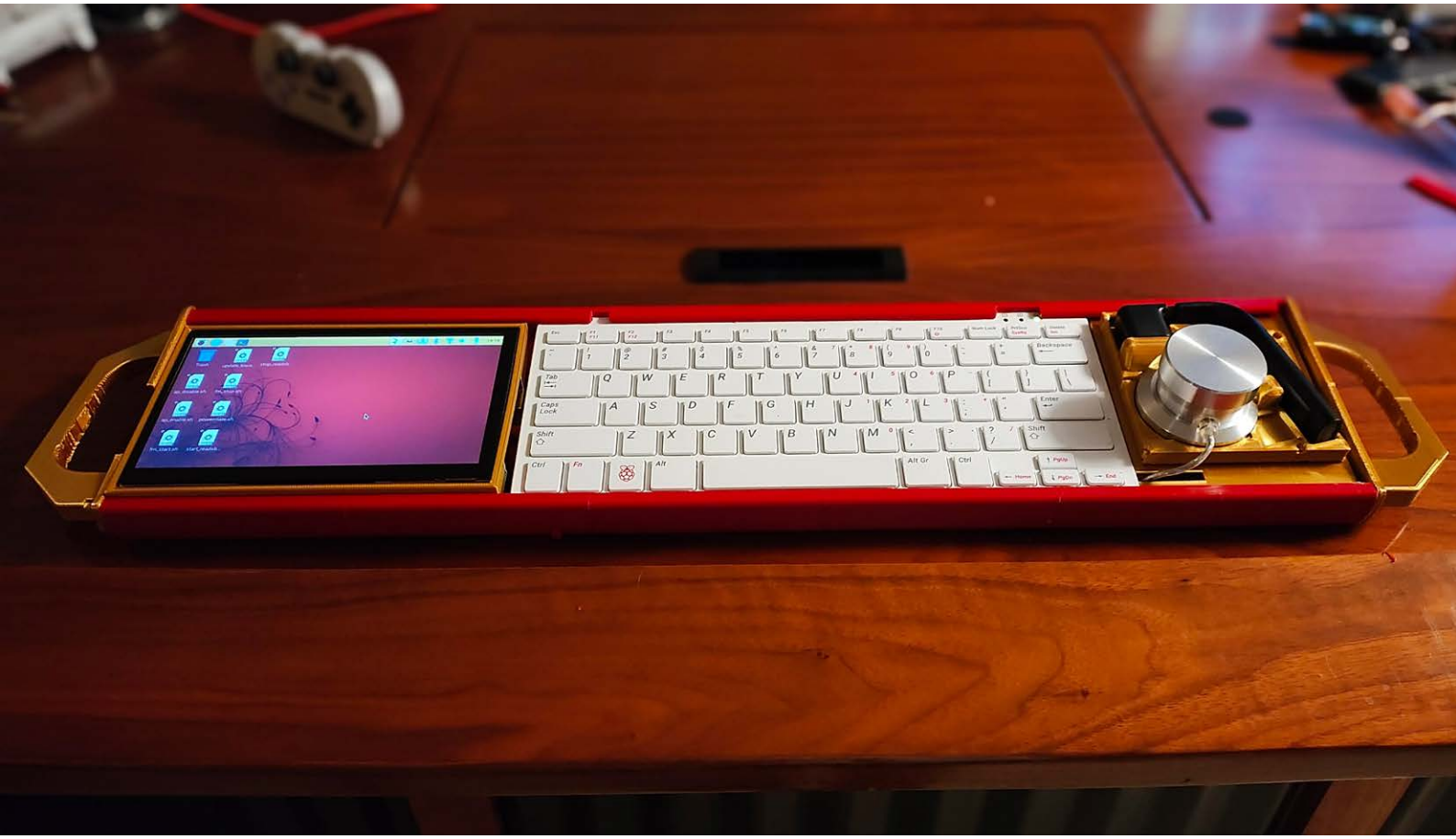
By Wolfebaine

rpimag.co/ApocolypseLater

Why do laptops look the way they do? Who decided that they should be shaped like a big hinge, with a keyboard and sockets for input devices on one side, and a screen on the other? This build by Wolfebaine turns the traditional on its head, starting with a Raspberry Pi 400 and making it wider to accommodate a 7-inch touchscreen at one end and a Griffin Powermate knob at the other, all mounted on a 3D-printed chassis. In other hardware, there's a software-defined radio built in, plus a 2TB SSD, which will be useful in the maker's original plans for an offline survival device – you can fit a lot of post-apocalypse rebuilding knowledge into 2TB of storage. We're not sure this form factor will catch on, but if it works for the maker, it is by definition a good design.

▼ The design is modular – the screen and the knob can slide out to be replaced with other elements





Slim Cyberdeck

By john3dc

rpimag.co/SlimCyberdeck

This beautiful hacker tool uses not one, but two Raspberry Pi devices: a Raspberry Pi Pico to handle the keyboard, and a Raspberry Pi Zero W as the main computer. It uses an Adafruit Sharp Memory Display, a Pimoroni LiPo Amigo Pro to handle charging to the 2500mAh battery, and a small but usable Rii X1 Mini keyboard (although modified enough so that you wouldn't realise it). It runs a terminal… and that's about it. You can use SSH to check on the status of headless devices such as servers. And there's a USB connector so you can plug in devices to retrieve data from them. More than that, it looks… serious. There's something about a Wi-Fi-enabled device that runs Linux and fits in your jacket pocket that feels a bit like science fiction, and with this unbelievably slim build, john3dc has made something that all time-travelling hackers should want to play with.

▲ The cyberdeck runs Raspberry Pi OS Lite, so there's no GUI - just the command line

3D print

Make nuclear physics dangerous again.

By **Toby Roberts**

rpimag.co/DemonCore

Back in 1946, physicist Louis Slotin was testing how close a plutonium sphere could get to going critical. Instead of using proper equipment, he held the neutron reflector with one hand and propped it up with a flat-head screwdriver—because apparently, that was science in the '40s.

Then, the screwdriver slipped. In an instant, the core went briefly supercritical, releasing a blinding blue flash and a deadly surge of radiation. Slotin reacted instinctively, knocking the reflector away—but it was too late. He had already absorbed a lethal dose and succumbed nine agonising days later.

It was only then that scientists truly grasped the dangers of handling nuclear material with basic hand tools.

And yet, who wouldn't want to make a Demon Core screwdriver holder? At least if you 3D-print it, there's no risk of triggering a radiation-induced apocalypse when your screwdriver inevitably slips.

So, first things first: this print (designed by high school CAD enthusiast Aglet) is big. The largest part has a 220mm radius, so unless you enjoy slicing things into a jigsaw puzzle, an Ender 3 might not cut it. However, printers with a 256×256mm bed will handle it like a champ.

I printed mine on a Bambu Lab P1S using some pretty standard settings: 10% infill, 0.2mm layer height, and basic PLA filament—nothing fancy, just solid, reliable, and gets the job done.

On an UltiMaker S5, this behemoth takes over two days to print—yes, you read that right. Two full Earth rotations. Even on my [Bambu Lab] P1S, the largest part still hogged seven hours of my life. So maybe schedule this one overnight and dream about it finishing.

A word of caution: orientation matters. Domes should be printed flat-side down, unless you enjoy watching spaghetti happen. The small middle dome needs support, and I highly recommend 'tree' supports because they work well and look kind of cool while printing.

Now, onto the finish. Unless you embrace the 'fresh-out-of-the-printer' look, you'll notice some delightful layer lines, especially on curved surfaces. If your slicer has variable layer height settings, use them – this can make your dome look smoother instead of like a stack of pancakes. If you're old-school, like me (or just really enjoy inhaling paint fumes), there's sanding and painting. I prefer the spray putty and sanding method, which basically involves layering, sanding, and repeating until you forget what year it is. Two or three rounds of this, followed by primer and a final coat, and you'll have a silky-smooth finish that'll make people think you CNC-milled it.

For that extra sci-fi shine, I hit the smaller dome with spray chrome paint and a light varnish. The main base dome was just primed and chromed, with a sneaky mist of black to give it that 'I've been through some things' aesthetic.

Bonus tip for the fancy folks with resin printers: you can paint on resin to cover layer lines and then use a UV light to cure the resin. It works, but it's also messy – like, 'you'll be peeling it off your hands for days' messy. If you do try this method, don't use cold resin (it's thicker and applies like glue), and consider thinning it with isopropyl alcohol for a smoother finish. More layers = fewer lines = a happier you.

And that's it! Now go forth and print wisely.

PRACTICAL AI WITH RASPBERRY PI

LEARN ABOUT, AND DEPLOY, ARTIFICIAL INTELLIGENCE TO PROJECTS WITH RASPBERRY PI TECHNOLOGY.

BY **LUCY HATTERSLEY**

Artificial intelligence is the buzziest of tech topics. And (for better or worse) this is the year that it is seriously being deployed into the world.

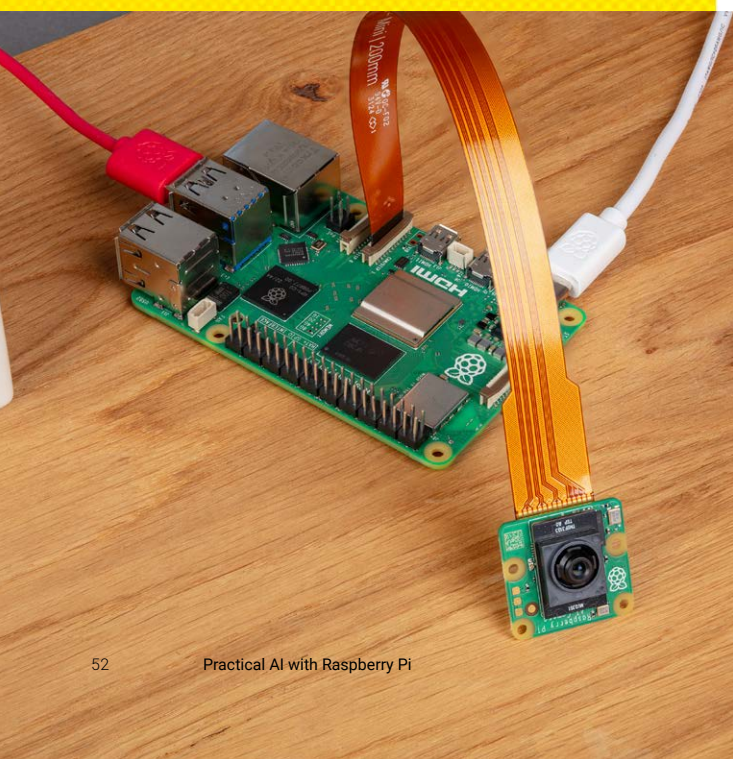
Ready or not, businesses and governments are swapping out workers for trained models, artists are pushing back against generative adversarial networks trained on their work, and writers are pushing back against generative pre-trained transformers. Meanwhile, autonomous car-driving technology is rapidly going through approval processes in various territories.

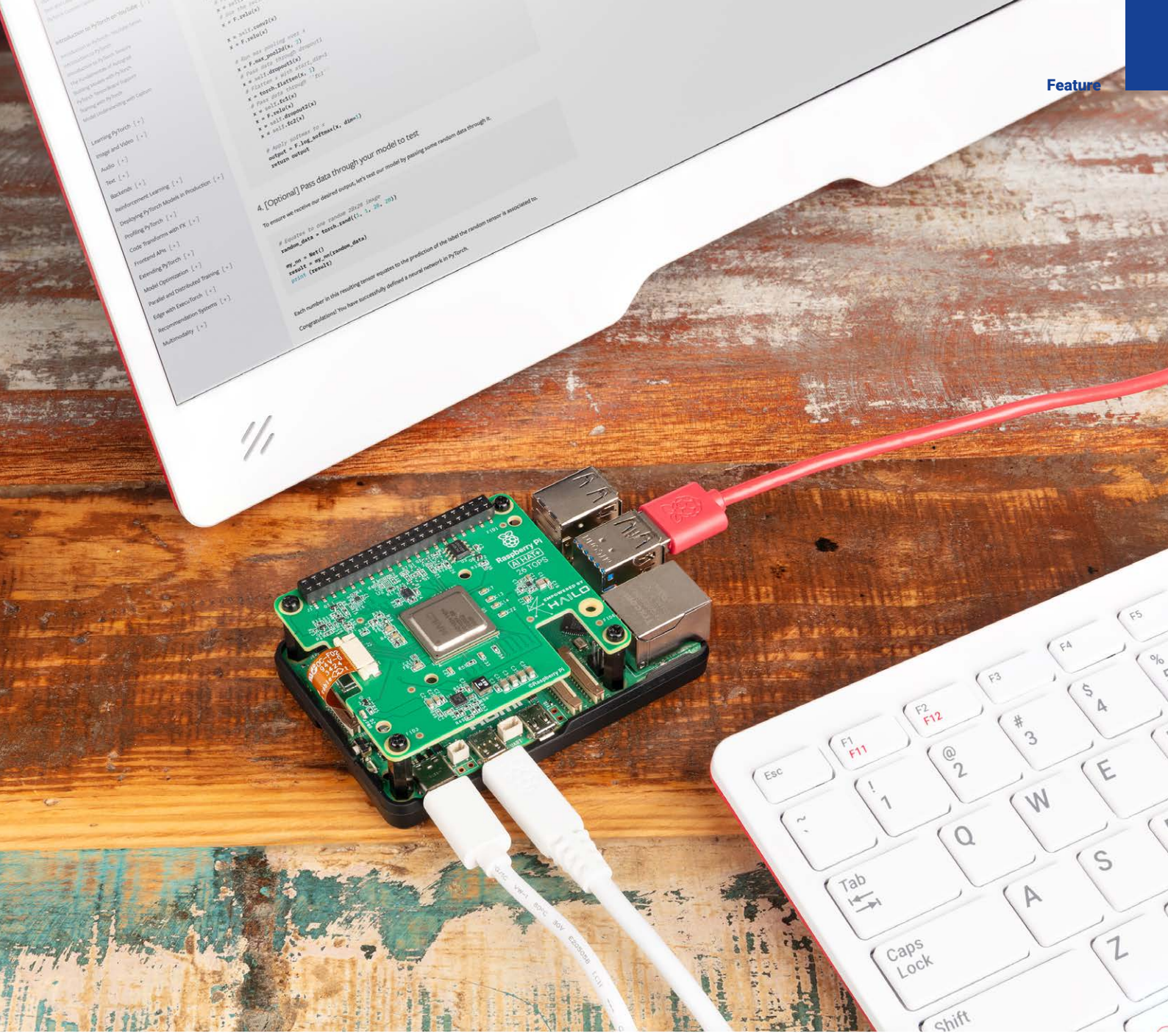
We live in interesting times. But you never know what the future will bring, so let's not get bogged down with worry. All this stuff is fascinating to learn, and the mental reward is huge. It's great to know how this stuff works.

This month we built an AI technology stack using Raspberry Pi technology. Raspberry Pi is uniquely placed to explore AI models thanks to its customisable nature, hackable input and output pins, and AI hardware extensions. Raspberry Pi 5 has vastly improved CPU and RAM capacity, and both AI HAT+ and AI Camera technology offer vastly improved inferencing speeds.

In this feature, we're going to explain some basic AI concepts to gain understanding of our hardware stack. And then go over the stack and start looking at some projects that are using this incredible equipment.

▼ Raspberry Pi's AI Camera enables you to perform vision inference in real-time without using the AI HAT+





We built an AI technology stack using Raspberry Pi technology

▲ Raspberry Pi's AI HAT+ being used to explore models

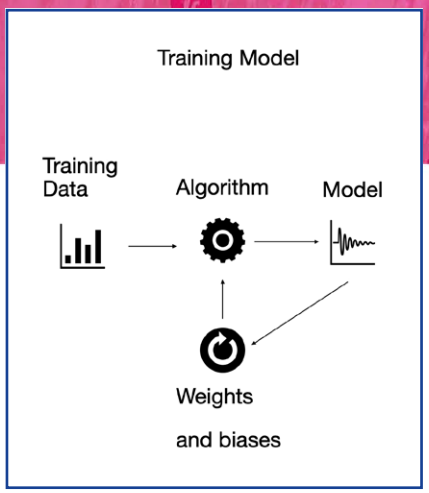
TRAINING BEFORE INFERENCE

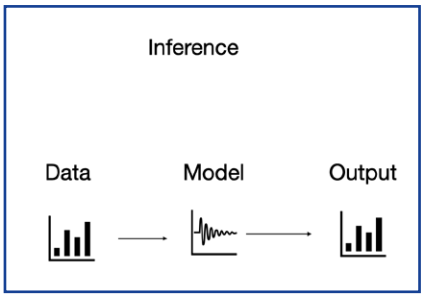
Artificial intelligence is an umbrella term that is – in itself – rather vague. It covers everything from very specific technologies, such as machine learning, deep learning, and natural language processing through to the use of AI technologies in hardware and software projects, and then there's a science fiction term that pits human intelligence against perceived computer intelligence.

It's for this reason that many AI experts rarely use the term artificial intelligence, and tend to hone in on the detailed technologies with distinct meanings. Like machine learning, or natural language processing.

One term you'll hear a lot in AI projects is the 'model'. An AI model is a mathematical representation of a system that learns from data. There are two distinct stages to a model: training and inference:

- **Training**. During training, an AI model is taught to recognise patterns in data. The computer goes through the data, adjusting parameters (known as Weights and Biases) to improve the accuracy of the output. The training process is hugely computationally intensive and while you can experiment with it at home, it typically takes place on dedicated hardware or in cloud datacentres.
- **Inference**. This is the process of running the model on new data (that hasn't been used for training). You pass the raw data (such as an image, text, or audio) into the AI model and get output in the form of a prediction, classification, or decision (e.g., this image is most likely a 'cat').





◀ During training, the model is refined by adjusting weights and biases

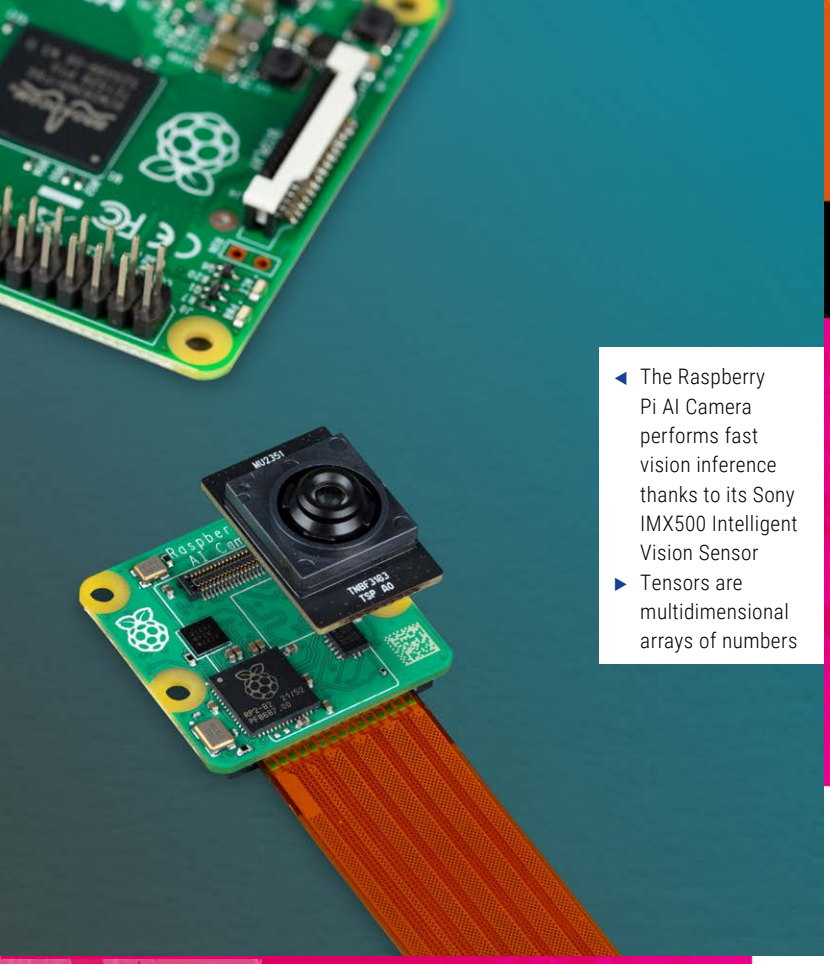
◀ During inference, the trained model is used to make decisions based on new data

While the models can be extremely large, many of them are perfectly functional on a Raspberry Pi 5 with additional hardware such as AI HAT+ or AI Camera.

Some models can also be run on a bare Raspberry Pi, with no additional AI hardware. But they will run extremely slowly. Sometimes this doesn't matter: it may take a few minutes to improve an image, and you may only be able to do face recognition at 2 frames per second.

For real-time inference and fast performance, you will need additional hardware such as Raspberry Pi AI HAT+ and Raspberry Pi AI Camera. These feature neural network accelerators for vastly speeding up inference time. This hardware enables you to perform real-time facial recognition, for example.

It is possible to train some neural networks on Raspberry Pi, but the process is quite slow and it's more commonplace to train models on dedicated hardware and deploy them on computers like Raspberry Pi.



◀ The Raspberry Pi AI Camera performs fast vision inference thanks to its Sony IMX500 Intelligent Vision Sensor

▶ Tensors are multidimensional arrays of numbers

Scalar	Vector	Matrix	Tensor
8	[1, 2, 3]	[1, 2] [3, 4]	[[1, 2] [1, 2]] [[3, 4] [3, 4]] [[1, 2] [1, 2]] [[3, 4] [3, 4]]

GET TO KNOW TENSORS

Key to how artificial intelligence operates are tensors. A tensor is a multidimensional array of numbers. Think of it as a list with nested lists inside. These form a shape based on the dimensions:

- **0D Tensor (Scalar).** This is a single number, such as 8 or 3.14.
- **1D Tensor (Vector).** A list of numbers, like: [1, 2, 3]
- **2D Tensor (Matrix).** A 2-dimensional array, like: [[1, 2], [3, 4]]. The shape would be described as (2, 2).
- **3D Tensor.** An array of matrices. This would have a shape described by the matrix references, like: (size, height, width).
- **ND Tensor.** These are higher-dimensional arrays used in machine learning models. These are harder to visualise as they move beyond three-dimensions. For example, a video might have: (batch, frames, height, width, channels).

tensors.py

> Language: **Python**

DOWNLOAD THE FULL CODE:
rpimag.co/tensorspy

```python
import numpy as np
import tensorflow as tf

# Creating a 1D tensor (vector)
vector = np.array([1, 2, 3])
print(vector.shape)  # Output: (3,)

# Creating a 2D tensor (matrix)
matrix = np.array([[1, 2], [3, 4]])
print(matrix.shape)  # Output: (2, 2)

# Creating a 3D tensor (e.g., image with 3 colour channels)
image_tensor = tf.random.uniform(shape=[64, 64, 3])
print(image_tensor.shape)  # Output: (64, 64, 3)
```

A model consists of layers of tensors. Imagine an array of these multidimensional arrays with links between them (that are weighted to adjust strength) and biases (that are used to adjust the output to fit). The shape of the network and the adjustments of the weights and biases are used to train the neural network to the task.

Running the models requires some intense mathematical processing, typically using matrix multiplication (for details on how that works, see **rpimag.co/matrixmult**).

If you want to learn more about tensors and experiment with them, here are two great guides:

- TensorFlow: Tensors (**rpimag.co/tensorflowbasics**)
- PyTorch: What is a Tensor? (**rpimag.co/whatisatensor**)

FUN FACT!

The prevalence of matrices in neural networks and the use of matrix multiplication is why graphics cards are so useful for training neural networks. Matrices are conveniently useful for creating the 3D graphics that modern games rely on.

Reach the TOP

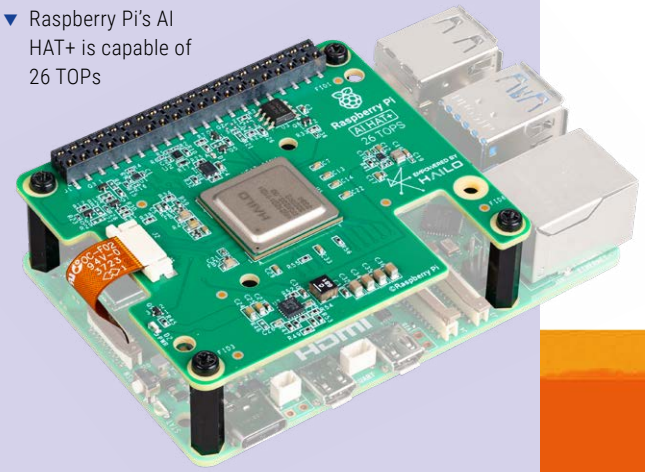
Now that we've become briefly acquainted with tensors, we can talk about TOPs (tera operations per second). This is the standard speed with which AI equipment is measured, and 'tera' is short for 10^{12} or 1 trillion.

Training and running AI models is hugely computationally intensive and relies on operations like matrix multiplication, convolutions, and algebra tasks.

A TOP is a trillion of these operations per second.

- **Coral USB Accelerator (4 TOPs)**. Early AI Raspberry Pi endeavours like Google's Coral accelerator were capable of around 4 TOPs.
- **AI KIT (13 TOPs)**. Raspberry Pi's AI Kit consists of an M.2 HAT+ with a Hailo AI acceleration module. New customers are now recommended to get the AI HAT+ instead.
- **AI HAT+ (26 TOPs or 13 TOPs)**. Two models are available, offering up to 26 trillion operations per second.
- **Raspberry Pi (around 0.5 TOPs)**. It's worth noting that you don't need AI accelerators to run AI models. A bare Raspberry Pi is capable of inferencing via AI models, it will just do it more slowly. Although accurate figures depend on your cooling, you can expect around half a TOP with a Raspberry Pi 5. And if you connect custom hardware such as Raspberry Pi AI Camera with Sony's IMX500 Intelligent Vision Sensor, you can get real-time object classification and face detection.

▼ Raspberry Pi's AI HAT+ is capable of 26 TOPs



Frameworks

TensorFlow and PyTorch are two deep learning frameworks. These provide extensive code support for developing and deploying models.

The two frameworks have pros and cons, and both are worth investigating. There are many, many subtle differences between TensorFlow and PyTorch, but in general:

- **TensorFlow**. Better for industrial deployment. Supports Python, JavaScript, C++, and Java (**tensorflow.org**)
- **PyTorch**. Better for research and experimentation. Supports Python and C++ (**pytorch.org**).

Experiment with TensorFlow in Raspberry Pi OS

The best way to understand tensors is to play around with them. We will use Thonny for our code experimentation and we'll need to add the TensorFlow package in a virtual environment.

Create a new folder for your project in your home directory. Ours is called 'practical-ai'. You can do this in terminal with:

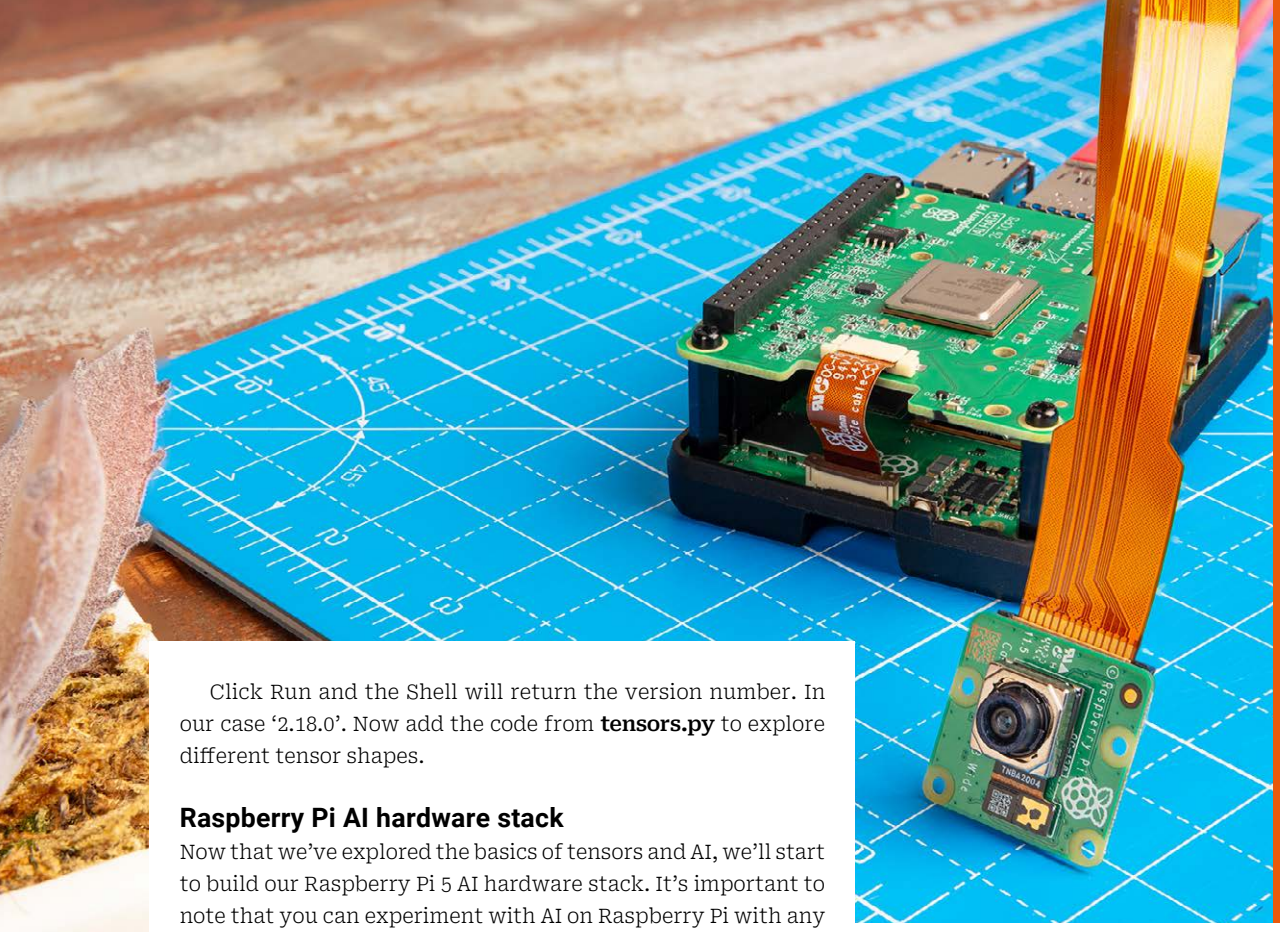
```
$ mkdir practical-ai
$ cd practical-ai
```

Now create a virtual environment and add the Tensorflow package (this will also install Numpy and other packages):

```
$ python3 -m venv venv
$ source venv/bin/activate
$ pip install tensorflow
```

Open Thonny and change the interpreter to your virtual environment. Click on **/usr/bin/python3** in the bottom-right and choose Configure Interpreter. Click the '...' icon next to Python Executable and choose the **venv/bin/activate** file inside your project directory. Click OK and test everything is working with this program:

```
$ import tensorflow as tf
$ print(tf.__version__)
```



◀ A Raspberry Pi AI hardware stack combining Raspberry Pi 5, AI HAT+ hardware, and a Camera Module

Click Run and the Shell will return the version number. In our case '2.18.0'. Now add the code from **tensors.py** to explore different tensor shapes.

Raspberry Pi AI hardware stack

Now that we've explored the basics of tensors and AI, we'll start to build our Raspberry Pi 5 AI hardware stack. It's important to note that you can experiment with AI on Raspberry Pi with any model, although we recommend a Raspberry Pi 5.

Here's our stack:

- **Raspberry Pi 5 16GB.** We've gone for the 16GB model to have space to contain models in RAM. In particular, we're using this to experiment with the whole Deepseek 01 model. **rpimag.co/raspberrypi5**
- **Active Cooler.** Keeping your Raspberry Pi cool is important when running inference models as overheating will cause Raspberry Pi OS to throttle performance. We're going for the official cooling option. **rpimag.co/activecooler**
- **microSD card 128GB.** We've gone for the largest microSD card around and because it's Raspberry Pi's own model, we can be assured of its performance. In our build, the PCIe 2.0 connection on Raspberry Pi 5 is connected to the AI HAT+, so we aren't using an NVMe drive. **rpimag.co/sdcards.**
- **Camera.** We've connected a Raspberry Pi AI Camera (**rpimag.co/aicam**) to our build so we can explore all the models, but you could use a standard Raspberry Pi Camera Module 3 (**rpimag.co/cam3**) alongside an AI HAT+ which will provide the performance boost. Raspberry Pi Global Shutter Camera (**rpimag.co/gscam**) is a great choice for industrial settings because it can capture rapid motion without introducing artifacts.
- **Case.** Our build is placed inside a Raspberry Pi Official Case (**rpimag.co/case**) to which we've glued a JOBY GorillaPod Tripod connector. You could also use a Bumper to keep things safe on your desk (**rpimag.co/bumper**).

GLOSSARY OF TERMS

Artificial Intelligence (AI)
An umbrella term for technologies that are expanding the capabilities of computers to areas previously performed by human intelligence.

AI Model
A mathematical representation of a system that has been created by repeatedly training it on data.

Inference
Running an AI model on new data to generate predictions, classifications, or decisions.

Matrix Multiplication
A mathematical operation performed on matrices of data. These are particularly useful for neural networks. Graphics cards or dedicated AI hardware perform these operations more quickly.

Tensors
Multidimensional arrays of data used in AI models.

TOPs (tera operations per second)
A metric for measuring the speed of AI hardware that represents one trillion operations per second.

Training
The process of creating an AI model by exposing it to data repeatedly and measuring the output while adjusting the weights and biases.

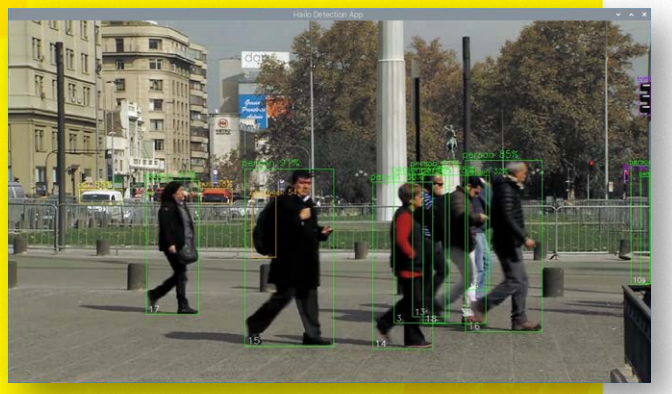
Weights and Biases
Parameters within the AI model that are adjusted during training to improve accuracy.

PRACTICAL AI PROJECTS

LET'S PUT OUR AI HARDWARE STACK TO WORK

Now that we've set up our hardware stack, it is time to start putting it to use. Here we are going to look at setting up an AI HAT+ and AI Camera Module and looking at all the AI models installed on Raspberry Pi (along with where to find additional models).

Make sure you work through the official documentation for both the AI HAT+ and AI Camera before you start. Each device has additional software installation requirements.



▼ Raspberry Pi Camera Module performing object detection

RASPBERRY PI DOCUMENTATION

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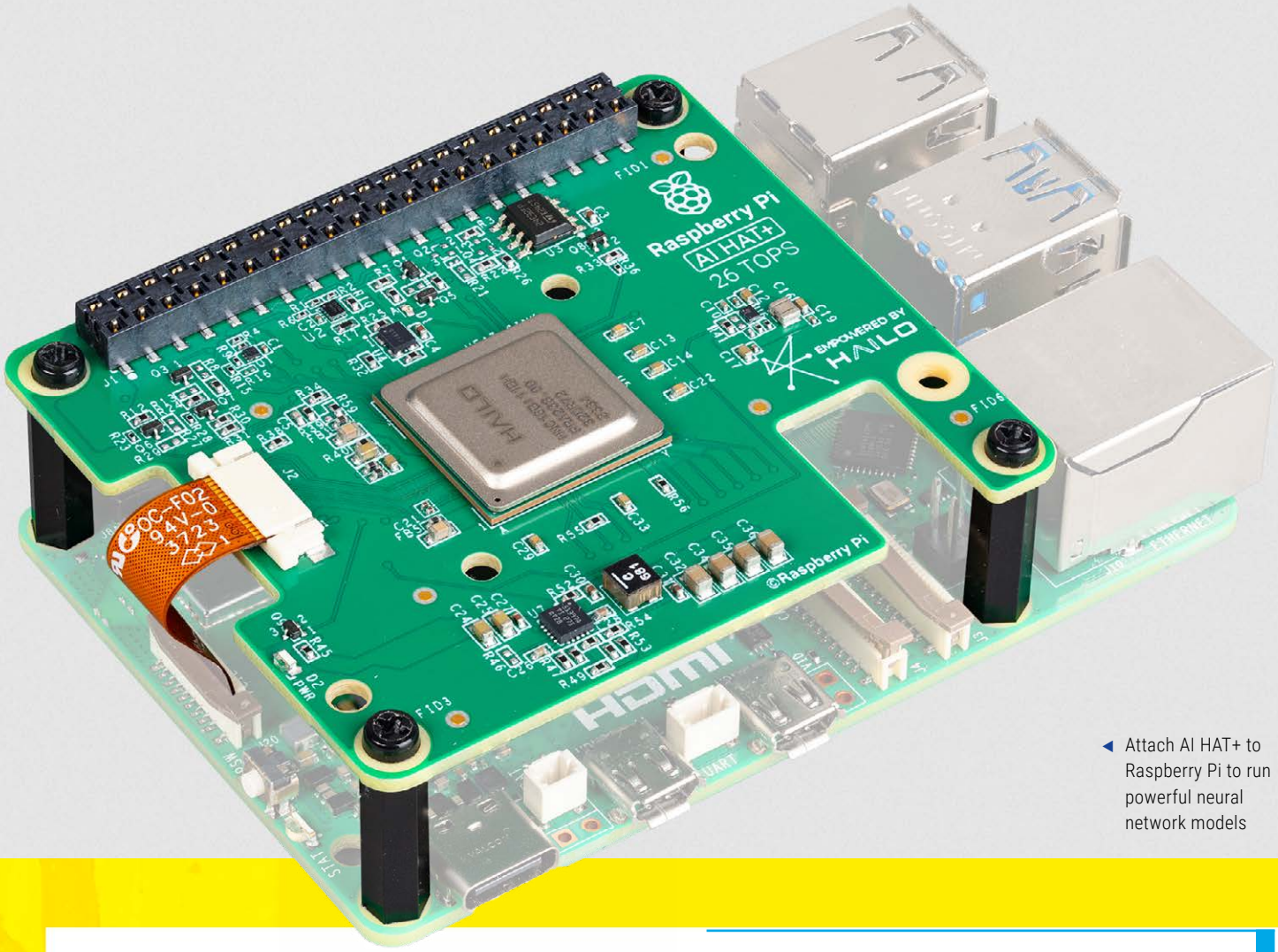


◀ Attach AI HAT+ to Raspberry Pi to run powerful neural network models

Update everything

First, ensure that Raspberry Pi OS is running the latest software. In a terminal window, enter the following command to update it:

```
$ sudo apt update
$ sudo apt full-upgrade
```

Press **Y** and **ENTER** to respond to the prompt to install the latest Raspberry Pi OS software.

Next, it's time to update your firmware. First, check that you are getting the latest version.

```
$ sudo raspi-config
```

Navigate to Advanced Options > Bootloader Version and ensure that Latest is chosen. Click OK and reboot your Raspberry Pi.

Open a terminal window and enter:

```
$ sudo rpi-eeprom-update
```

A great way to investigate what's going on in one of the most high-profile parts of tech

If you see 'BOOTLOADER: up to date', then you are ready to move on. If you see '*** UPDATE AVAILABLE ***', then it's time to update your firmware.

```
$ sudo rpi-eeprom-update -a
$ sudo reboot
```

Run `rpi-eeprom-update`. You should see 'up to date'.

▼ Enable PCIe Gen 3 to speed up inference

Setting up AI HAT+

Connect your AI HAT+ to Raspberry Pi (see the documentation at **rpimag.co/aihatdocs**) and install your Raspberry Pi Camera Module (**rpimag.co/camdocs**).

Enable PCIe Gen 3.0. This will improve the performance of your AI HAT+. Open a terminal window and enter:

```
$ sudo raspi-config
```

Choose Advanced Options > PCIe Speed and YES to 'Would you like PCIe Gen 3 to be enabled?'. Reboot your Raspberry Pi.

Now install the Hailo AI software:

```
$ sudo apt install hailo-all
```

This installs the following dependencies:

- Hailo kernel device driver and firmware
- HailoRT middleware software
- Hailo TAPPAS core post-processing libraries
- The rpicam-apps Hailo post-processing software demo stages

Reboot your Raspberry Pi:

```
$ sudo reboot
```

...and check everything is working:

```
$ hailortcli fw-control identify
```

You should see output containing 'Board name: Hailo-8'.

```
$ rpicam-hello -t 10s
```

...should start the Camera Module and show a preview window for ten seconds.

Detecting people with AI HAT+

The Camera Module software includes rpicam-apps. This is a suite of camera applications that implement a post-processing framework (which passes the image through the camera system via a number of image processing routines).

POST-PROCESSING FRAMEWORK

You can read more about the post-processing framework in the Raspberry Pi documentation.

rpimag.co/postprocessing

Install the latest rpicam-apps package:

```
$ sudo apt install rpicam-apps
```

This demo displays bounding boxes around objects detected by the neural network.

```
$ rpicam-hello -t 0 --post-process-file
/usr/share/rpi-camera-assets/hailo_yolov6_
inference.json
```

Alternatively, you can try another model with different trade-offs in performance and efficiency. To run the demo with the YOLOv8 model, run the following command:

```
$ rpicam-hello -t 0 --post-process-file
/usr/share/rpi-camera-assets/hailo_yolov8_
inference.json
```

Different models perform different vision-based tasks. The next demo performs object detection and segments the object by drawing a colour mask on the viewfinder image. Run the following command to try the demo on your Raspberry Pi:

```
$ rpicam-hello -t 0 --post-process-file
/usr/share/rpi-camera-assets/hailo_yolov5_
segmentation.json --framerate 20
```

The next demo performs 17-point human pose estimation, drawing lines connecting the detected points. Run the following command to try the demo on your Raspberry Pi:

```
$ rpicam-hello -t 0 --post-process-file /usr/
share/rpi-camera-assets/hailo_yolov8_pose.json
```

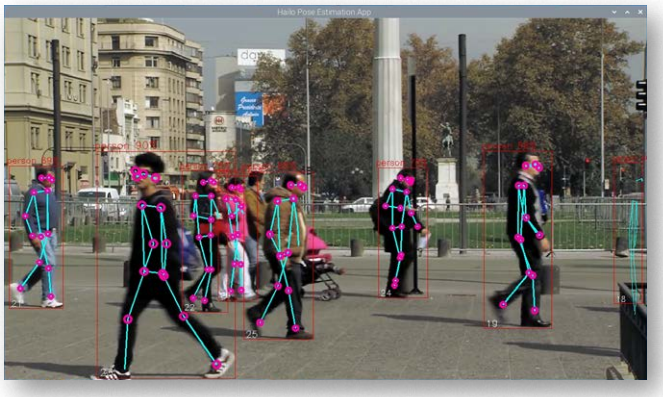
Take a look at the various models at:

```
$ ls /usr/share/rpi-camera-assets
```

And test them out with:

```
$ rpicam-hello -t 0 --post-process-file [path-
to-model]
```

▼ Raspberry Pi Camera Module performing pose detection



GET MORE MODELS

- Hailo has also created a set of demos that you can run on a Raspberry Pi 5, available in the Hailo GitHub repo: **rpimag.co/hailoexamples**
- You can find Hailo's extensive model zoo, which contains a large number of neural networks, in this Hailo GitHub repository: **rpimag.co/hailomodelzoo**
- Hailo also provides a Model Explorer that is used to search and locate the best model for your project: **rpimag.co/hailomodelexplorer**
- Check out the Hailo community forums and developer zone for further discussions on the Hailo hardware and tooling: **rpimag.co/hailocommunity**

Using the AI Camera

The Raspberry Pi AI Camera (**rpimag.co/aicam**) features a Sony IMX500 image sensor that provides low-latency, high-performance AI capabilities to camera applications without needing the AI HAT+ (or AI Kit).

It runs custom neural network models on the IMX500 sensor. Usage is similar to AI HAT+. Make sure your Raspberry Pi is up-to-date and install the IMX500 firmware:

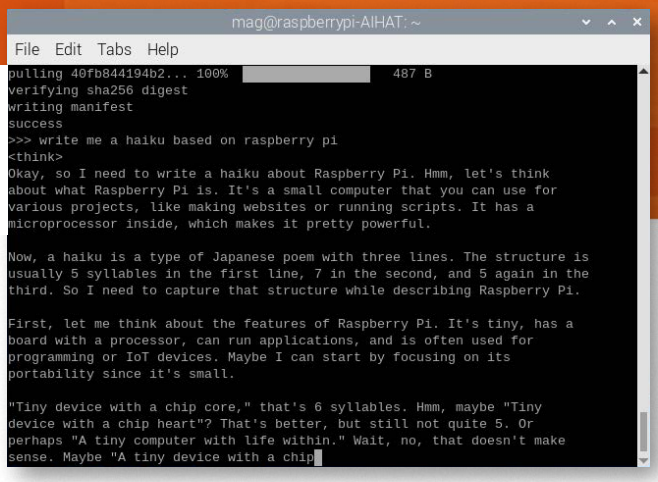
```
$ sudo apt install imx500-all
```

This command:

- installs the **/lib/firmware/imx500_loader.fpk** and **/lib/firmware/imx500_firmware.fpk** firmware files required to operate the IMX500 sensor
- places a number of neural network model firmware files in **/usr/share/imx500-models/**
- installs the IMX500 post-processing software stages in rpicam-apps
- installs the Sony network model packaging tools

Reboot your Raspberry Pi:

```
$ sudo reboot
```



▶ Running a DeepSeek-R1 large language model on Raspberry Pi

The following command runs rpicam-hello with object detection post-processing:

```
$ rpicam-hello -t 0s --post-process-file
/usr/share/rpi-camera-assets/imx500_mobilenet_
ssd.json --viewfinder-width 1920 --viewfinder-
height 1080 --framerate 30
```

The following command runs rpicam-hello with pose estimation post-processing:

```
$ rpicam-hello -t 0s --post-process-file
/usr/share/rpi-camera-assets/imx500_posenet.json
--viewfinder-width 1920 --view
```

Running DeepSeek-R1 locally

DeepSeek is a generative pre-trained transformer that is available as an open-source model (the model weights have been made available, **rpimag.co/deepseekr1**).

It is possible to run DeepSeek-R1 on an 8GB or 16GB Raspberry Pi thanks to Ollama (**ollama.com**). You don't need the AI HAT+ or AI Camera for this, although it does run quite slowly. It's great for experimentation.

Open a terminal window and enter:

```
$ curl -fsSL https://ollama.com/install.sh | sh
```

Check that it works:

```
$ ollama --version
```

You can run the DeepSeek-R1 small model which has 1.5bn parameters. While this is fun to play around with, it will hallucinate answers wildly and produce inaccurate results.

```
$ ollama run deepseek-r1:1.5b
```

It will pull the model online and provide you with a text-based interface:

```
>>> Send a message (/? for help)
```

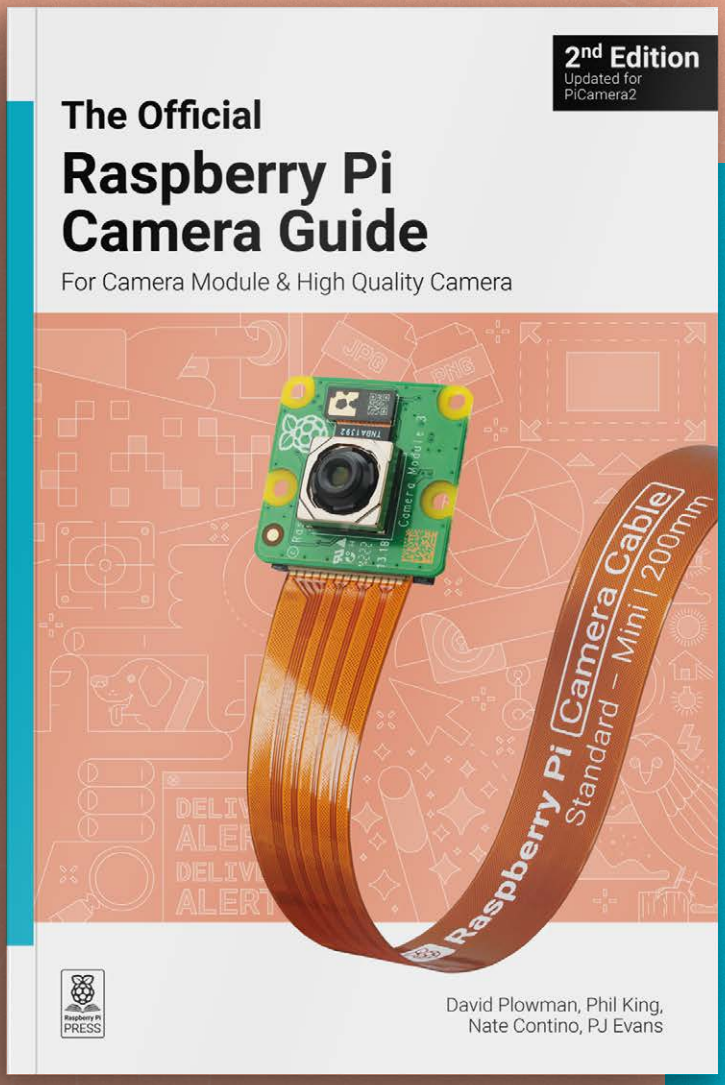
Start chatting to it and ask it questions. It will run through its thinking process as it works. We asked it to tell us a Raspberry Pi joke, and it said:

```
Pi (3.14) is like a Pinata! And don't forget to
wear your Raspberry Pi Shoes!
```

To run a more powerful model with 7 billion parameters, enter:

```
$ ollama run deepseek-r1:7b
```

We asked it to generate a Raspberry Pi haiku. It got it slightly wrong, so there is a way to go with these language models, but it's impressive for a locally running model and a great way to investigate what's going on in one of the most high-profile parts of tech.



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Build a CRT emulation console

Use Recalbox's RGB Dual HAT and emulation distro to connect Raspberry Pi to CRT TVs and VGA monitors

Maker
K.G. Orphanides
K.G. is a writer, game developer and musician who not only owns a CRT TV, but has to be actively prevented from buying more when they visit charity shops.

twoot.space/@owlbear

Retro games just don't look the same on modern LCDs. Computer game pixel art of the 1980s and 1990s was designed to benefit from the fuzzy edges, bleeding colours and low resolutions of PAL, NTSC and SECAM CRT TVs and monitors. The phosphor dots that make up a CRT TV's pixel grid appear rounded, as compared to the hard edges of pixels displayed on LCD and OLED monitors.

Artwork that takes advantage of every limitation of the system and screen

Casting shade

Computer game artists were familiar with these limitations and took advantage of them to create pixel art that gave the impression of depth, shading and smooth edges. Look at a NES game such as Wizardry (**rpimag.co/wizardry**), and you'll see artwork that takes advantage of every limitation of the system and screen, such as the dot-pitch – the tiny black spaces between each pixel on a CRT – to create extra detail.

You can reproduce the effect in emulators with judicious choices of CRT shaders and even artificial scan lines, but these require extra processor power to create and often fail to reproduce all the conditions those early developers of in-game graphics took advantage of.

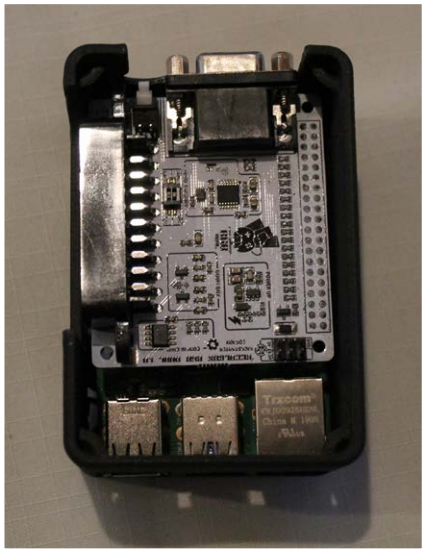
Second-hand CRT televisions are still available to buy cheaply from second-hand shops, and allow you to play old-school games as they were intended, but outputting to them from modern hardware remains a challenge.

Warning!

Copyright

This feature discusses the use of legally distributed games and system ROM images for a variety of vintage computers. However, please note that many other titles are distributed online without their rights holders' permission, and are not legal to use under UK law.

rpimag.co/legalroms



◀ The RBG Dual HAT allows a Raspberry Pi to be connected to a CRT display via SCART or VGA

▲ Modern games for retro consoles, such as action puzzler Arkagis Revolution for the Sega Mega Drive, easily match top-flight releases from back in the day

▶ A rich homebrew scene and various official Sega ROM set releases over the years make the Mega Drive a particularly good choice to emulate

Mario SCART

Made by the French Recalbox team, with whom regular readers will be familiar from the Recalbox emulation distro that we've used in projects including our arcade cabinet build, the RGB Dual is a Raspberry Pi HAT that provides high-quality analogue RGB graphics output via both a 640×480 VGA output for use with retro monitors and a 240p Peritel (SCART) port that you can plug into most CRT TVs for the best possible quality graphics. Other features include the 'boom box' DAC, a 'Wake Up Button' so you can easily power Raspberry Pi on, and a fan header in case you wish to add cooling. You can also buy or make (**rpimag.co/recalrgbcase**) your own 3D printed case for your Raspberry Pi and RGB Dual, which gives you a nicely finished device for you to keep next to your TV.

There are two frequency switches, the first of which can be set to either attempt to auto-detect the region of games and change the RGB Dual's output display frequency accordingly or lock the RGB Dual to 50Hz for PAL and SECAM TVs (only NTSC supports up to 60Hz). The second allows you to switch between a 15kHz horizontal refresh rate, for use with standard TVs and 31kHz, used by VGA monitors and some arcade machine displays. By default, the switches are set to 50Hz and 15kHz.

You'll ideally want to use the RGB Dual with Raspberry Pi 3 or 4. You can also use it with Raspberry Pi Zero 2 or Raspberry Pi 400 (with a GPIO extender). Raspberry Pi 5 works but doesn't have audio over SCART due to hardware changes, so you'll have to use Bluetooth audio or a USB DAC.

The forthcoming RGB Dual 2, only for use with Raspberry Pi 5, has an integrated DAC that natively supports Raspberry Pi 5's audio output, and adds a few more features, including composite video out, a 3.5mm audio output, 16:9 aspect ratio support, and support for Namco's GunCon 2 PlayStation 2 light gun controller. Production is set to be funded via a Kickstarter campaign on 31 March 2025. See **rpimag.co/rgbdual2** for further info.

Spec your system

If you want to smoothly emulate later-generation consoles such as the Dreamcast, this'll go better with an 8GB Raspberry Pi 5, for all its lack of support for audio out over SCART. However, for emulation of anything up to the 32-bit era, you should be fine with Raspberry Pi 4. We recommend at least a 32GB SD card, just because that makes it easier to load up as much homebrew as the internet's retro programmers can provide.

You'll also want an appropriate controller and – if you're playing retro computer games – a mouse and keyboard. Bluetooth controllers like the ubiquitous Sony DualShock 4 and USB pads like 8BitDo's retro controllers both do nicely. GPIO controllers aren't an option here, as the GPIO is already in use.

Finally, you'll need a SCART lead and, of course, a CRT TV to connect your Recalbox setup to. We strongly recommend using an RGB Dual case to protect your new mini console.

You can leave your HAT on

RGB Dual is a typical Raspberry Pi HAT – you mount it on the GPIO header and a pair of plastic stand-offs clip into Raspberry Pi's mounting holes on the opposite side to support the full-width card. Depending on whether you plan to connect it to a VGA monitor (ideal for playing retro PC games) or a CRT TV, you'll need either a VGA cable or a SCART lead. You'll also want to check the switches we mentioned, especially if you're using a VGA monitor, but they come already set for PAL TV regions. A small square of cellophane must be peeled off to provide access to the switches for the first time. Once the HAT is attached, case everything up and plug in your peripherals.

Get set up

Use Raspberry Pi Imager to burn Recalbox to a microSD card – you'll find it in the Emulation and Game OS submenu. Insert it, connect your hardware, select the SCART input on your TV, and power on Raspberry Pi. Recalbox will finish setting itself up and you'll get to see a fun intro video. Once you're into the menus, you can try out a few of the pre-loaded homebrew games, but you'll at very least need to connect to the network to get your own games onto the system. If you're using Wi-Fi rather than an Ethernet connection, press Start to open the System menu > Network Settings > Enable Wi-Fi, then select your network's SSID and enter the password in the Wi-Fi settings. A keyboard makes this easier.

Snake ROM 'n' roll

Note that not every emulator will work out of the box. Some require system ROM files, which in some cases have been made available for free or to purchase by their current rights-holders. Check out our Emulate Everything feature in issue 133 (**rpimag.co/133**) or the updated version of it in *Retro Gaming With Raspberry Pi 3rd Edition* (**rpimag.co/retrogamingbook**) for a comprehensive table of which devices require system files and where to find them.

You'll be able to access Recalbox's browser-based management dashboard at **http://recalbox.local/** and connect to its shared storage directories via **smb://RECALBOX.local/share**, where you can copy BIOS and ROM files to your console over the local network. Windows users might need to patch in some extra registry entries to access the share (**rpimag.co/w10network**)

You will also be able to connect to **root@recalbox.local** via SSH or SFTP, with the password **recalboxroot**.

Homebrew games galore

There's a whole world of homebrew out there, but to get you started, here's where to find game ROMs that you can just drop into the relevant **~/share/roms/** directory for each console and get playing:

- Mega Drive: **rpimag.co/itchmd**
- NES: **rpimag.co/itchnes**
- Master System: **rpimag.co/itchms**
- Game Boy: **rpimag.co/itchgb**
- Game Boy Color: **rpimag.co/itchgbc**
- Game Boy Advance: **rpimag.co/itchgba**

▲ To play emulated retro games on your CRT TV, you'll need your Raspberry Pi and RGB Dual HAT, a controller, and a SCART lead

Part 01

Meshtastic

Use Raspberry Pi Pico to enhance your network

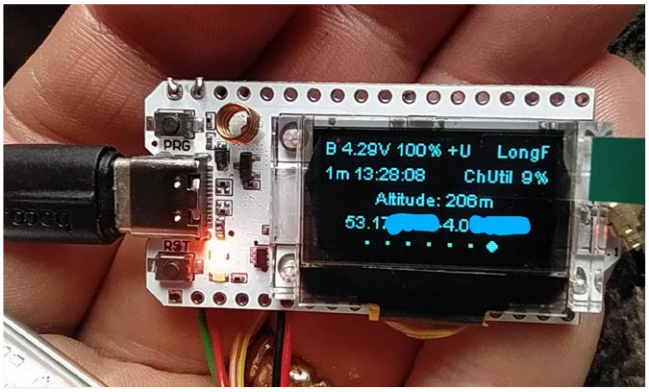
Maker
Jo Hinchliffe (aka Concretedog)
With a house and shed full of lathes, milling machines, 3D printers, and more, Jo is a constant tinkerer and is passionate about making. Obsessed with rockets and robots and much more besides, he often releases designs and projects as open source.

concretedog.blogspot.com

We've looked at the Meshtastic project before, back in *HackSpace* issue 80 (rpimag.co/hs80), which is a great read that you should definitely check out if you are unfamiliar with Meshtastic: it would serve as a great introduction for these articles. As a brief introduction, Meshtastic is an open-source project that uses affordable LoRa-equipped hardware to create off-grid communications networks (**Figure 1**). Beyond that, it's a capable and fun platform for experimenting with different hardware and antennas and other technical areas.

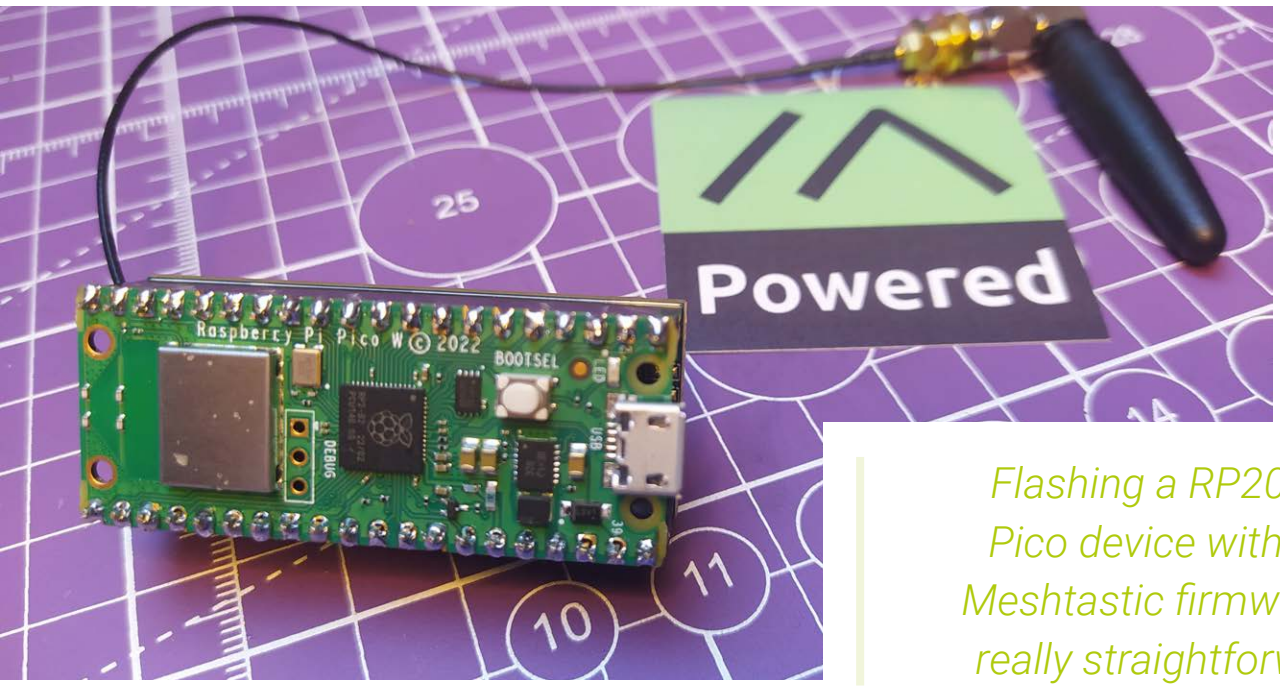
In the first part of this two-part look at Meshtastic topics, we will explore options to set up a budget Meshtastic device using an RP2040-based Raspberry Pi Pico W, and we'll also look at adding a cheap GPS module to a Meshtastic device. In the second part of the series, we are going to build a standalone solar-charged RP2040/Pico device which can act as a Meshtastic repeater, and we'll look at some interesting use cases for the device. Finally, we'll look at connecting Meshtastic to another open-source application to allow teams to share location and messaging whilst completely off grid.

As a primer for Meshtastic, there are numerous ways in which the devices can be operated. The essential idea is you have a Meshtastic device which is running the Meshtastic firmware and there are various ways that a Meshtastic device might be interacted with. One approach is to have a complete Meshtastic device, which may have a screen and a keyboard, and therefore one can send and receive messages, and view other statistics about the local Meshtastic network, all on one device. There are a few mass-manufactured devices for this, such as the Lilygo T-Deck Plus.



▶ **Figure 2:** A Heltec V3 board is a common choice for a budget Meshtastic device

At the more budget-conscious end of the range of Meshtastic options, there's a heap of devices which can potentially be used in collaboration with your mobile



◀ **Figure 1:** A Meshtastic device made from a Pico W and an add-on module

▼ **Figure 3:** SX1262 LoRa add-on board for Raspberry Pi Pico family

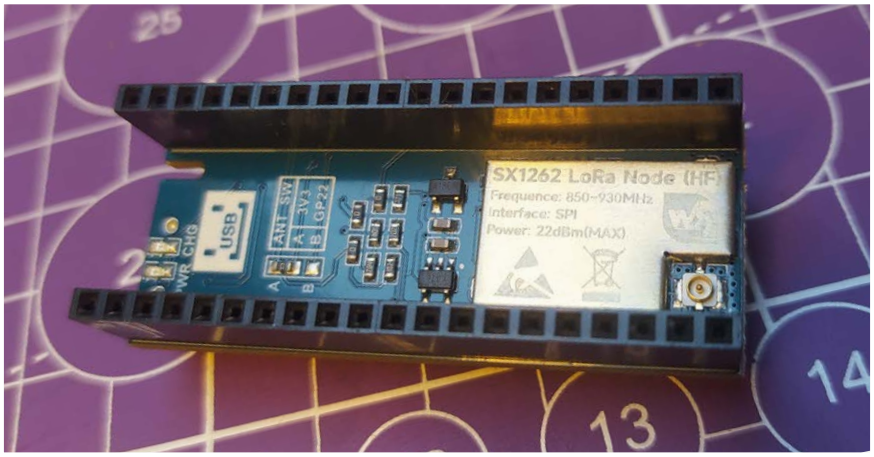
Flashing a RP2040/ Pico device with the Meshtastic firmware is really straightforward

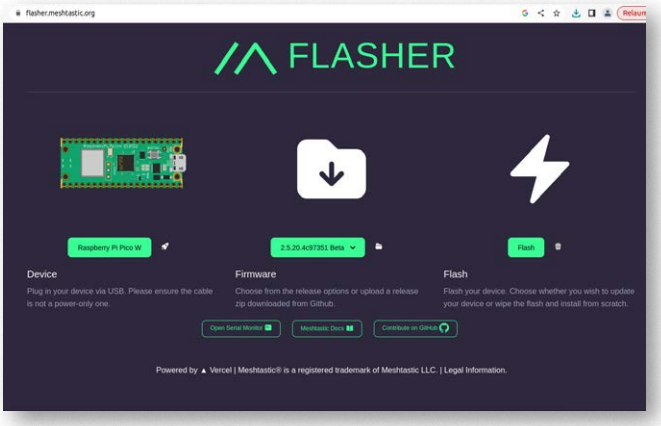
phone, laptop, or other portable Wi-Fi/Bluetooth or USB device. A really common device for this is the Heltec WiFi LoRa 32 V3, which has a small screen on board, but you interact with the device, sending and receiving messages, via the Meshtastic app on your phone and a Bluetooth connection (**Figure 2**). Sometimes, though, you might want to have a device that's just a node that you don't particularly want to connect to directly. The use case for this is as a Meshtastic repeater, or you could consider it a range extender. As a working example, I get much better results from a Meshtastic device placed in my garden than I do inside my (thick-walled) Welsh miner's cottage. However, I don't particularly want to stand in my garden all the time to interact with the node. A decent approach here is to place a standalone device in the garden in a good position and then use another device in the house, perhaps on a windowsill, with which I have a Bluetooth connection to my phone.

Outdoor connection

The device in the garden in this example doesn't need to have a screen, or even really a way to directly connect to it via Bluetooth. For these devices, a Pico or other RP2040-powered device can be a great option. With no screen attached and no Bluetooth or wireless active, they can be reasonably efficient in terms of power consumption and they are certainly at the affordable end of the available Meshtastic device options. Let's take a look at an option.

As we already have some Pico W boards, a good option is to add a Waveshare SX1262 LoRa Node Module (**Figure 3**). This LoRa module is designed specifically for Pico – and if your Pico has header pins soldered, you can plug it straight into the Waveshare SX1262 Module. The module has a handy silkscreen graphic indicating where to line up the USB port on the Pico. You'll notice that the Waveshare device has a connector for a single-cell battery on board and, excellently, it will charge the battery via the Pico USB port; indeed, the Waveshare SX1262 we bought came with an included LiPo cell. The SX1262 also has on board a small IPEX 1 connector to connect the coaxial cable for the included antenna. Press this connector carefully into place and then screw on the supplied small antenna. These antennas are great to get going with, but you can certainly increase the range of the device with an antenna upgrade down the line.

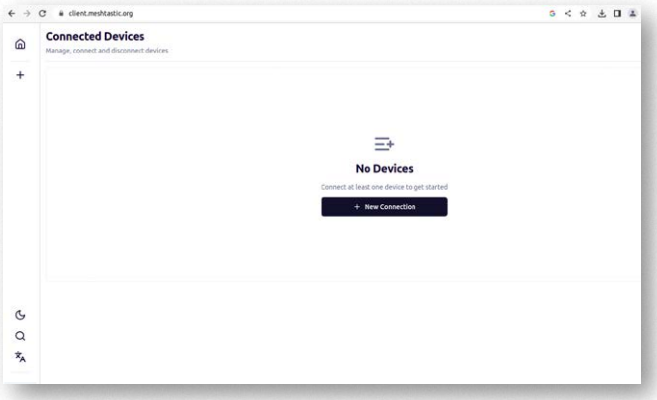




▲ **Figure 4:** Using the Meshtastic Web Flasher tool makes it really straightforward to flash devices with the correct firmware

Flashing an RP2040/Pico device with the Meshtastic firmware is really straightforward using the Meshtastic Web Flasher tool (**Figure 4**). Navigating over to the page, you can then select Raspberry Pi Pico W from the 'Devices' menu. Next, click the Firmware button and select the firmware you want to install. We've tended to opt for the latest stable version rather than the beta development versions. Finally, and unlike flashing other Meshtastic devices, when you click the Flash button, you will get the option to download the firmware UF2 file. If you have played with Raspberry Pi Pico before, you'll recognise this as the drag-and-drop format of firmware that can easily be placed on the Pico for installation. To do this, plug in your Pico to your computer while holding down Pico's BOOTSEL button. You should see a DFU mode drive appear as a connected drive on your computer. Simply drag and drop, or copy and paste, the UF2 file from your downloads into the connected Pico drive, wait a few seconds, and the drive should disconnect and reboot, running the Meshtastic firmware. The Pico Meshtastic currently has some issues in that, unlike other devices, you can't connect to the Pico via Bluetooth and you can't connect to it over Wi-Fi using the web UI due to a lack of HTTP support. However, don't despair: we eventually want to use this device as a standalone repeater, and there is a simple way to connect to the device for configuration.

Leaving the Pico W device connected to your computer, navigate over to the Meshtastic web client and click the '+ New Connection' button (**Figure 5**).



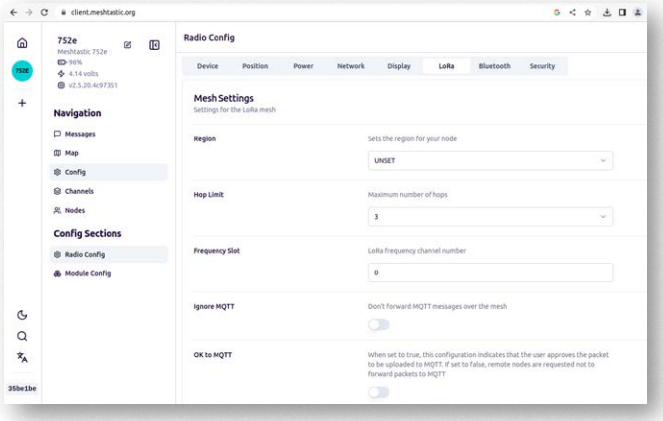
◀ **Figure 5:** The Meshtastic web client allows you to connect to a Meshtastic device using HTTPS, Bluetooth, or in this case a USB serial connection

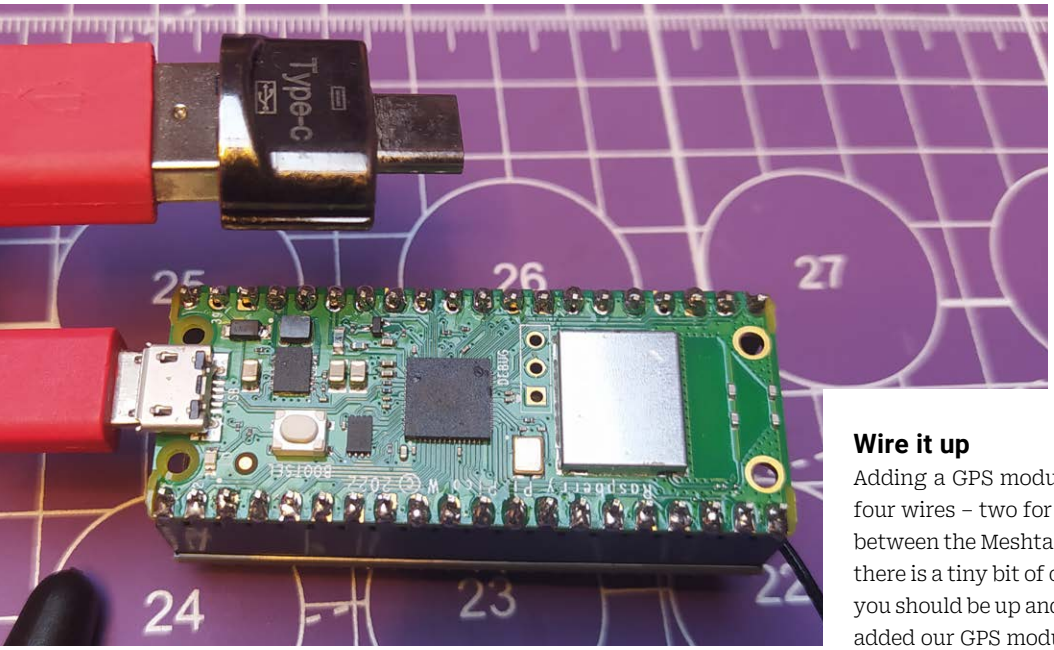
In the next window, select the Serial tab from the three available tabs, then click New Device. Select the serial connection that refers to your device in the resulting window and you should now see the device connect and the Meshtastic web client spring into life.

Radio radio

At this point, your Pico node is up and running, but can't connect to any other nodes since the radio region – and therefore the operating frequency of the radio module – isn't set. To do this, click Config and then Radio Config; you'll see in the Mesh Settings window that the first item is Region. Currently the region is set to 'Unset'; click this drop-down menu and set the region to your locale, so for us that was EU. Of course, you can also edit any other items, the name of your node, channels setup, and more in the web client (**Figure 6**).

▼ **Figure 6:** Until the LoRa region is configured, the device won't be able to connect to any Meshtastic devices or network





◀ **Figure 7:** Using a USB-C to USB-A adapter to connect the Pico Meshtastic device to the Android application via USB OTG

▼ **Figure 8:** Soldering four wires is all it takes to add GPS capabilities to a Meshtastic device

Another option for interacting with our Pico W Meshtastic device is using a wired USB OTG connection to our phone and using the Meshtastic app. We needed a USB-C to USB-A adapter to be able to connect to the Pico (**Figure 7**); the device was automatically detected and we found we could select '/dev/bus/usb/001/002' listed in the Meshtastic app connection menu. This is a great option if you want to interact with the device in the field. We'll leave this Pico/Waveshare device at this stage, but in the next issue we're going to look at setting this device up as a standalone repeater with battery and solar charge system.

Another great DIY Meshtastic project is to add GPS to a device so that you can show your device position to other Meshtastic devices or for tracking an item your device is attached to. Of course, again, you could simply buy a Meshtastic device with GPS capability, but where is the fun in that! For this section, we are going to connect a GPS module to a Heltec V3 Meshtastic device as we don't particularly plan to carry the Pico-based device as a mobile module.

The Heltec Wi-Fi LoRa 32 V3 is a classic entry-level module for Meshtastic. It's affordable, has an on-board screen, and connects well to the Meshtastic app via Bluetooth. Similarly to the Waveshare SX1262 add-on board, the Heltec V3 has a battery connector and you can recharge a connected battery via the USB-C connector. We are going to add a really cheap and cheerful GPS module, a NEO-6m, which is an older GPS module, commonly available, and has been used in many, many hardware projects over the years!

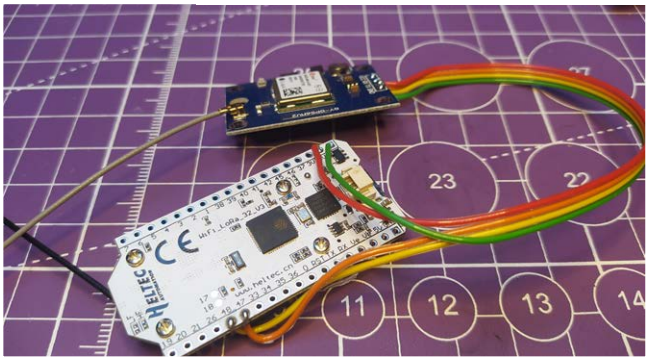
Wire it up

Adding a GPS module to a Meshtastic is as simple as soldering four wires – two for power and two for RX and TX connections – between the Meshtastic device and the GPS module. Beyond that, there is a tiny bit of configuration to do in the Meshtastic app and you should be up and running. It's probably worth noting that we added our GPS module to a Heltec V3 that we had previously set up using the Meshtastic Web Flasher and we had confirmed it as an operational Meshtastic device.

We'll need four wires to solder between the Heltec V3 and the NEO-6m (**Figure 8**). On the NEO-6m, connect the VCC pin to the 3V3 pin on the Heltec V3; likewise, the GND pin on the NEO-6m needs to connect to the GND pin. Finally, solder the RX pin on the NEO-6m to pin 48 and then the TX pin to pin 47. After checking your connections, you can then power up the Heltec V3 device and connect to it using the Meshtastic app via Bluetooth. You should see an LED light on the NEO-6m confirming you have power to the board.

QUICK TIP

Always connect an antenna to your Meshtastic device before powering up, as powering a LoRa radio without an antenna attached can damage it.



In the Meshtastic app, click the three-dots menu icon and select the Radio Configuration menu, then the Position submenu. Scroll down this menu and then, under the heading 'GPS mode', use the drop-down box to change the mode from 'NOT_PRESENT' to 'ENABLED'. Then, slightly further down the page, you will find a section where you can redefine pin numbers (**Figure 9**). Look for the heading 'Redefine GPS_RX_PIN' and then, in the dialog, change the value 0 to 48. Next, do similar for the TX pin by changing the value of 'Redefine GPS_TX_PIN' from 0 to 47. Finally, and crucially, scroll down to the very bottom of this page and hit the Send button to push these changes to your device. The device should reboot (disconnecting and reconnecting to the app) and when you are reconnected, after a wait of maybe a few minutes, the device will begin to broadcast its GPS location – well, kind of, as there's one more thing to consider.

If the primary channel of your Meshtastic device is the default public 'Longfast' channel then the Meshtastic firmware, by default, will display an inaccurate GPS location. For example, in **Figure 2**, the location of this device is around 1km from my actual position (**Figure 10**). The reason for this is that by default Meshtastic doesn't want to broadcast your exact position, for privacy reasons. To enable a precise position to be broadcast, you need to go into your Channel settings via the Radio Configuration menu, click on the Longfast channel, and turn on the 'Precise location' button. If you then check your position in the map tab, you will see, after it updates, that it should be a good match for the device's position. This means that as you perhaps add private channels on your Meshtastic devices, you can choose channel by channel whether you share your rough location, precise location, or not share location information at all.

Join us in the next issue when we continue to develop our Pico-based, solar-equipped Meshtastic node and look at some fun use cases for both the Pico device and our GPS-enabled devices.

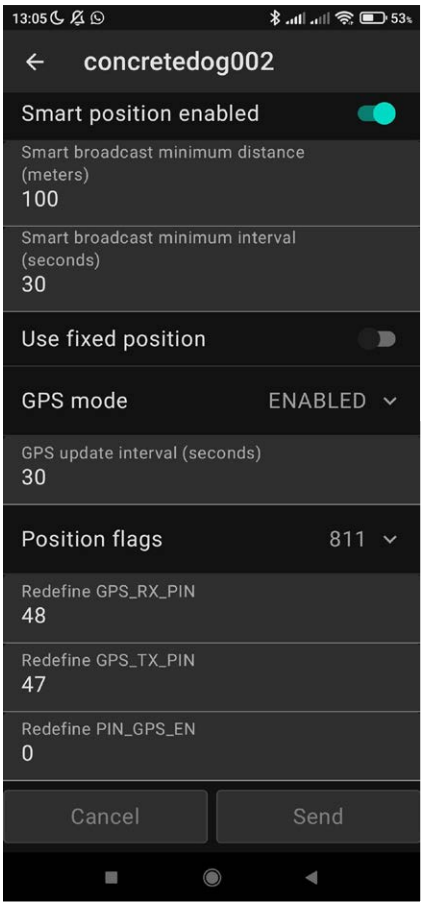


Figure 9: Configuring the RX and TX pins and enabling the GPS device in the Meshtastic app

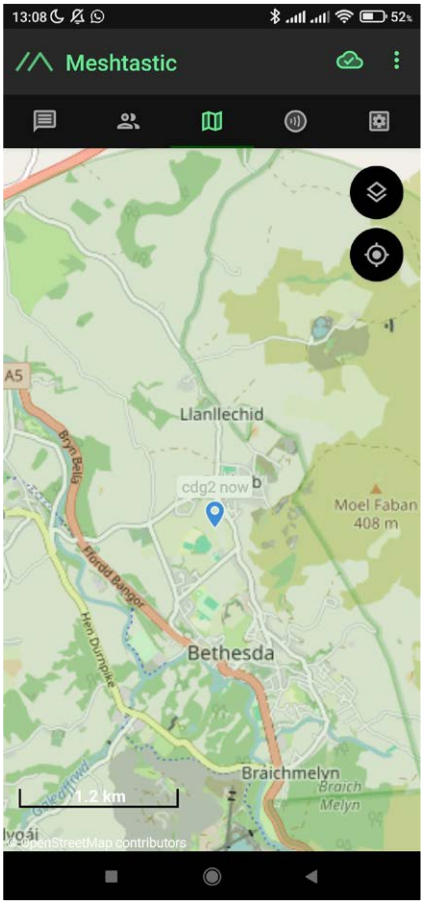
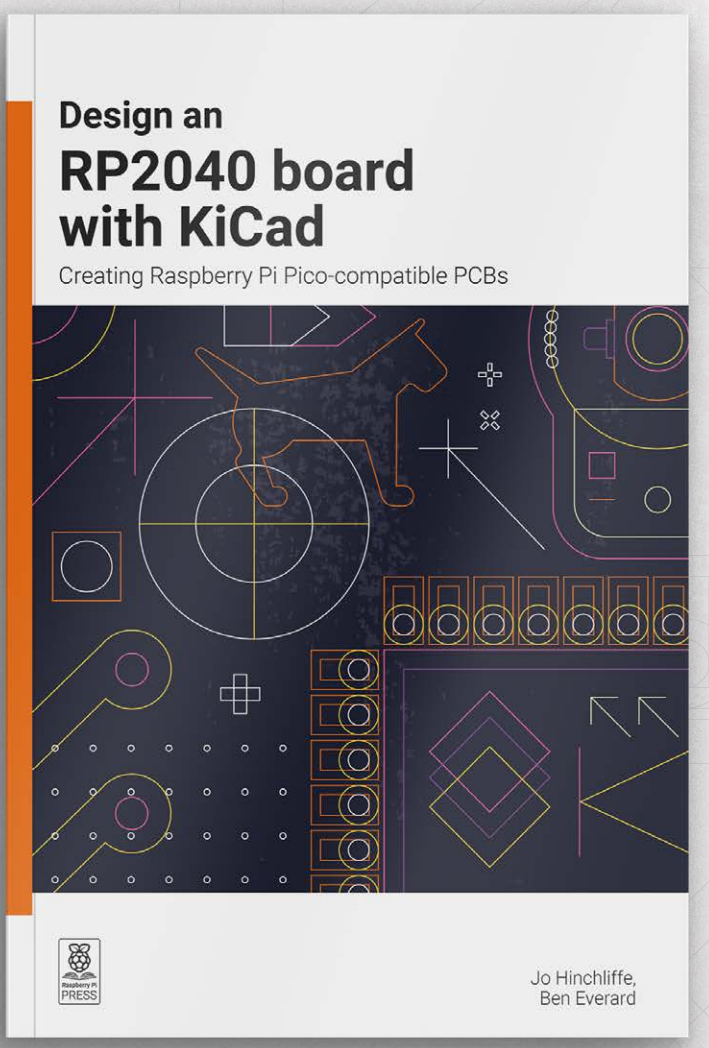


Figure 10: The default GPS settings on the public 'Longfast' channel are deliberately not accurate until a precise location mode is enabled

QUICK TIP

Unless you can place a device in an excellent 'top of a mountain on a mast' position, it's good practice to use client modes in Meshtastic rather than router modes.



KiCad is an amazing piece of free and open source software that allows anyone, with some time and effort, to make high-quality PCB designs.

- ***Create a schematic for a microcontroller board using Raspberry Pi's RP2040***
- *Select the right components*
- ***Customise the hardware for your needs***
- *Lay out and route the PCB design*
- ***Prepare your board for manufacture and assembly***
- *Write software to get your design working*

Buy online: rpimag.co/kicad2040

Build a smart CO_2 sensor

Is your environment affecting your alertness? Become air aware with a Raspberry Pi-powered CO_2 sensor

Maker

PJ Evans

PJ is a writer, software engineer and tinkerer. Working at home for so long, he's learnt to open a window now and again.

mastodon.social/@mrpjevans

YOU'LL NEED

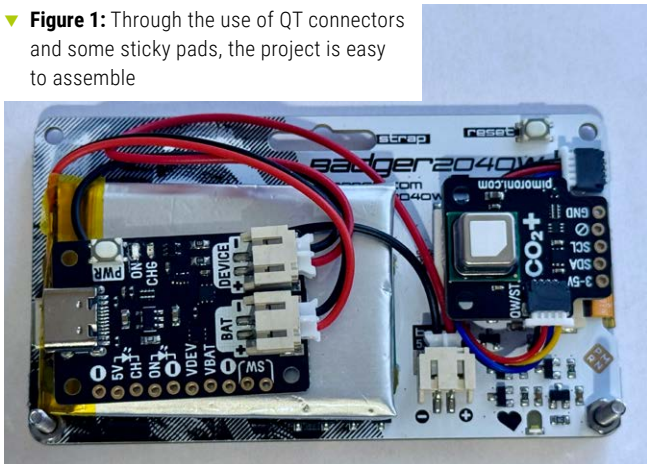
- Badger 2040 W
  rpimag.co/badger2040w
- SCD41 CO_2 sensor
  rpimag.co/scd41
- LiPo Amigo
  rpimag.co/lipoamigo
- 1200 mAh 3.7 V LiPo battery
  rpimag.co/1200lipo
- 4-pin JST-SH cable (50 mm)
  rpimag.co/jstsh

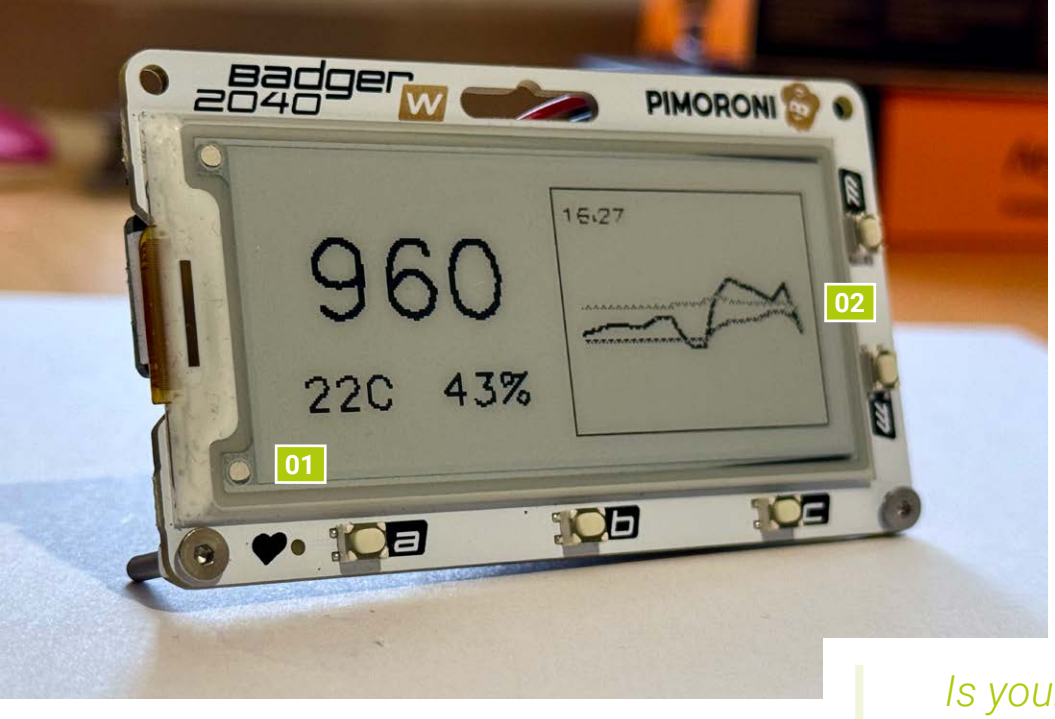
There's something in the air. Well actually: there's lots of things in the air, not just good old oxygen. We exhale carbon dioxide (CO_2) and that means that in an enclosed space containing one or more people, the amount of CO_2 can increase unless there's good ventilation. When CO_2 goes over 1000 ppm (parts per million) in a room, it can start to have consequences for your clarity of mind. At 2000 your cognitive ability can become seriously impaired. Do you know if your room or workplace is giving you brain fog? Let's build a monitor and find out!

01. Burn your badger!

Please leave any black and white furry mammals alone. What we mean is make sure your Badger 2040 W is ready for use. This groovy little Raspberry Pi Pico W and e-ink screen combo was intended as an interactive name badge, but it's also great for making a tiny display. We need to be sure that it's running the Pimoroni flavour of MicroPython so it has all the libraries it needs to communicate with the screen and buttons. It should come with everything you need, but if you're looking for a fresh start, follow the instructions to install Badger OS here: **rpimag.co/badger2040git**. On restart, you should see a menu displayed. You're good to go.

▼ **Figure 1:** Through the use of QT connectors and some sticky pads, the project is easy to assemble





01. The easy-to-read e-ink screen gives clear readouts

02. Hiding behind the screen are the sensor, battery, and Raspberry Pi Pico W

02. Set up your environment

We're going to use Thonny to upload code to the Badger. Thonny is installed by default in Raspberry Pi OS (**thonny.org**), so launch it. Connect the mounted Pico W to your computer using a USB cable. At the bottom-right of the screen you will see 'Local Python'. Click on the text and you should be able to select your Pico W. When you select it, the Shell window should display a welcome message and the familiar '>>>' of Python. If not, you may need serial drivers for your computer to allow the Pico W to communicate. There's more help here: **rpimag.co/badger2040starter**.

03. Text on your badger!

Again, please do not take any kind of marker to our furry friends. Let's test the screen drivers are working correctly. From the prompt in the Shell, type in the following code:

```
import badger2040
badger = badger2040.Badger2040()
badger.set_pen(15)
badger.text("Hello Badger", 20, 20)
badger.update()
```

You should get a black screen and 'Hello Badger' in white. We've now proven that everything is working and can move on to the CO_2 sensor.

04. Plug in your CO_2 sensor

Disconnect your Raspberry Pi Pico W from the computer and make sure it has no other form of power to it. Carefully (static strap recommended!) remove the CO_2 sensor from its packaging. You'll see a connector on the side marked 'QW\ST'. Connect your 50 mm QT cable. Make sure it's the right way up – you shouldn't need to force it in. Now find the QW\ST connector on the Badger, next to the reset button. Again, carefully insert the connector. Double-check everything before reconnecting the Badger to any kind of power.

Is your room giving you brain fog?

05. Testing the sensor

Before we start sticking anything to anything else, let's check the sensor is working as expected. Connect your Badger back to the computer and make sure you can get to the prompt in the Shell windows as before. Now create a new file on the Badger by right-clicking in the 'Raspberry Pi Pico' file list and select 'New file'. Save it as **sensor_check.py** and add the code in the listing (overleaf). Save again then press the 'Play' button in the top menu bar. Watch the Shell window. After a few seconds, readings of CO_2, temperature, and humidity should appear.

Warning!
LiPo batteries
LiPo batteries must be treated with respect and charged/discharged within the parameters listed in their datasheet. You should never dent, bend, puncture, crush, or otherwise damage them. You should only consider these kinds of batteries for your projects if you've done your research and understand the risks. **rpimag.co/batterysafety**

06. Get sleepy

One of the many great features of the Pico W is its deep sleep mode. When activated, the system will shut down except for a very low-powered timer that will tick over, barely consuming power, until it's time to start up again. The result, for our project, is that we can extend battery time from hours to weeks by only consuming power when reading the sensor and updating the display. Try this out by adding:

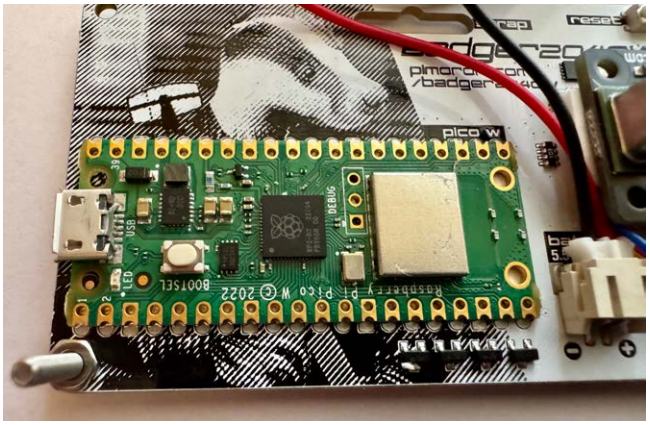
```
import badger2040
```

...at the top of the file and...

```
badger2040.sleep_for(1)
```

...after the `print` statement.

Now, your Pico W will measure the CO_2 once a minute and snooze in-between.



▲ The flush-mounted Raspberry Pi Pico W sits behind the battery

07. Let's get pretty

Now we've tested the screen, the sensor and deep sleep, let's put them all together. The code is a little long, so we've uploaded it to **rpimag.co/badgerwatchgit** where you can download it:

```
git clone https://github.com/mrpjevans/badgerwatch
```

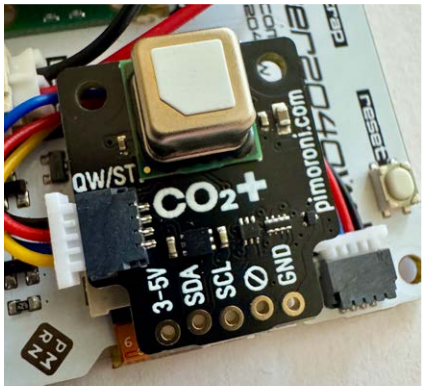
The code will take a measurement from the sensors and update the display with the readings. As a bonus, it'll also draw a simple graph so you can track changes over time. It will then sleep for five minutes before reading again. Create a file called **co2.py** in the root of your Pico W file system and paste the code in. Running it in Thonny should update the display.

08. Bringing it online

If you've got a Badger 2040 with the W at the end, it means you have a Wi-Fi-capable Pico (if not, skip the next two steps). So, let's take our sensor one step further and connect it to your local network. For this first example, we'll just add a timestamp by using your local time server (NTP) to get the current time. This script connects to your local Wi-Fi, then queries the NTP server. Once it has the time, it adds it to the graph. Copy the file **co2_wifi.py** to your Badger. Find the file **WIFI_CONFIG.py** which will already be on the Badger. Open that file up and change the SSID, password, and country code to match your settings. Run **co2_wifi.py** in Thonny and check everything is working.

09. Adding MQTT

Let's make the internet connection a little more useful. In our final version of the script, we'll transmit the readings to an MQTT broker which can then be read by services such as Home Assistant. If you're new to MQTT, you'll need to set up a broker, so here's a tutorial that will guide you through it: **rpimag.co/donotdisturb**. From **rpimag.co/badgerwatchgit**, upload **co2_mqtt.py**, **umqtt_simple.py** and **MQTT_CONFIG.py** to your Badger as before. Edit **MQTT_CONFIG.py** to set your client name, broker address, and topic. Save it and then start the **co2_mqtt.py** script in Thonny. Use your favourite MQTT monitoring tool to view the result.



▲ The all-important CO_2 sensor also provides temperature and humidity measurements

10. You have the power

Two jobs left: first, we need to start the script on Pico boot. In Thonny, edit the file **main.py** on the Badger. This file is always run when power is applied. Change it to say:

```
import co2_mqtt
```

...and nothing else. (If you're not using MQTT, just change it to `co2` or `co2_time` as you want)

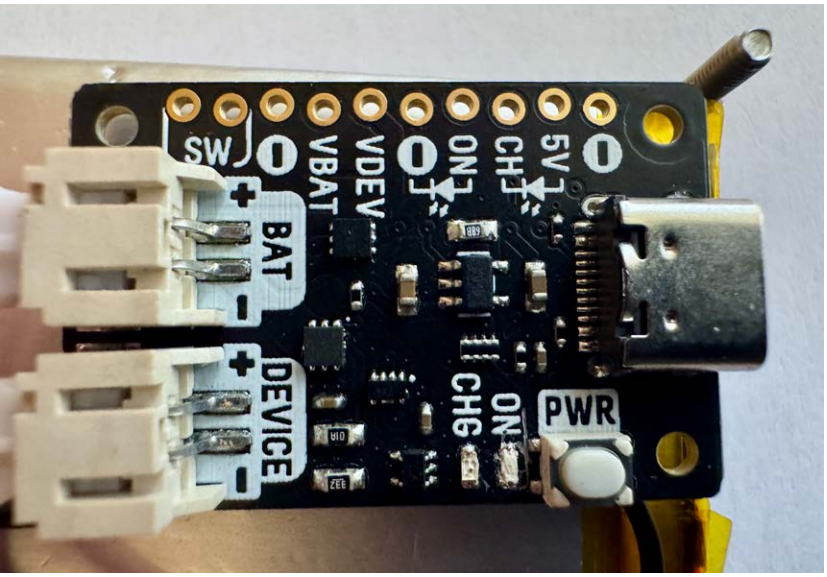
Next, disconnect the Badger from your computer. Connect your LiPo charging circuit to the power connector on the Badger and then your LiPo battery to the circuit where marked. Press the power button and your CO_2 monitor should come to life.

11. Tidy-up time

Once you're confident everything is working, you can mount the CO_2 monitor, battery, and charger onto the back of the Badger. Sticky pads work well for this, but make sure the USB-C port of the LiPo charger is accessible. See **Figure 1** for an example of how to do this. If you have some long 2.5mm nuts and bolts, you can create feet by adding them to the bottom screw holes. With MQTT publishing, you can expect your sensor to last three to four weeks on battery power, or even longer if not using Wi-Fi.

12. Over to you

This project demonstrates how you can make use of a small e-ink display and take advantage of sensors to gather information and send it anywhere you want. Pimoroni and other vendors have many different types of input and output devices that use either QT or STEMMA, so it's not just CO_2 you can measure. Discover what else you can build or see what you can do with a stream of MQTT data. Most of all, have fun with it and hopefully you'll know when that window needs opening for a bit.



Use a good sensor

Beware of cheaper CO_2 sensors that just measure particles. They are nowhere near as accurate as the one we've used here.

Safe CO_2 Levels

400–800	Good
800–1200	Fair
1200–1800	Poor
1800–2000+	Bad

More info: **rpimag.co/usingco2monitors**

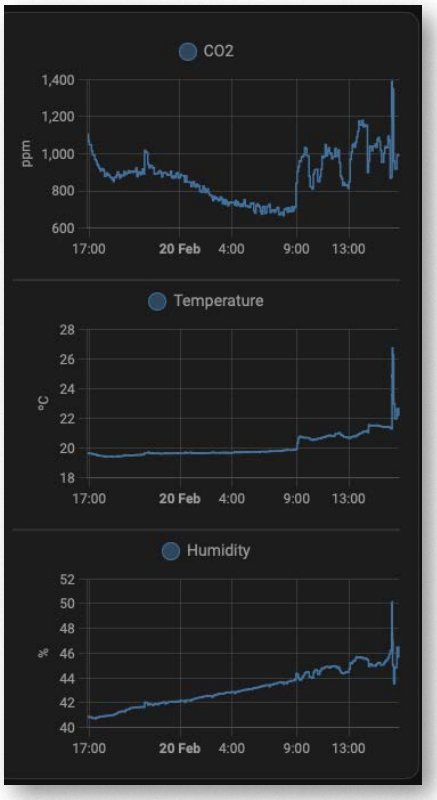
- This nifty circuit safely charges your battery
- Use the Pico W's Wi-Fi capability to chart levels in Home Assistant

sensor_check.py

DOWNLOAD THE FULL CODE:
rpimag.co/sensorcheckpy

> Language: **Python**

```
001. import breakout_scd41
002. from pimoroni_i2c import PimoroniI2C
003. import time
004.
005. BREAKOUT_GARDEN_I2C_PINS = {"sda": 4, "scl":5}
006. i2c = PimoroniI2C(**BREAKOUT_GARDEN_I2C_PINS)
007.
008. breakout_scd41.init(i2c)
009. breakout_scd41.start()
010.
011. while True:
012.     if breakout_scd41.ready():
013.         co2, temperature, humidity = breakout_scd41.measure()
014.         print(co2, temperature, humidity)
015.     time.sleep(1)
```



Bake your own circuits

Assemble your own printed circuit boards without getting your fingers burnt

Maker

Rob Miles

Rob has been playing with software and hardware since almost before there was software and hardware. You can find out more about his so-called life at **robmiles.com**.

@robmiles

YOU'LL NEED

- A printed circuit board and components to solder in place
- A tiny circuit board hotplate
- Some right-angled tweezers
- A syringe containing 138°C low-temperature flux solder paste
- A syringe holder (search for 'welding oil booster')

Powerful free tools such as KiCad have greatly simplified circuit board design and there are lots of companies who can turn your designs into physical boards. But how do you assemble your circuit? In this article we're going to explore the tools and techniques you can use to create your finished surface-mount devices.

Tiny keyboard

Our example project for surface-mount soldering, the MIDI Cheesebox, has twelve buttons and twelve coloured pixels. You can use it as a tiny musical keyboard and three-track sequencer. It contains a Raspberry Pi Pico running a CircuitPython program to emulate a MIDI instrument. You can find out more about it on GitHub here: **rpimag.co/cheesebox**. **Figure 1** shows the original Cheesebox (as featured in issue 113, **rpimag.co/113**) on the right-hand side. This contains twelve individual switches and a ring of NeoPixels. On the left you can see the much slimmer version that uses a custom printed circuit board.

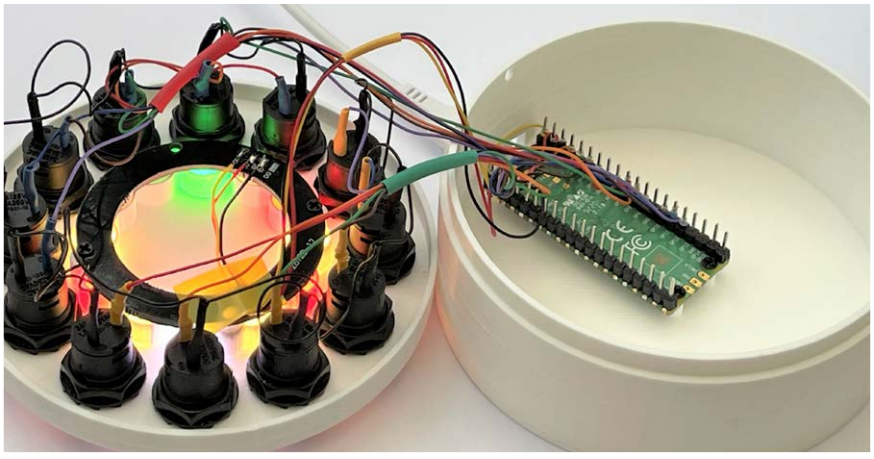
Figure 2 shows the wiring inside the original Cheesebox. Each of the twelve switches is connected to an input pin on the processor. The author was keen to make it easier to create the hardware and fortunately he knew someone who could create a KiCad design for the circuit. Thanks for that, Brian.

It turned out to be very easy to send the circuit for manufacture and around a week later, six shiny boards arrived. It took a little while longer for the surface-mount LEDs and switches to turn up, but soon the author had all the parts on hand and no excuse for not building something.

Soldering on

We've been soldering things together for over 5000 years, which is around the same age as some of the plumbing in the author's house. Soldering was originally used in jewellery and tools, but it is now widely used in electronic devices.

◀ **Figure 1:** Switching to a printed circuit board design made it possible to add an OLED display to the device



▼ **Figure 2:** It took the author a couple of hours to make a Cheesebox from scratch

Solder is a metal alloy that can be melted to bond metal elements together

Solder is a metal alloy that can be melted to bond metal elements together. The first electronic circuits were created by hand-soldering the components and wires together. In the first version of the Cheesebox, the author used a soldering iron to melt solder onto each of the connections. Solder used for electrical work contains a 'flux' element which cleans things up and removes oxides.

QUICK TIP

A pick-and-place machine is not beyond the means of the determined maker. They can be bought for around the price of a high-quality 3D printer and look like they would be great fun.

Soldering individual components together is painstaking work and limits the complexity of the circuits you can make. Halfway through the last century, someone had the bright idea of 'printing' copper circuits onto fibreglass. The first printed circuit boards (PCBs) had holes into which component leads were inserted, with solder used to hold them in place. Then another bright person suggested 'surface-mount' boards covered in solder pads onto which components were placed. These days, 'pick-and-place' machines are used to put the components onto the solder pads covered in solder paste and everything is soldered together by simply heating the whole component until the solder melts and forms the connections.

For the Cheesebox project, the author plays the role of the pick-and-place machine using a pair of right-angled tweezers. But before we can place any components, we need to get some solder onto the board.

▲ **Figure 3:** The 'welding oil booster' is the yellow component. You tighten the bolt down the syringe as the solder is used up

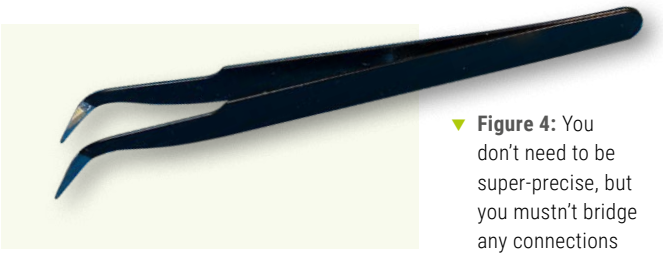
Figure 3 shows the solder paste syringe used by the author. This worked very well. The first time the author did some surface-mount work, he didn't have the benefit of the 'welding oil booster', which made dispensing precise amounts of solder paste much more difficult.

Figure 4 shows solder paste applied to the solder pads. It also shows some components in place. You need to be very methodical and make sure that you put some solder on every pad. Once you've got the solder in place, the next thing to do is place the components onto the board.

Masking up

If you want to make the process slightly easier, you can order a solder mask along with your boards. This is a metal stencil with holes for each connection. You lay it on top of your board and align it with the connection points. Then you spread solder paste over the stencil, depositing a blob of solder on each connection through the holes. Then you just have to place the components on the board. A mask makes things easier and quicker, but it is an extra expense. The author managed fine without one.

Surface-mount components are usually enclosed in tapes which are rolled into reels. A pick-and-place machine pulls the top off the tape and removes each component from it before placing it on a board. For the Cheesebox, the author had to remove all the components from tapes before putting them in place. He used the right-angled tweezers shown in **Figure 5**. These made it much easier to pick up and position the very small components on the board. The final part of the process involves heating the whole board so that the solder paste melts and forms the connections.



▼ **Figure 5:** A pair of right-angled tweezers is essential for accurate placement of tiny components

▼ **Figure 4:** You don't need to be super-precise, but you mustn't bridge any connections

Warning!
Hot solder
Soldering irons and hotplates get very hot, and stay hot for a long time after they're unplugged. Don't touch the hotplate or the circuit board on top of the hotplate while it's switched on, and remember to leave it to cool down after you've finished using it.
rpimag.co/soldering

◀ **Figure 6:** You set the desired temperature on the front

Figure 6 shows a small hotplate specifically designed for soldering. It was bought from the author's favourite Chinese component supplier. The temperature of the top plate can be set on the front panel, which also displays the current plate temperature when the oven is in use. Setting the temperature to 160°C worked well. The oven was heated up from cold with the assembled board on top. When the temperature display showed 160, the oven was switched off and the board left to cool. It is important to avoid any sudden changes in temperature.

The hotplate gets as hot as the top of a stove. Be very careful not to touch the circuit board or the top of the plate when it is in use. And don't touch the top of the plate to see if it is still hot like the author did.

QUICK TIP

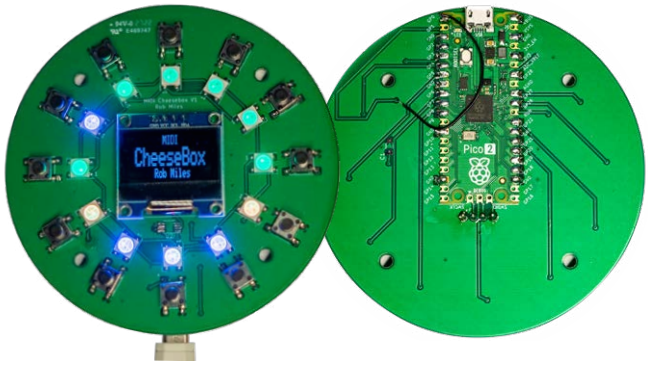
Buy the smallest syringe that you can and do all your soldering as quickly as possible. The paste tends to dry up once you open it, so it is unlikely you will be able to use it again after a few days.

When the board heats up, the grey paste turns to solder and the flux burns away, cleaning the connections. It is fun to watch as the surface tension in the liquid solder pulls components into place. When the solder has cooled, you should find that all the components are held in place and connected together.

The Pico which controls the Cheesebox is soldered onto the back of the board

Figure 7 shows a completed board working well. The Pico which controls the Cheesebox is soldered onto the back of the board. This had to be done by hand once the board had cooled down. However, you can use surface-mount techniques with a Pico because it has 'castellated' edges.

Figure 8 shows the Pico soldered onto the back of the circuit board. When you solder a Pico to a board like this, use a piece of sticky tape to hold the Pico in place while you solder the first few connections on one end. Then remove the tape and solder the rest of the connections. The author was surprised by how easy it was to create working devices this way. He plans to make more circuit boards in the future.



▲ **Figure 7:** The boards all worked first time

▲ **Figure 8:** The extra jumper wire is there because the original design included a signal buffer which turned out not to be needed. The wire bypasses this

Unusual tools: deburring and chamfering

A smooth solution to rough edges

Maker

Dr Andrew Lewis

Andrew is a specialist fabricator and maker, and is the owner of the Andrew Lewis Workshop.

lewis-workshop.com

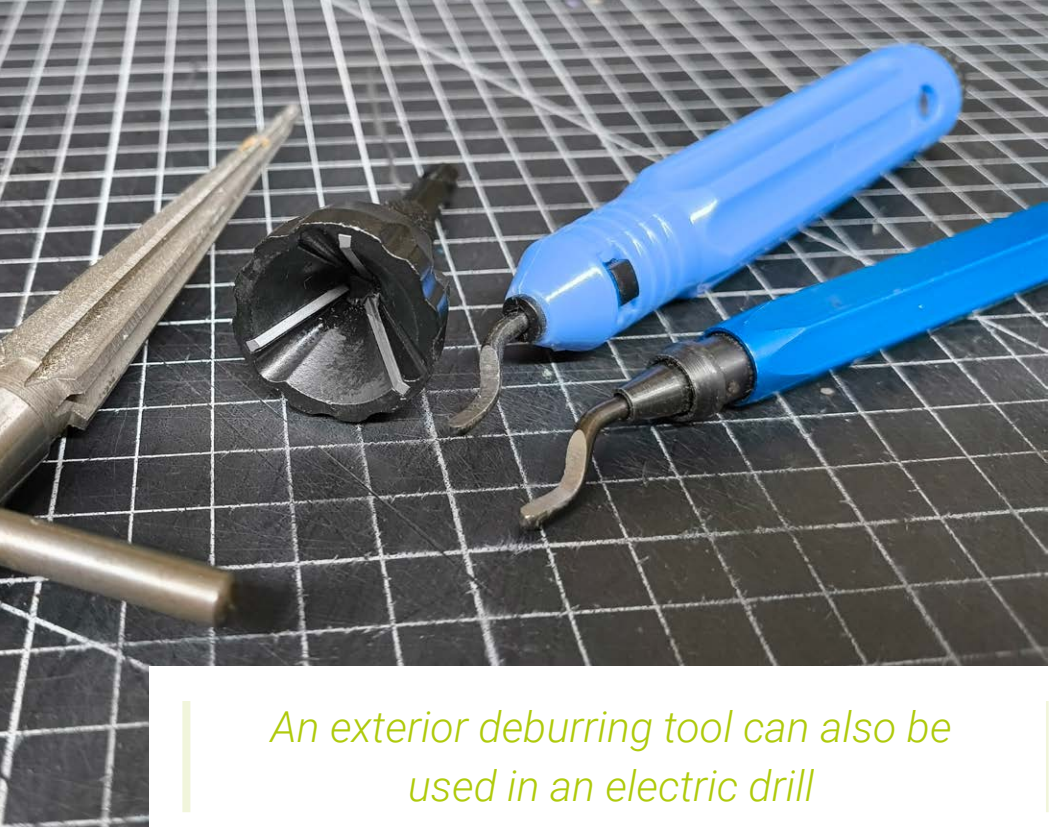
Warning!

Fire

Flame polishing should take place in a controlled environment, away from children, pets, and other flammable materials

rpimag.co/fire

Life is very seldom as precise or fair as we would like it to be. This is particularly true when we're machining or 3D-printing parts. There's often a trade-off between precision and some other factor like clamping, and very few machines in the real world are perfectly calibrated. Materials, too, are not perfect objects. Plastics and metals all stretch and shift when they're being machined and it's not uncommon to feel a nasty burr when you remove a part from a machine chuck or 3D printer bed. There's an entire universe of tools dedicated to the removal of these burrs and sharp edges, but unless you're a machinist you might not be aware that they exist at all. The most common of these is the 'deburring knife' (often just called a 'deburring tool') is a straight-handled knife with a short, sharp, curved blade. Unlike a regular knife, the blade has a blunt tip with a slightly rounded edge, and more importantly, the blade can rotate freely in the handle of the knife. The blades are disposable, and hard enough to cut thin steel. Although they're primarily designed for metal work, they are also surprisingly effective tools for plastic and metal work. The freely revolving blade makes it easy to follow the contours of an object, with the blunt tip resting on the object itself. It's ideal for removing a slight elephant-foot from a 3D print, which can be particularly useful when you need to join parts with close tolerances and print without a raft.



◀ You can use lots of different tools for the process of deburring, including die grinders and emery paper. However, the term "deburring tools" generally refers to a specific set of bladed tools that are used almost exclusively for deburring, the most common of which is a deburring blade. Also shown in this image are an external rod chamfering tool and a tapered reamer, which are sometimes used for deburring rods and holes

An exterior deburring tool can also be used in an electric drill

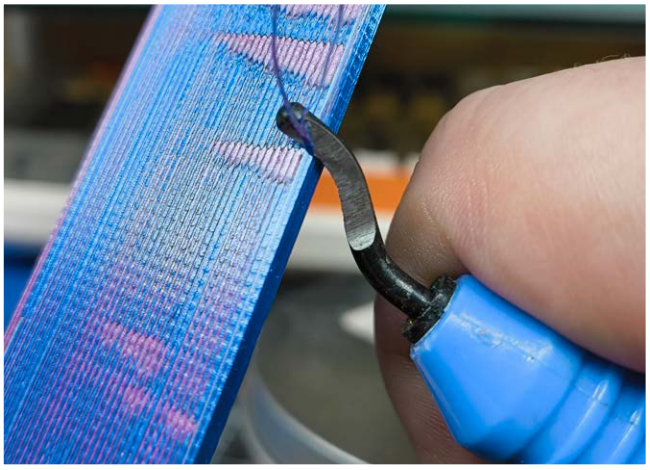
External or internal

If you want to deburr the edges of a piece of bar stock or the internal edge of a hole, then you should consider using an external or internal deburring or chamfering tool. An internal deburring tool looks very much like a countersink with a single cutting edge. The tool is conical, meaning that it can drop neatly into a hole and remove any burrs from the edge without distorting the roundness of the hole. An internal deburring tool isn't intended to smooth the interior sides of a hole, just the edges. Finishing a hole is an entirely different process to deburring, and is usually accomplished with straight reamers or a flexible hone and emery paste. You will find exterior deburring or chamfering tools extremely useful if you are working with threaded bar stock or straight stock used for locking pins. Although it can be used as a hand tool, an exterior deburring tool can also be used in an electric drill or impact driver. The advantage of the external and internal deburring tools over a simple file or some emery paper is that the tools have a regular round profile that makes it simple to maintain roundness on the stock you're deburring. If you're working with threaded bar, you'll be able to get a round edge to your threads in a matter of seconds.

Fire: an alternative option

One issue with deburring tools in general is that they rely on a sharp cutting edge to remove material. When working with plastic, that single-point cutting action can stretch the plastic and leave a slight discolouration. While there are several ways to deal with this, the easiest is flame polishing. Flame polishing is the process of flash-heating the surface of a plastic object to leave a glossy finish and remove any obvious stress or scuff marks. Flame polishing with a butane or propane torch isn't difficult but it can take a little bit of practice. The main points to remember are to keep the flame moving and keep your distance from the object relatively constant. A propane torch can reduce plastic to a puddle of liquid in a couple of seconds, so the most important thing is to not linger with the flame for even a second. If you're doing it right, the discolouration should disappear immediately. Remember that once you finish, the plastic will be heated beyond its glass point and will be slightly tacky. Any mark you make on the surface while the plastic is in this state will be permanent, so stay clear until it has cooled down.

▼ Deburring knives are usually best suited to chamfering-type operations on the relatively straight edges of an object



Warning!

Moving parts

If you do decide to use an internal deburring tool with an electric drill or bit driver, take care to do it safely – do not deburr any of your skin.

rpimag.co/movingpart

Soap and mould making

3D-print your own mould and hand-make a bar of an all-natural daily staple

Maker

Nicola King

Nicola is a freelance writer and sub-editor. Her load of flannel this month is very much intended to be used with some soap.

@holtonhandmade

We'll take a look at soap bar making, with an eye on 3D-printing your own soap mould too

It's a daily necessity and common household substance that we all use in some form or another as, not only does soap cleanse, but it also sanitises and destroys bacteria. Following the Industrial Revolution, alongside a growing awareness of sound sanitary practices and advertising to encourage bathing with soap, soap bars became popular and mass production swiftly followed. Today, we don't think twice about buying bars of soap with our groceries, and may sometimes opt for slightly fancier soap bar versions (perhaps a certain French brand that this author is partial to) as gifts for friends and family.

Soap, though, is also something you can make yourself, to your precise specifications in whatever colours, shapes, or sizes that you like, and as gifts for others. You can make your soap nourishing, exfoliating, scented, embossed, and customise as you wish. In this tutorial, we'll take a look at soap bar making, with an eye on 3D-printing your own soap mould too, and using software (Blender) running on a Raspberry Pi to design a mould.

Soap science

A bar of soap is usually made of a fat/oil/wax combined with an alkaline substance often referred to as 'lye' (aka sodium hydroxide). Saponification is the result when the fat and the alkali are heated together and a natural chemical reaction occurs. In addition, soap molecules are both hydrophilic and hydrophobic, so they bind to both grease and water – so when you wash with soap and water, the molecules help lift the dirt, germs, and oils from your skin and can be rinsed away.

TOP TIP

If adding mica powder/colour to your soap, be subtle. Too much will bleed out into any lather from your soap.

▲ Our magnificent 3D-printed mould, in a rather fetching colour. This took around an hour to 3D-print, and we used a freely available file for the print. There are many free files out there, but you can also buy your favourite design file or, of course, design your own bespoke and unique soap mould

Other soap-making methods

Apart from the 'melt and pour' technique already discussed, which is best for beginners, there are other ways of making soap. However, great care is required when dealing with some of the ingredients:

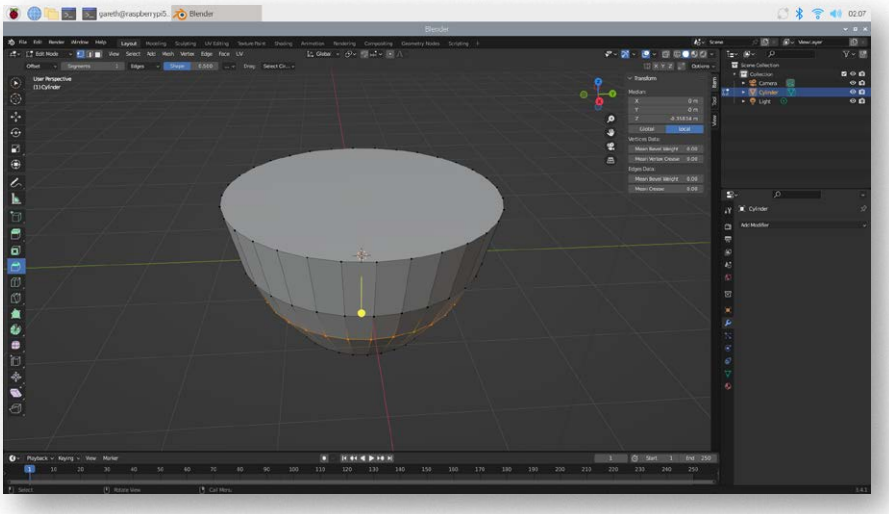
- Cold process (at relatively low temperatures, 30–50°C) soap making is where you make soap from scratch. First of all, anyone wanting to try this technique must be aware that this method involves the use of sodium hydroxide, to form something called 'lye'. Gloves, goggles, a well-ventilated workspace, protective clothing, and a face mask are essential when dealing with this substance. Basically, this process involves adding the sodium hydroxide to water and whisking, which causes a heat reaction and vapours – that you do not want to breath in – until the sodium hydroxide has dissolved. Then, a melted oil (perhaps olive or coconut) is mixed with the lye solution when both of these solutions have cooled and are at around the 40°C mark. As the mixture turns opaque and thickens, the maker can add fragrance etc., before pouring it into a mould. It then needs to cure/set, and it can sometimes take 4–6 weeks before the soap is fully cured and ready to use.
- Hot process soap making – as with cold process, you get to choose all of the ingredients that you want contained within your soap. The only real difference here is that a source of heat is used to accelerate that saponification chemical reaction – instead of pouring the mixture into a mould immediately, heat is used to force saponification using a slow cooker or suchlike (don't use it for food preparation afterwards!). This means your soap is ready more quickly once cooled, but it still does benefit from a week or two to cure.
- Milling/rebatching – not as popular a technique, but it involves grating down previously made cold process soap and then mixing it with a liquid in order to create a new remoulded batch of soap.

As a footnote, soap making has existed for many centuries. The earliest recorded evidence of soap making dates to around 2800 BCE, when fats are thought to have been heated with wood ashes.

Warning!
Chemicals
We're using the beginner-friendly 'melt and pour' technique here, but if you do want to go all industrial and start using sodium hydroxide to make soap from scratch, please do it in a ventilated area and always use the correct PPE.
rpimag.co/chemicals

YOU'LL NEED:

- Melt-and-pour soap base
- A heat-resistant jug/silicone spatula to melt the soap base in
- Scales
- Knife
- Essential oil/s (optional)
- Colour/dried flowers/mica powders (optional)
- Isopropyl alcohol (optional)
- Mould (3D-printed or purchased)
- 3D-printer and filament to print a mould (optional)
- Protective clothing



By adding and scaling Loop Cut rings to a cylinder in Blender, you can shape it for your 3D-printable mould

Note that as the Raspberry Pi hardware doesn't support the required OpenGL 3.0 API by default, you'll need to use a prefix to run Blender with software rendering:

```
LIBGL_ALWAYS_SOFTWARE=true blender
```

The application will then open on the desktop. Note that Blender works well on a Raspberry Pi 5 (ours has 8GB RAM), but it will run a little slower on a Raspberry Pi 4 (or earlier model).

The easiest way to create a simple mould design is by using a preset 3D shape in Blender. For instance, select Add > Mesh > Cylinder. (Delete the existing cube.) To widen the top of the cylinder, switch to Edit Mode select the top points, press **S**, and move the mouse to adjust the scale. Add a Loop Cut in the middle of the shape with **CTRL** + **R**, then move it up a little and scale it outwards after pressing **S**. You can then create a lower Loop Cut in similar fashion. You should now have a rough bowl shape. You can smooth the edges a little by selecting all (press **A**) and using the Bevel tool.

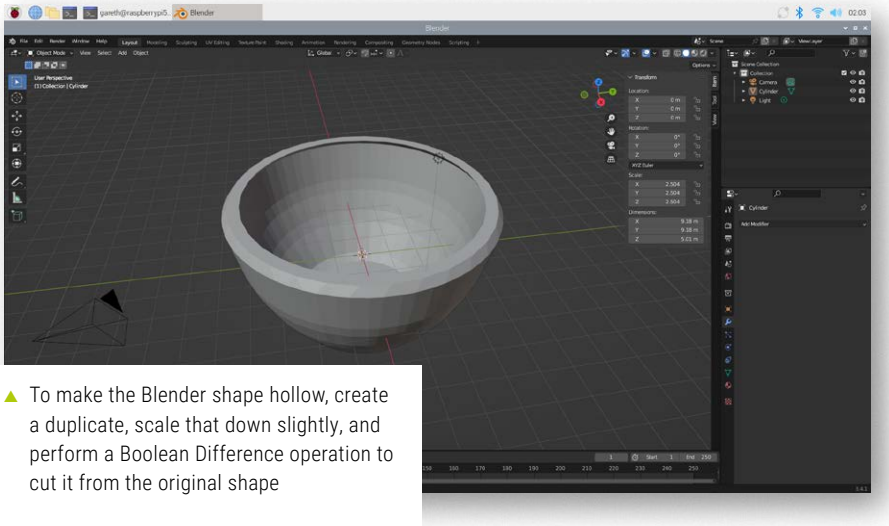
Now, whilst it would be great to have the time to make soap from scratch and watch the saponification process unfold, we've chosen to take the easiest and quickest soap-making route here: the 'melt and pour' technique, working with a pre-made soap base. There are many positives to this: it is by far the safest method, especially if you want to involve children in the making process, it hardens in just a few hours, and it gives you more time to concentrate on either the aesthetic look of your mould and/or your soap. The choice of soap-making technique is obviously down to individual choice. But, before we make a bar or two, let's think about what to make it in, and how a 3D printer, some software, and a Raspberry Pi can help us.

Mould making

The simple mould that we have 3D-printed for our soap was made using the following file, available under a Creative Commons licence: **rpimag.co/flowersoapmould**. It's designed by Lavenderguy and is a perfect, uncomplicated design that creates a really nicely shaped soap. It's also a mould that we'll be able to use again and again!

You can use any CAD software to design a 3D-printable mould, but we found the easiest to use is Blender. You can install it on a Raspberry Pi with the following terminal command:

```
sudo apt install blender
```



To make the Blender shape hollow, create a duplicate, scale that down slightly, and perform a Boolean Difference operation to cut it from the original shape

You now have a solid 3D shape, but need to make it hollow to make a usable mould. The easiest method is to Duplicate (**SHIFT** + **D**) the shape in Object Mode, move the duplicate straight up (holding **Z**) a little so it protrudes above the original's top, then scale the duplicate (Cylinder 001) down a little. Now select the original shape (Cylinder), click on Modifiers (wrench icon in the right-hand toolbar), and select Add Modifier > Generate > Boolean. With the default Difference option selected, click in the Object field and choose Cylinder 001, then click the down arrow icon and Apply. Delete Cylinder 001 and you'll be left with a hollow bowl shape. If you want to stretch it into an ellipsoid, select the shape in Object Mode, then click on Item in the sidebar and increase the X or Y value.

Before exporting the shape as an STL file for 3D printing, you should note that metres (m) in Blender equate to millimetres (mm) in the STL. So, adjust the X, Y, and Z dimensions accordingly in Blender. Finally, select File > Export > STL and click on Export STL.

To create more complex shapes, you'll need to hone your Blender skills, but you can access some extra preset shapes by installing the Extra Mesh Objects add-on (**rpimag.co/blenderextraobjects**). For instance, for a rounded bar mould, select Add > Mesh > Roundcube, then change Operator Preset to Clay Bar. Adjust the X, Y, Z dimensions to your preference, then slice off the top part of the bar: in Edit mode, switch the camera to the X preset viewpoint, toggle X-ray view on (so you can select hidden points), then select the top half of the shape and right-click > Delete Vertices. To add thickness to the shape's walls, use the Solidify modifier: select Add Modifier > Generate > Solidify, adjusting the Thickness value before selecting Apply.

Shape some soap

With mould in hand, whether bought or 3D-printed, let's now make some bars. First of all, take a look at the size of your mould(s) and judge how much soap you are going to need to fill it/them. We cut some slices from the base with a sharp knife and chopped them up into small pieces (around 300 g in total, for filling two moulds) to aid the melting process, putting them in our heat-resistant jug.

Next, we boiled some water and placed it in a large bowl, and sat the jug in the water, obviously being careful not to touch the water ourselves. It can take a few minutes for the soap to melt, but give it time. Another option is to use a microwave to heat it, best done by using in 30-second bursts, but do make sure that your jug is microwaveable and won't be used for any culinary purposes afterwards. Be aware that the melted soap will be hot, so don't splash yourself. Also be aware that you don't want the soap to overheat, so ensure that it does not get above around 70°C. Stir it with a spatula to make sure the clumps of soap base are breaking down. Some suggest spraying the mixture, once melted, with some isopropyl alcohol (to help disperse any bubbles), but that is optional.

TOP TIP

In the tutorial we used Blender to make a 3D model for a mould, but you could use other software such as FreeCAD.

More on moulds

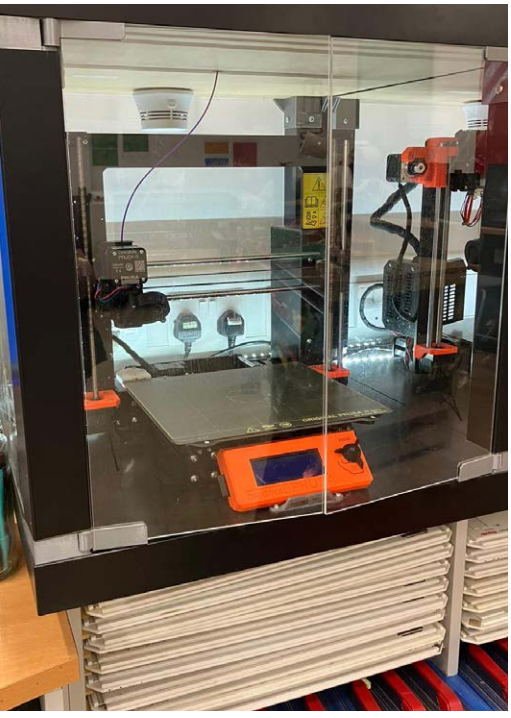
Many of the soap moulds that are available to buy are made of silicone, as this makes it way easier to get the soap out of the mould once it is set – it is simply a question of bending the mould back and easing the soap out, as silicone is pliable, durable, and flexible.

Our 3D-printed mould was made from a fairly standard, rigid filament. To get the soap out of the mould, we had to slightly warm it by floating it in some hot water for a couple of minutes – until the soap slid out. Another option is to place it in the freezer for 24 hours, and this should also help loosen the soap bar.

That said, you might want to consider what you make your soap mould out of before you even switch your 3D printer on. Here are some specific points to think about:

- Consider using a flexible filament (such as TPU – thermoplastic polyurethane) for your 3D print. These filament types can be more tricky to print with and stringing can occur, but if you can get over that hurdle, it's worth it to have a flexible mould at the end of the process.
- Think also about making your very own silicone mould by casting it inside a rigid 3D-printed mould. You would have to think very carefully about the design of the latter so that once you've poured liquid silicone into it, you achieve the shape you want.

▼ The large 3D printer that was used to produce our mould. A huge thank-you to the Design and Technology department at Bournemouth School for Girls (this author's sister teaches there) who undertook the 3D print for us. If you don't own a 3D printer, see what facilities might be available to you locally, perhaps in a makerspace, or seek out local individuals who might offer a 3D printing service



▲ Dried lavender tops off our finished soaps, also scented with lavender

TOP TIP

It's always a good idea to wear old clothing when making anything like this, especially if you use any dye… general mess is part of the process!

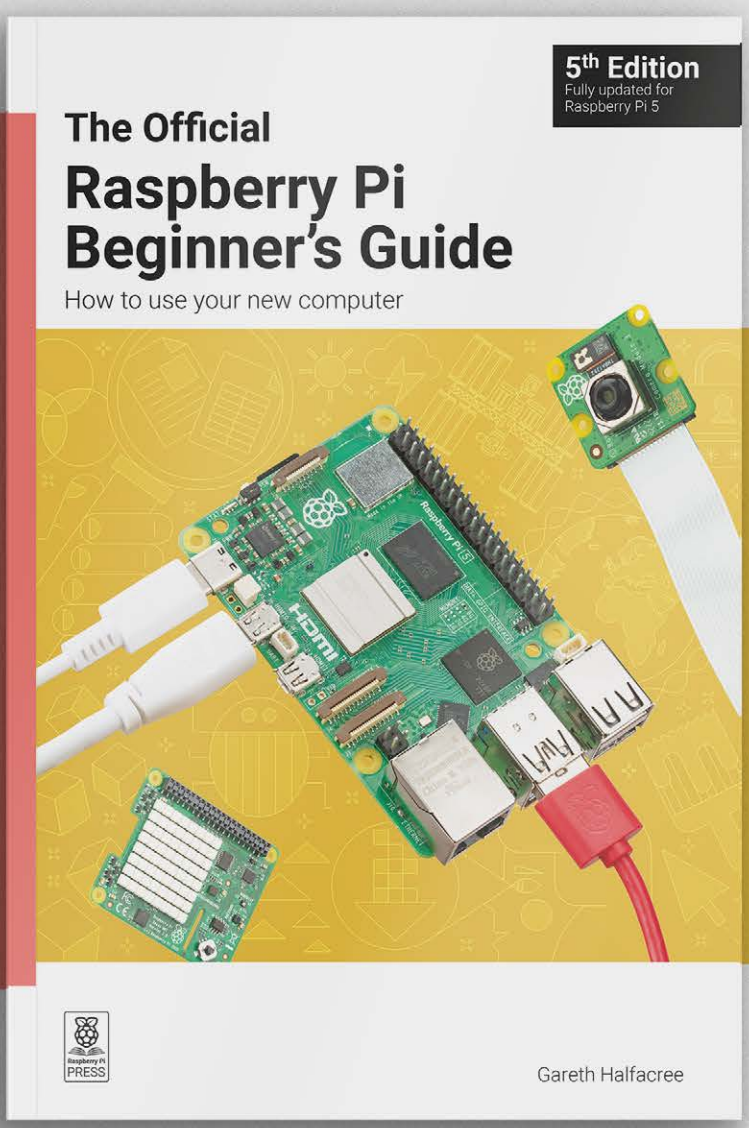
With your soap base melted, you are now ready to add any colouring or scent. We added some purple mica powder, but found we needed very little – the same applies to any essential oils (again lavender). Be sparing, and stir in until dispersed and the colour is even. We found that we had to work fast once the base had melted, as the mixture will start to thicken reasonably quickly. That said, you can always blast it in the microwave for 15 seconds to loosen it again. Then, you are ready to pour your mixture into the mould. We added some dried lavender in the base of each mould, slowly poured the mixture over the top to avoid bubbles, and left it to set for 24 hours, although it was properly set after about six hours. You can then remove it from the mould, lather up, and enjoy!

Other ideas

There are plenty of ways of making interesting and unique soap bars. Here are just a few suggestions:

- Lovely layers – different layers of soap together in one bar. Multicoloured, or maybe ombré, effects look great. Once the first layer has started to harden up with a 'skin' on top, you can add the next layer.
- Embeds – for example, make some soap letters (tip: a more shallow sugar fondant mould is great for this), then embed them in your layered soap bars.
- We added some dried lavender to our soap bars, but you can add plenty of other things too in the base of your moulds – dried flowers, oats, dried citrus slices, poppy seeds, coffee beans, seaweed, grains, raw honey, Epsom salts, etc. Some of these additions have exfoliating properties, and some just look and smell beautiful.
- Add relief designs to a finished bar of soap, embedding a clear stamp in the soap before it hardens, then carefully removing it once set. You could also make holes in bars of soap and feed them through some natural hemp so they can be hung up.

Learn coding
Discover how computers work
Build amazing things!



rpimag.co/beginnersguide

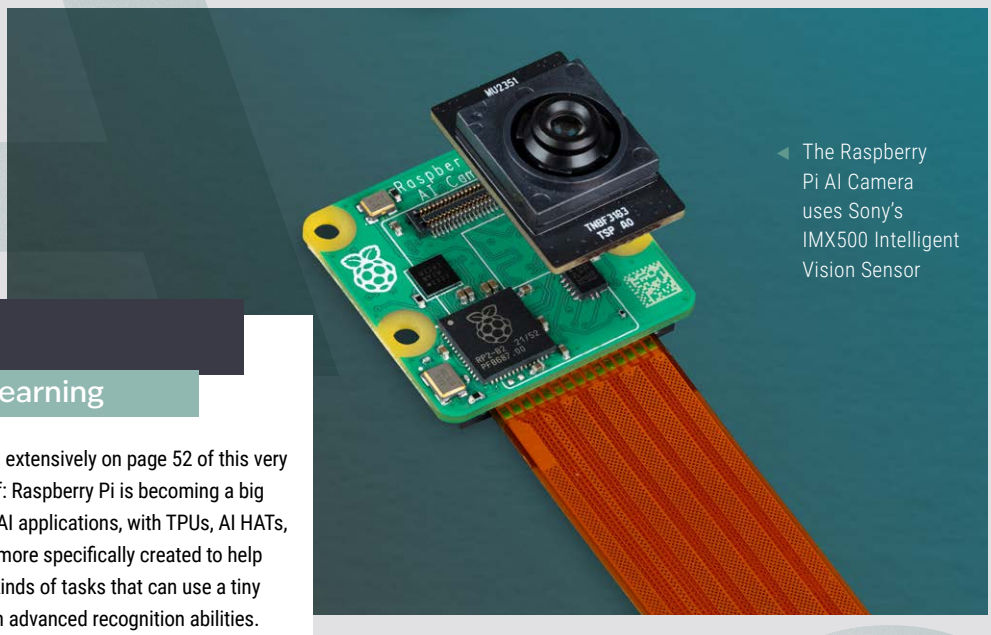
The A to Z of Raspberry Pi

Thank the Phoenicians for this alphabetical guide to everything Raspberry Pi. By last on the roll call,

Rob Zwetsloot

Raspberry Pi has been around for 13 years, which means there's a lot to learn about it. Never fear though, as here at Raspberry Pi Official Magazine we have this very definitive A to Z of everything Raspberry Pi. Or at least, 26 things Raspberry Pi. We could not find anything that began with ß.

Think you have a better suggestion for a letter? Or even one for ß? Email us at **magazine@raspberrypi.com** and we'll print the best ones in issue 153.



The Raspberry Pi AI Camera uses Sony's IMX500 Intelligent Vision Sensor

AI

Machine learning

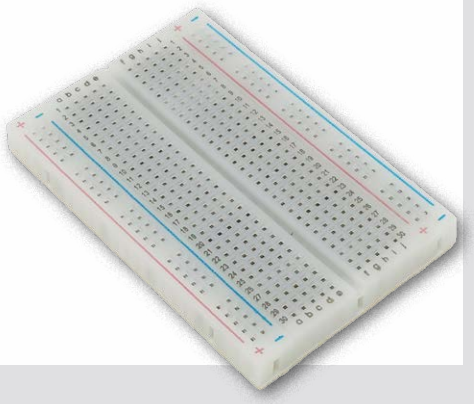
We've covered AI extensively on page 52 of this very issue, but in brief: Raspberry Pi is becoming a big deal in practical AI applications, with TPUs, AI HATs, AI Cameras and more specifically created to help it with different kinds of tasks that can use a tiny Raspberry Pi with advanced recognition abilities.

Electronic circuits are a huge part of Raspberry Pi

Breadboard

Prototype your circuits

Electronic circuits are a huge part of Raspberry Pi thanks to its GPIO ports allowing you to read sensors and activate components. Breadboards are integral to this, as they allow you to learn electronics and test circuits without any soldering, and with reusable parts.



We like these half-size boards with labelled positive and negative rails at the top and bottom

Camera Module

Take photos or analyse video

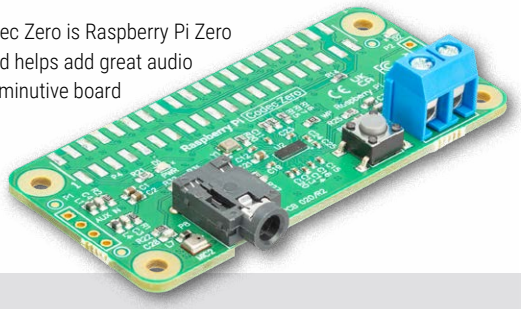
Raspberry Pi Camera Modules come in a variety of flavours – from your standard point and shoot, to high-quality cameras with interchangeable lenses, global shutter varieties, infrared sensors, and now the AI Camera. People use it for fun and for important vision-based AI tasks like checking production lines.

Switch out CS type lenses to get the perfect shot

DAC

An aural delight

Turn Raspberry Pi into a hi-fi stereo with an audio DAC (digital to analogue converter) and choose from multiple varieties that connect via RCA cables, stereo connectors, and 3.5 mm headphone jacks to suit your audio needs. Audiophiles would even choose these over the headphone jack in older Raspberry Pi models.



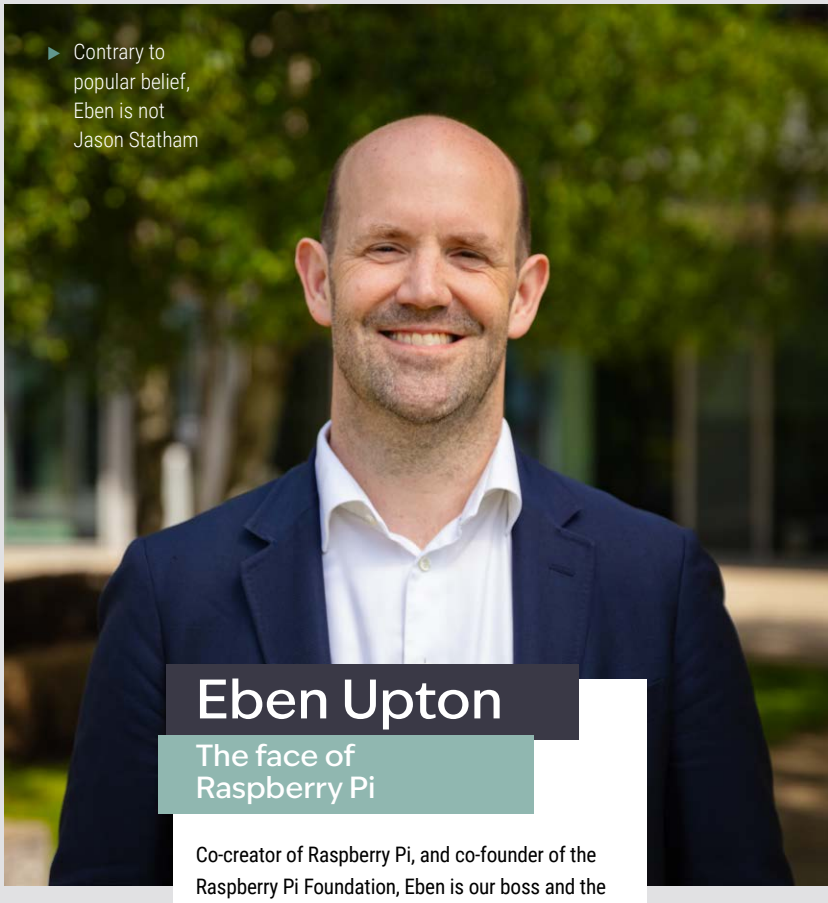
▶ The Codec Zero is Raspberry Pi Zero sized and helps add great audio to the diminutive board

File server

Network-attached storage

A very basic but perfect use of Raspberry Pi is as a file server on your own network. Whether you're purely using it as a network hard drive using Samba, a VPN access point, Plex, local web server, or even a home automation server, its low-power consumption and small size means it's one of the best home file server solutions ever.

◀ The Argon EON (**rpimag.co/argoneon**) is a purpose-built NAS case for Raspberry Pi



▶ Contrary to popular belief, Eben is not Jason Statham

Eben Upton

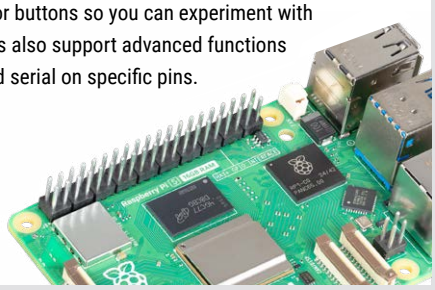
The face of Raspberry Pi

Co-creator of Raspberry Pi, and co-founder of the Raspberry Pi Foundation, Eben is our boss and the public face and CEO of Raspberry Pi PLC, the part of Raspberry Pi that actually makes computers (and microcontrollers, etc.). You'll see him at the occasional event and whenever a new Raspberry Pi product is announced. His wardrobe is not filled with black turtle-necks, though.

GPIO

Connect to the world

General Purpose Input and Output, these 40 pins (26 on the original Raspberry Pi models) allow for people to expand the capabilities of Raspberry Pi far beyond what is available with the base board, or let you hook up LEDs or buttons so you can experiment with electronics. These pins also support advanced functions like I2C, PWM, SPI, and serial on specific pins.



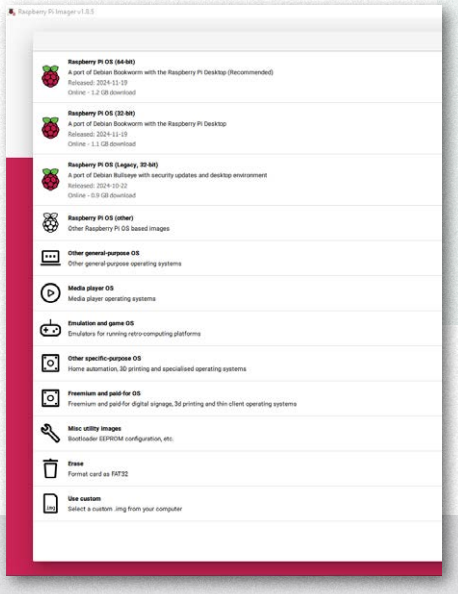
▶ These 40 pins are a powerful part of Raspberry Pi

Imager

Install anything to Raspberry Pi

Imager is a multi-purpose app that deals with just about anything related to booting a Raspberry Pi. After selecting a Raspberry Pi model, you can choose from a list of recommended operating systems or install your own image to an SD card or other storage device. It can even do advanced EEPROM configuration and format an SD card.

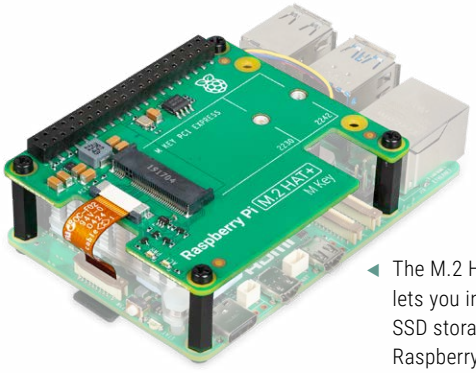
▼ Alternative OSes are filtered by category



HAT

Hardware Attached on Top

Get it, because it's like putting a hat on Raspberry Pi? HAT, and HAT+, are actually standards set out by Raspberry Pi (read about them here: **rpimag.co/hatsheet**). They range from simple things like adding more USB ports, to advanced robotics and home automation extras.



◀ The M.2 HAT+ lets you install SSD storage to Raspberry Pi

Jams

Worldwide community events

Raspberry jam is a delicious preserve for bread or Victoria sponges, while Raspberry Jam (upper-case J) is the punny name of community events hosted around the world. They also receive some support from Raspberry Pi too, and we list them in the magazine and online – check out page 124 for upcoming events , or head to **rpimag.co/events**.

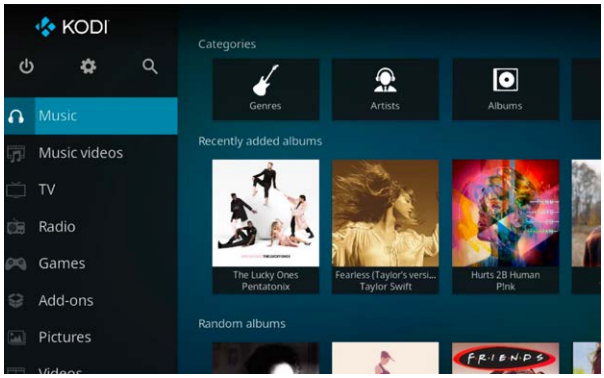
RASPBERRY JAM

▲ Events come in a variety of names, but Jams are the most recognised

Kodi

Media PC software excellent

In another life, Kodi started as a hack for the original Xbox, and is now one of the most popular pieces of HTPC (home theatre PC) software. There are several operating systems built around it for Raspberry Pi (LibreELEC is a fave), and its lightweight and fast approach to media organising and playback make it a perfect fit.



▲ The interface is very clean and allows for easy indexing of all your media

One of the most popular pieces of HTPC software

LEDs

Light up your projects

Whether you're using basic LEDs that just need some power to turn on in your circuit, or you're controlling programmable NeoPixels to create elaborate light displays during a holiday, LEDs are a core part of many Raspberry Pi hobby projects.

▶ The humble LED is a diode, so current only flows in one direction

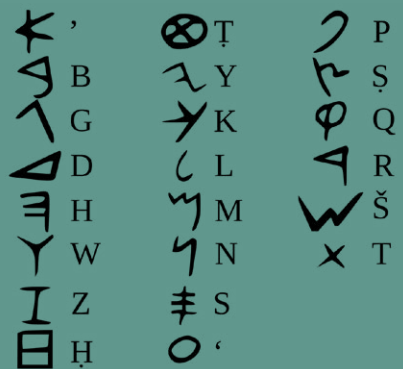
Magic mirror

House of the future

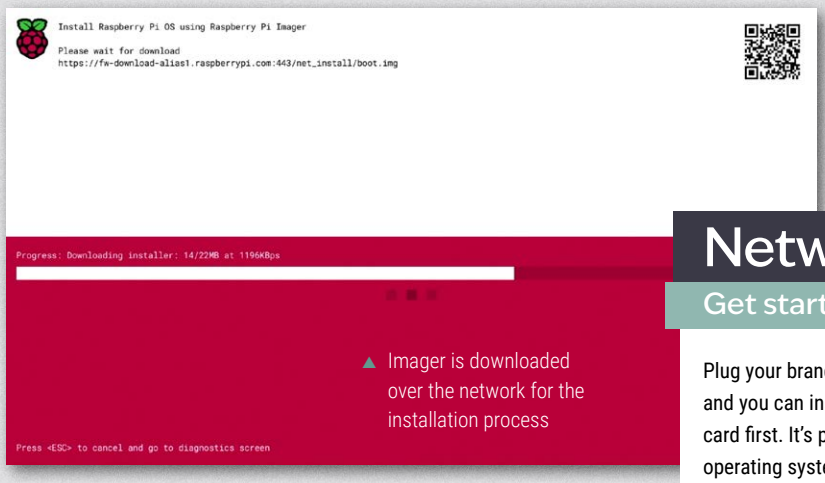
Our original top project from issue 50 (**rpimag.co/50**), as voted for by the community, this is a deceptively easy project that requires either a minimal knowledge of carpentry, or a good frame find at IKEA to fit a monitor. The software is dead easy to set up at (**magicmirror.builders**) and it looks very cool. It's also very practical.

▼ A spare Raspberry Pi, a spare monitor, some reflective glass, and a frame

Alpha Beta



The modern alphabet of many languages can be traced back to the Phoenicians, who created the first true alphabet around 1000 BCE, which itself was descended from Egyptian hieroglyphs. The Latin alphabet to which the English alphabet is most closely related only had 23 letters, so thanks to 2000 years of progress there are three more items on this list.

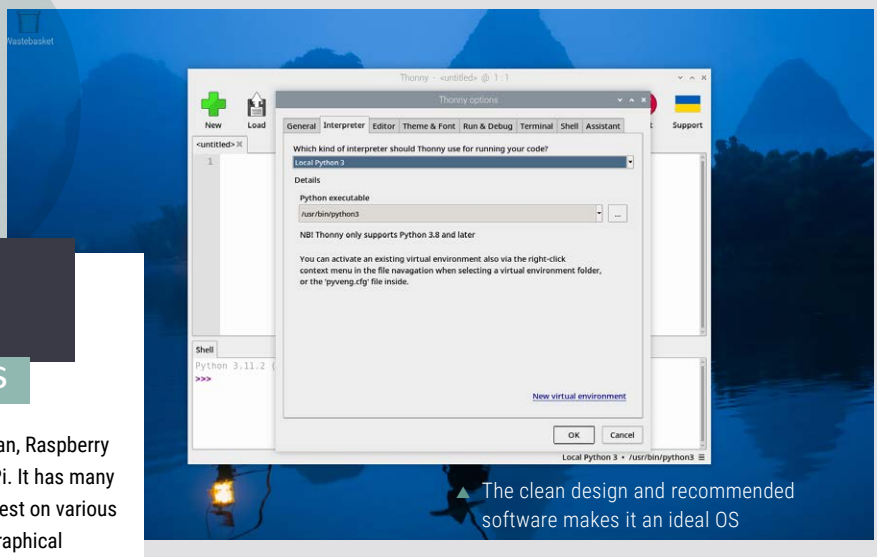


▲ Imager is downloaded over the network for the installation process

Network install

Get started fast

Plug your brand new Raspberry Pi into your router via an Ethernet cable and you can install Raspberry Pi OS without having to prepare an SD card first. It's pure tech magic, and even lets you choose different operating systems to install to the SD card. You'll need a Raspberry Pi 4 or newer for this method, though.



▲ The clean design and recommended software makes it an ideal OS

Operating system

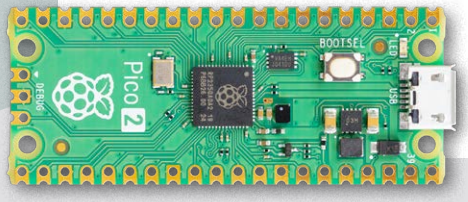
Raspberry Pi's own OS

Based on the Linux distribution Debian, Raspberry Pi OS is custom-built for Raspberry Pi. It has many optimisations to help it run its very best on various Raspberry Pi computers, a custom graphical interface, a selection of pre-installed software, and it's also incredibly flexible and customisable by users. It's perfect for Raspberry Pi.

Pico

Microcontroller by Raspberry Pi

Raspberry Pi Pico and Pico 2 are very different from a standard Raspberry Pi. First of all, they're not computers, they're programmable microcontrollers that are better suited for a single task. They draw less power, are very small, and the chip running – RP2040 or RP2350 – can be embedded in other systems too.



◀ Tiny but mighty, Pico's GPIO pins are more versatile than a standard Raspberry Pi

QWERTY

Keyboards, peripherals, and more

As well as computers, you can get a Raspberry Pi branded mouse, monitor, USB 3.0 hub, cases, and yes, a keyboard. This also includes the excellent Raspberry Pi 400 and 500, Raspberry Pi built into a keyboard like the home computers of the 1980s. The peripherals tend to be basic, cheap, but high-quality, and pair great with a 500.

▼ The official Raspberry Pi keyboard is available for multiple regions and keyboard types

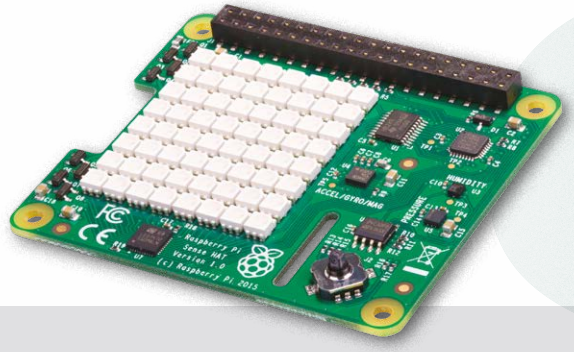
Developed for use on the International Space Station

Sense HAT

Space-worthy sensors

Developed for use on the International Space Station as part of the Astro Pi coding challenge for young students, it packs a series of environmental and motion sensors, a little joystick, and an 8×8 RGB LED matrix. It's great for electronics education, and a new updated version has been released.

▼ There are slots for the camera cable so that you can use the whole suite of Raspberry Pi sensors

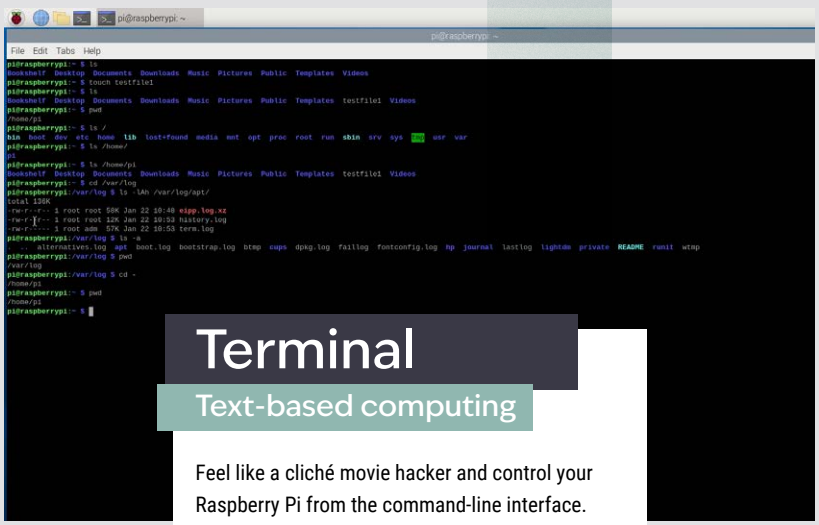


RetroPie

Perfect retro gaming

We were once absolutely amazed at how easy RetroPie was to set up – now it seems commonplace to have such easy-to-use retro gaming software on Raspberry Pi. It has a huge range of emulators you can access, compatibility with tons of official hardware, and can boot Kodi. Just bring your own games.

▲ RetroPie uses the popular EmulationStation and RetroArch as front-ends



Using **cd** to move into a directory and saying 'I'm in' is quite fun

Terminal

Text-based computing

Feel like a cliché movie hacker and control your Raspberry Pi from the command-line interface. You may also use it in a headless scenario, where you have a remote Raspberry Pi that doesn't need to have a desktop interface running. Networking, automatic hard drive mounting, file sharing, and more is also only accessible via a terminal.

UHD

4K video from Raspberry Pi

Raspberry Pi has always been HD, with 1080p output at launch at a time when even the flagship games consoles couldn't handle it well. Raspberry Pi 4 and 5 both have two Micro HDMI ports that support 4K resolutions with no problem, allowing for the ultimate media PC experience.

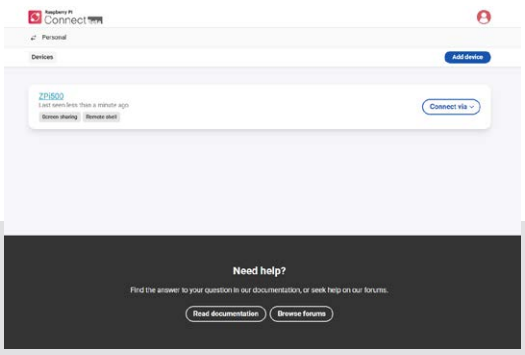
The jump from one 1080p output to dual 4K was huge for Raspberry Pi

VNC

Remote control

Raspberry Pi is very small, but monitors and keyboards are not always as small. With VNC you can connect remotely to a Raspberry Pi and its desktop from the comfort of another computer. Raspberry Pi Connect is an official system that makes use of this to securely connect to your Raspberry Pi via a web browser anywhere in the world, with minimal lag.

Raspberry Pi Connect is built into Raspberry Pi OS too, making it easy to set up



Wi-Fi

Wireless networking and sharing

While not always standard on Raspberry Pi, or even Pico, Wi-Fi and Bluetooth are now an integral part of many Raspberry Pi models. Raspberry Pi also works great as a wireless access point for when you need a wireless network on the go for portable projects or very old hotels.

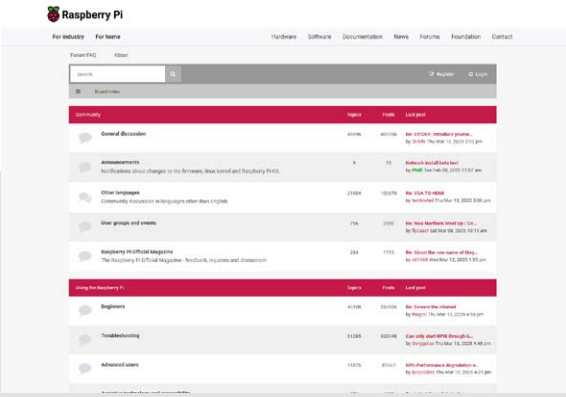
The antenna is printed into the circuit board, right next to the radio chip

You

It takes a community

As the community magazine, you might think we're a bit biased, but we think the global community is one of the most important parts of Raspberry Pi. Our magazine is filled with the incredible projects you all create, and you're helping to inspire others to make something.

▼ The Raspberry Pi Forum is a great place to take part in the global maker community

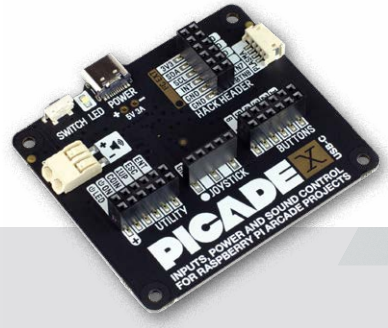


X HAT

Arcade machine builder's dream

A tiny HAT for a tiny computer used in many full-sized arcade machines from a time when the tech had to be huge. Instead of buying expensive and hard-to-maintain cabinets from 40 years ago, why not build your own custom machine that can play more than one game?

▼ It also helps to power the excellent Picade kit from Pimoroni

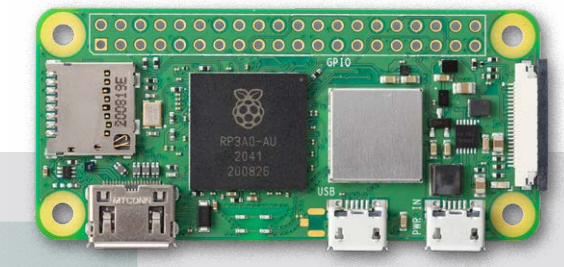


Zero

The mini Raspberry Pi computer

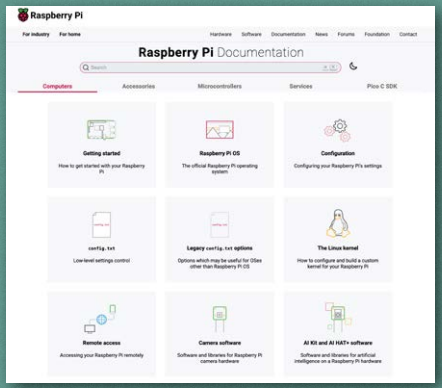
Launched on this very magazine in December 2015, Raspberry Pi Zero and Zero 2 are chewing-gum-stick sized computers that can handle just about anything a Raspberry Pi can. Raspberry Pi Zero 2 has the same power as Raspberry Pi 3, making it very capable despite its size.

▼ We love Raspberry Pi Zero and we're always surprised what tiny projects it has been slipped into

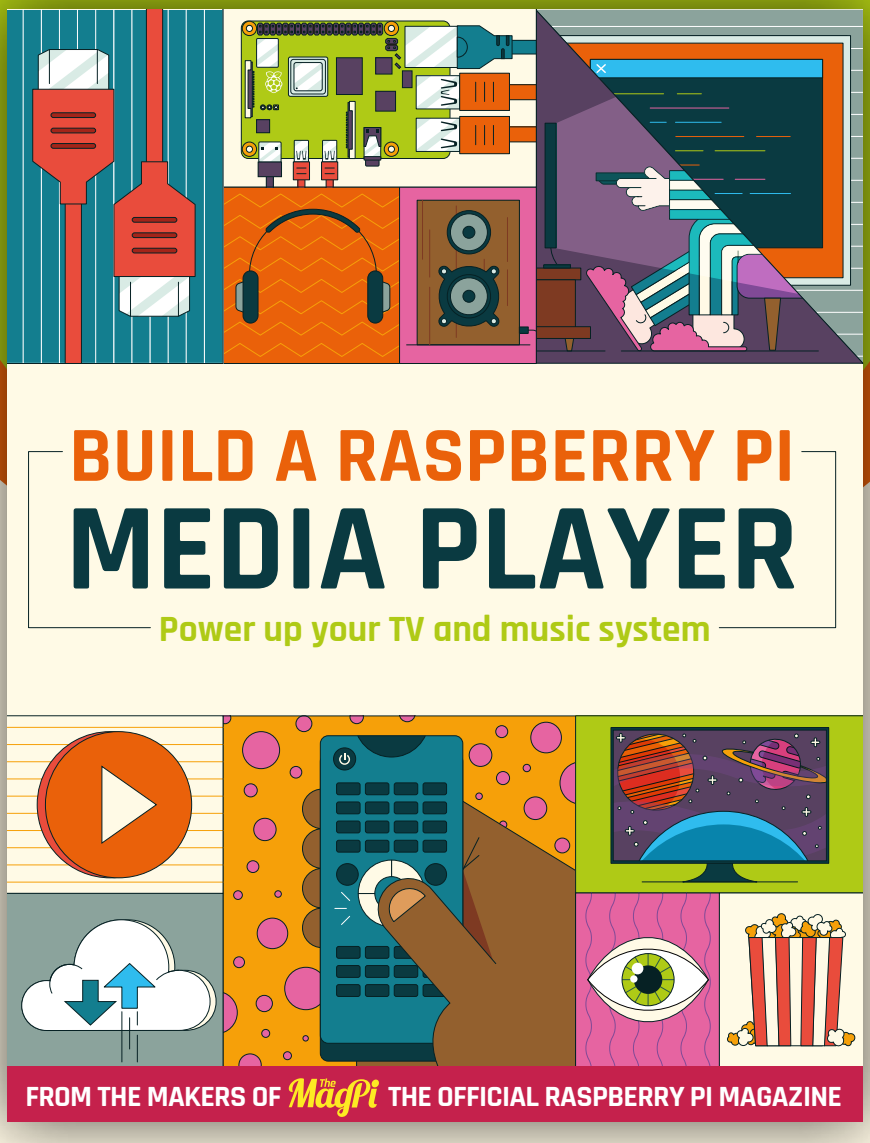


Glossary

For an A to Z of everything you'll ever need to know about using Raspberry Pi, make sure to check out the official documentation (**rpimag.co/docs**). It's easily searchable and covers just about everything you'll ever need to know about using Raspberry Pi.



Your FREE guide to making a smart TV



rpimag.co/mediaplayer

ONLY THE **BEST**

Smart home accessories

By **Phil King**

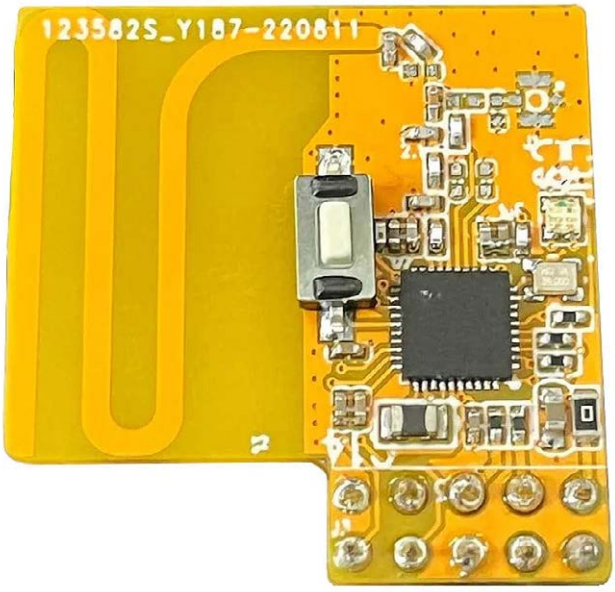
While there are numerous proprietary ecosystems for smart devices, by running Home Assistant on Raspberry Pi you can enjoy a much more versatile and customisable smart home setup. It can also work with most existing smart devices – typically it will detect them automatically on your network; if not, there's a raft of integrations and add-ons available to make things work.

As we've covered in previous guides, Home Assistant is easy to install via a dedicated OS available in the Raspberry Pi Imager tool (found under Other Specific-Purpose OS > Home Assistants and Home Automation). Just flash it to a microSD card, insert that into a Raspberry Pi 4 or 5 connected to your router via Ethernet, and boot it up as usual. Once Home Assistant has configured itself, it'll create a web dashboard where you can add, monitor, and control smart devices.

With a smart home setup being the Raspberry Pi project du jour, and The Pi Hut (**thepihut.com**) launching a new smart home store section, it's a good time to round up some of the best smart devices and sensors, all of which can be integrated into a Home Assistant setup.

800 Z-Wave GPIO Module

Zooz | £22 / $24 | zooz.com



This mini GPIO module adds Z-Wave connectivity to Raspberry Pi

This Zooz long-range wireless module will enable your Raspberry Pi to communicate with Z-Wave devices. Z-Wave is a wireless communications protocol that's designed especially for the smart home. One of its main advantages is that it offers reliable (less prone to interference) long-range communication using a mesh network of devices. So it's ideal if your Wi-Fi coverage is patchy around your home. Z-Wave's low-power signal also makes it ideal for battery-powered smart sensors.

Just pop this mini module onto GPIO pins 31–40 (furthest away from Raspberry Pi's USB ports) and it'll be accessible on the **dev/ttyAMA0** port. One caveat: you need to disable Bluetooth before using it, by altering the **config.txt** file. Then, when running Home Assistant, it will be accessible and you can install the Z-Wave JS server add-on to communicate with your Z-Wave devices.

Alternatively, you could just plug in a Z-Wave USB stick, which also means you don't need to disable Bluetooth.

Verdict

Works well, but you do need to disable Bluetooth.

7/10

Wave Plug

Shelly | £26 / $27 | shelly.com

Once you have added Z-Wave connectivity to your Raspberry Pi, using a GPIO module or USB stick, it can communicate with a range of Z-Wave devices and sensors. Note that Z-Wave should not be confused with the Zigbee wireless protocol, which has similar advantages of low power and long range – although not directly compatible, the two can communicate via Home Assistant.

Based on Z-Wave, the Wave Plug is similar to Wi-Fi smart sockets, enabling you to turn a standard non-smart device such as a table lamp on and off remotely. We tried out the three-pin UK version, but there's also a two-pin US model. Once you plug it into a regular mains socket, there are two methods for connecting it to your Z-Wave network. The (UK version's) LED ring then pulses green and you can view it in Home Assistant, along with stats such as energy consumption (kWh), current (A), voltage (V), and power (W). It also has overheat detection.

Verdict

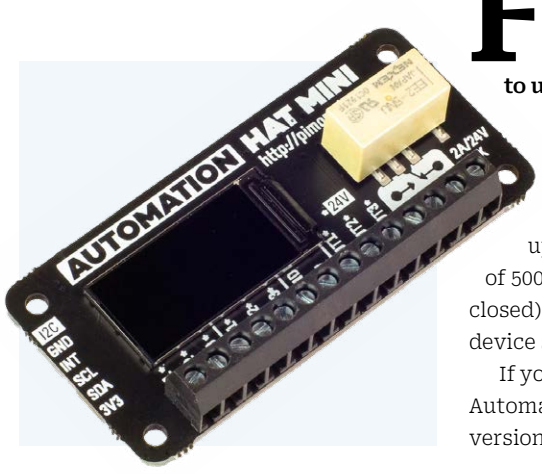
A good way to make dumb devices smart.

8/10

◀ The LED ring is colour-coded for levels of power consumption

Automation HAT Mini

Pimoroni | £23 / $24 | pimoroni.com



For home automation projects wired directly to Raspberry Pi, if you want to switch higher-voltage (i.e. more than 3.3V) devices on and off, you'll need to use a relay HAT to handle those higher power loads.

Along with multiple analogue and buffered inputs, the Automation HAT Mini features a single relay switch and three sinking outputs for controlling devices connected to the screw terminals, with a tolerance of up to 24V. The sinking outputs allow a maximum current of 500mA; the relay up to 2A – connected on the NC (normally closed) or NO (normally open) side, depending on whether your device spends more time switched on or off respectively.

If you need more relay switches, you could opt for a full-size Automation HAT, which has three, although it lacks the Mini version's full-colour LCD for showing useful status info.

Verdict

Ideal for wired home automation projects.

9/10

BLU Door/Window Sensor

Shelly | £18 / $19 | shelly.com

An alternative to using Z-Wave or Zigbee connectivity for smart home sensors is to use standard Bluetooth. The main downside is the typically shorter range (around 10m indoors), which is also affected by obstructions such as walls, so you may find you need to use a Bluetooth to Wi-Fi gateway such as Shelly's own Gateway USB stick.

Once connected to your Home Assistant setup on Raspberry Pi, the Bluetooth-based BLU Door/Window Sensor will send its open/closed status, along with detected light level and the angle of opening. Just use the supplied sticky pads to mount the main unit onto the outer edge of a window or door, and a smaller part on the frame, so the two are adjacent when the window/door is shut. Even with a bevelled frame on our window which meant the two parts were slightly tilted, it worked reliably and reported a status change near instantly.

When the two parts are separated, an 'open' status is broadcast

Verdict

A good option for a home security setup.

8/10

BLU RC Button 4

Shelly | £16 / $16 | shelly.com

As well as sensors for your smart home setup, you may consider adding some input devices to control devices and trigger actions without the need to bring up the Home Assistant dashboard every time.

With Bluetooth connectivity, the Shelly BLU RC Button 4 has four good-size push-buttons – labelled only with raised dots – that you can assign to trigger automations within Home Assistant. In addition, you can use long, double, and triple presses of each button as discrete inputs, so could have up to four different functions per button.

It's simple to set up an automation in Home Assistant: just add a trigger (e.g. button 1 press), optional extra conditions, and select one or more actions. We created some for our buttons to toggle lights on and off, as well as playing music and text-to-speech from a smart speaker.

The unit comes with a sticky pad to attached the holder to a wall – the buttons section can be removed and pocketed – and is powered by a CR2032 coin cell battery.

Verdict

Good-size buttons with a total of up to 16 functions.

8/10

Each button can trigger up to four different functions

BLU Motion Detection Sensor

Shelly | £21 / $22 | shelly.com

We have created many a Raspberry Pi project using a PIR motion sensor connected to the GPIO pins, which does limit its practicality unless you have very long jumper wires.

Since it has Bluetooth connectivity and CR2477 battery power, the BLU Motion Detection Sensor is more versatile and comes with a sticky pad so you can place it wherever you like, perhaps in a hallway opposite a door.

By default, the sensor broadcasts its motion detection status, illuminance, and battery status whenever the detection status changes – or it can act as a beacon, transmitting every 30 seconds. To try it out, we placed it in a cupboard to protect our chocolate stash! When triggered, it set off a Home Assistant automation to play a spoken message on a nearby speaker.

The unit has a default 'blind time' (during which it won't be retriggered by further motion) of 60 seconds, but this – along with the sensitivity – can be adjusted in the Shelly Smart Control mobile app.

Place this Bluetooth PIR sensor to detect intruders

Verdict

A responsive sensor that can be put anywhere.

8/10

1PM MINI GEN3

Shelly | £14 / $15 | shelly.com

You'll need a qualified electrician to install this kind of smart switch into an existing socket or light switch. Billed as 'the world's smallest Wi-Fi relay switch with power metering', the 1PM Mini Gen3 does what it says on the tin and allows remote control of electrical appliances, supporting up to 8 A at 240 V AC mains power. As well as having an embedded web interface, it'll work with a Home Assistant smart home setup.

Verdict

Good, but you'll need a pro to install it.

8/10

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we get technical

Argon ONE V5

Another month, another case. As **PJ Evans** finds out, this one means business

Argon 40 | **rpimag.co/argononev5** | From £28 / $35

SPECS

PORTS:
6 × USB, USB-C, 2 × full-size HDMI, 3.5 mm audio

ADD-ONS:
Up to 2 × NMVe M.2 SSD (2230, 2242, 2260, 2280), Zigbee module with antenna, OLED screen, UPS

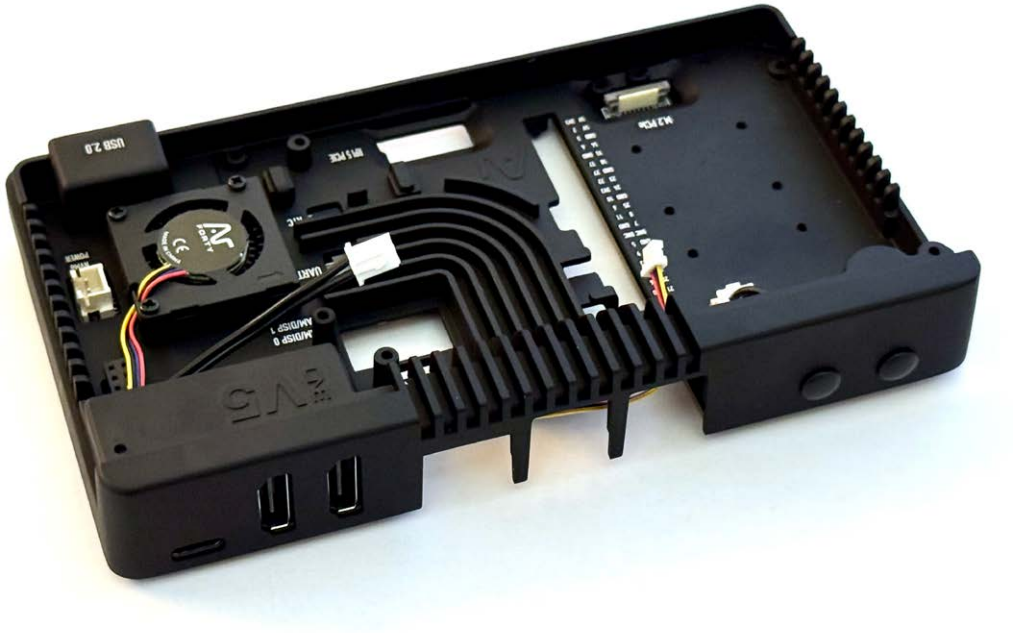
COOLING:
Passive aluminium, active 30 mm PWM fan

▶ A much more industrial design from Argon

Argon 40 is not messing about. After an eyebrow-raising detour into the budget case market with its perfectly serviceable Poly+ range, it is back to what it is known for with the latest in its premier ONE range.

There has, however, been a shift in approach. Whereas the original ONE and a Raspberry Pi 5-compatible V3 version sported a sleek sports car-like styling, the new V5 is an absolute unit. Its roots can be found in the industrial design of the NEO range, and this is clearly an evolution of that style. So what makes this new case so different? Let's start with the basics.

The first thing that strikes you is the sheer size. This is not a small case, and that's because it has a few tricks under its tough exterior. Argon is clearly intending this case to be your powerhouse server. Removing the solid aluminium lid, we find space for your Raspberry Pi 5 along with some impressive passive heatsinking and a mounted PWM 30mm fan. On-board



ports – including the GPIO header – are exposed within the housing for projects and there's a few millimetres of clearance for adding your own bits and pieces. Argon's signature daughterboard design is here too, with a PCB that plugs into the USB-C and HDMI ports of your Raspberry Pi, breaking them out to full-size HDMI and an additional two front-mounted USB-A connectors. Slotting it all together onto the plastic base creates a solid unit for your next project.

Features and upgrade options

There is a very good reason this case is so much larger than standard. Alongside the Raspberry Pi, there is space for two M.2 NVMe slots for up to full-sized 2280 solid-state drives. This case then becomes a NAS with SSD RAID capability. You can purchase the add-on PCBs for each M.2 separately or pre-mounted, offering flexibility on price and future upgrade options. Then, nestling next to the front-mounted USB ports, there's an audio-out port. This case comes with a DAC built-in, which upgrades it further to a potential media server.

Home automation enthusiasts may be tempted by the optional Zigbee add-on which plugs into the daughterboard and comes complete with an antenna which mounts to the case externally. If you're using the case headless and want to see some info at a glance, the £9 OLED module adds a tiny screen to the top of the case for you to use as you wish. Finally, another option is to add a dedicated uninterruptible power supply (UPS), which sits neatly under the case. Argon has created an entire ecosystem around the simple concept of a case.

We were supplied with a manual, thermal pads for the various Raspberry Pi chips, and additional thermal pads for protecting the M.2 SSDs. Assembly was easy and the result was formidable. It may not look as pretty as its predecessors on your living room cabinet, but you'll probably be able to drop it from some height without causing it much damage.

> *Argon is clearly intending this case to be for your powerhouse server*

▲ There is excellent heat dissipation and port access inside

◀ All the usual rear ports plus full-size HDMI and antenna mount points

Verdict

If you are looking to build a home server for media, automation, or just data storage, this is a well-priced option that will keep your Raspberry Pi cool and protected with a wealth of upgrade options.

10/10

ED-SBC3300

A mini-ITX motherboard powered by Raspberry Pi CM5. By **Phil King**

EDATEC **rpimag.co/sbc3300** From £189 / $233

SPECS

FEATURES:
Compute Module 5, mini-ITX motherboard, RTC, Wi-Fi/Bluetooth (optional), 4G LTE (optional)

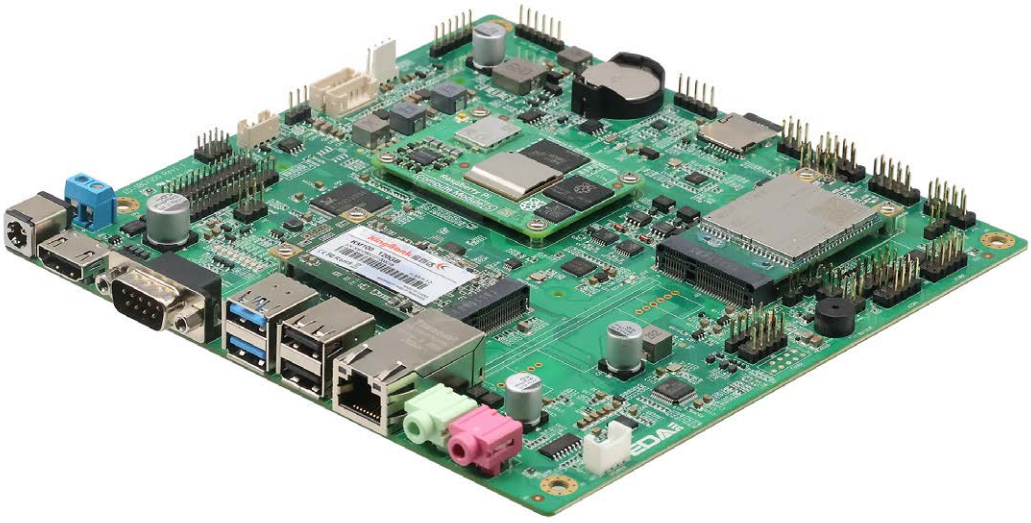
CONNECTIONS:
2 × USB 2.0, 2 × USB 3.0, HDMI, Gigabit Ethernet, DB9 RS232 serial debug, 6 x RS232 JCOM, 2 × RS485, 9V-36 V DC two-pin/barrel jack power; Optional: 3.5 mm stereo audio out and mic, LVDS display, speaker

RAM / STORAGE:
2GB, 4GB, 8GB, or 16GB (CM5) DDR RAM; 16GB, 32GB, or 64GB eMMC; optional SSD / microSD

▶ Ports featured vary by model, but include full-size HDMI, USB 2.0 and 3.0, and DB9 serial debug

Based around a Raspberry Pi Compute Module 5 (CM5), EDATEC's ED-SBC3300 range of industrial computers packs a whole load of processing power. The mini-ITX motherboard is identical to that of the earlier ED-SBC2300 range, but swaps out the CM4 for a CM5. Adherence to the mini-ITX form factor, with a 170×170mm footprint, means the motherboard can fit into any standard mini-ITX enclosure – or variants such as ATX and micro-ATX.

The ED-SBC3300 range comes in four main model types, offering numerous possible configurations for RAM (from 2GB to 8GB), eMMC flash storage (from 16GB to 64GB), connectivity (Wi-Fi/Bluetooth and/or 4G LTE), along with other ports and features. The ED-SBC3320 model we tested also included optional microphone and stereo audio out 3.5mm jacks, an LVDS display interface supporting up to 1080p 60Hz, and a PoE module for an alternative power method.



With the CM5 pre-installed, the mini-ITX motherboard measures 170×170 mm

The motherboard is packed with connection headers, along with numerous status LEDs

Well connected

The main ports are situated along one edge of the board. These include a full-size HDMI video output and an arrangement of USB and Ethernet ports depending on the model: ours featured 2 × USB 3.0, 2 × USB 2.0, and one Gigabit Ethernet.

There's a DB9 port for the RS232 COM0 serial interface for debugging purposes. Among the numerous breakout headers around the board, you will find six more JCOM RS232 serial connections (with five usable pins each), along with a couple for the RS485 serial protocol – often preferred in industrial settings due to its longer cabling and lower noise capabilities.

Other features scattered around the motherboard include a CR2032 battery holder (for powering the CM5's real-time clock), microSD card slot, and M.2 SATA interface to connect an SSD.

For the all-important power supply, you have two main choices (other than using the optional Power-over-Ethernet): a two-pin terminal connector or standard (5×2.5mm) barrel jack. Either way, there's a welcome wide input range of 9V–36VDC.

Before powering it up, you'll want to connect the supplied external antenna(s) to the tiny U.FL connectors for Wi-Fi/Bluetooth (on the CM5 itself) and 4G LTE (on the module). If using 4G, you'll also need to briefly lift out the PCIe-connected module to insert a nano SIM into the slot hidden beneath it.

> *The motherboard can fit into any standard mini-ITX enclosure*

Booting up

Once connected to an HDMI monitor, the unit booted up quickly into the desktop version of Raspberry Pi OS Bookworm pre-installed on the eMMC. As with the ED-IPC3100 reviewed last issue, we found we needed to configure the Wi-Fi connection via the raspi-config tool, as the desktop tool wasn't responsive. To connect to 4G (with a nano SIM card inserted into the slot secreted beneath the module) takes a little configuration via the Terminal, as explained in the online manual.

Since our review unit lacked the usual heatsink covering the area around the CM5, we were unable to test the latter's passive cooling performance. The board also lacks a Raspberry Pi 5-style JST-PH header for connecting a PWM fan such as EDATEC's own CM5 Active Cooler; instead, there's a four-pin 'FAN' header (adhering to the standard requirements of mini-ITX) that should be usable with an Active Cooler if you substitute its 12V power pin with a 5V one elsewhere on the board (such as J21 pin 1).

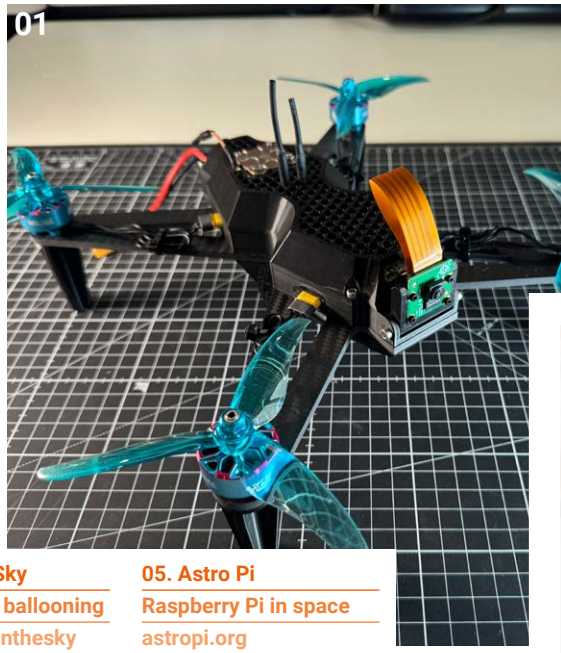
Verdict

A powerful and versatile CM5-based mini-ITX board with plenty of serial port headers, along with a dual (HDMI/LVDS) display capability.

8/10

10 amazing: airborne projects

Take to the skies with Raspberry Pi and a dream (or helium)



Is it a bird? Is it a plane? Is it a tired cliché? No, it's a Raspberry Pi and/or Raspberry Pi Pico flying high up in the sky! These projects defy gravity and send your electronics soaring – sometimes you control it, sometimes you track it, and sometimes you have to get a telescope out to see the vessel it's located in. Grab your aviator goggles and let's take off.

01. Pico 2 Drone

Miracle flyer

rpimag.co/pico2drone

Created by maker intern Louis Wood, who also made the LEGO card shuffler, this drone started with a 3D-printed body before moving to a less-brittle CNC-routed carbon fibre. It also has a Raspberry Pi Zero aboard.

02. Pi0drone

Zero can fly

rpimag.co/pi0drone

This smart drone build uses a Raspberry Pi Zero, the PXFmini board made specifically for drone use, and comes in under $200, which is pretty good.

03. RC plane OSD

Bird's-eye view

rpimag.co/rcplaneosd

Update your RC plane with not only a POV camera, but also flight telemetry, including battery voltage so that you know when you need to bring the plane back home.

04. Pi in the Sky

High-altitude ballooning

rpimag.co/piinthesky

Within a few months of Raspberry Pi launching, Dave Akerman was sending balloons up with Raspberry Pi to take photos of the upper atmosphere. He even broke several records doing it.

05. Astro Pi

Raspberry Pi in space

astropi.org

Sitting aboard the International Space Station is Astro Pi, a special hardened version of Raspberry Pi with a Sense HAT attached. School students can enter a competition to get their code running on it.

06. DIY Quadcopter Drone

Pico 1 powered

rpimag.co/diyquadcop

Built around a Raspberry Pi Pico 1 and its RP2040, this cool project does a little less than the Pico 2 Drone; still, it's very impressive that it works at all.

07. Remote-Controlled-Airplane

Raspberry Pi 3 remote

rpimag.co/rcairplane

This is an open-source project (it's on GitHub) for creating an RC airplane with a Raspberry Pi 3B+ as the brains of the operation – although you can probably upgrade it if you need to.

08. GASPACS CubeSat

Orbital Raspberry Pi

rpimag.co/gaspacs

Designed to test aerobraking through an inflatable AeroBoom in low Earth orbit, this undergraduate-developed Raspberry Pi-powered CubeSat was in space for 117 days.

09. Hovercraft

Technically airborne

rpimag.co/hovercraft

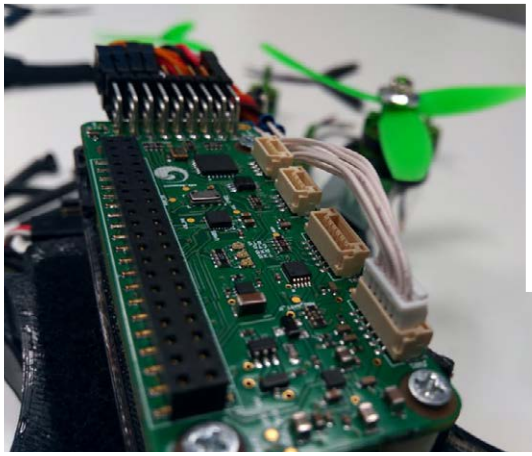
This Wiimote-controlled hovercraft was showcased at Coolest Projects 2016, using a Raspberry Pi alongside the Wii Remote to move the cardboard hovercraft around.

10. Pi Zero Plane

Fixed-wing Zero

rpimag.co/zeroplane

Instead of being elevated with rotors, this one uses aerodynamic lift to fly. As the name suggests, it features a Raspberry Pi Zero, along with the PXFmini drone add-on.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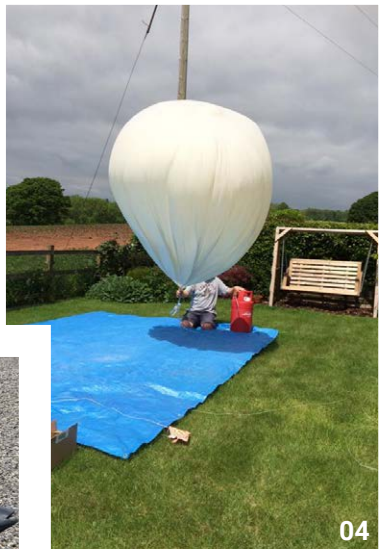
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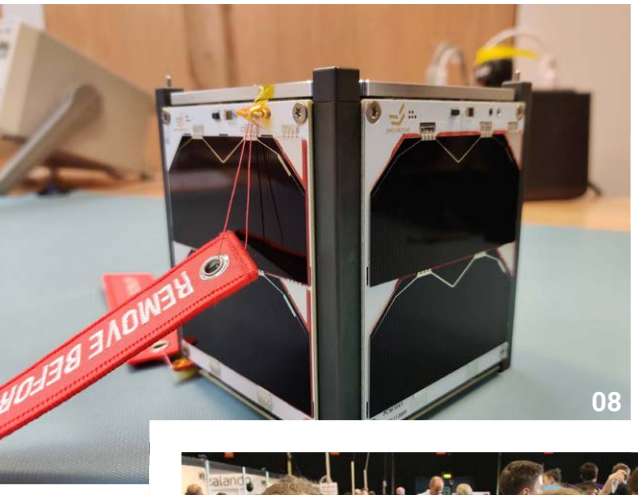
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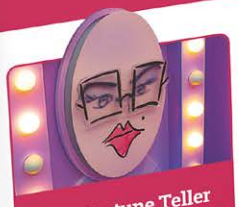
THE Official RASPBERRY PI HANDBOOK 2025

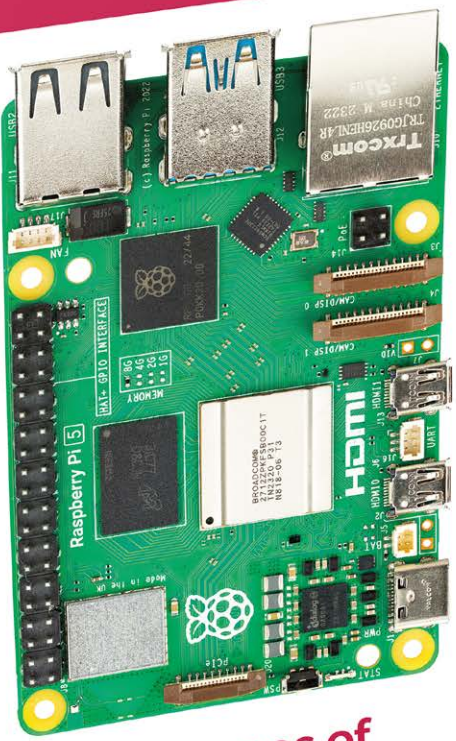


Olga **Fortune Teller**

Astrophotography

Exoskeleton

Blue **ROV2**



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Nicola King

Craft tutorial writer and word checker Nicola has been part of Raspberry Pi magazines for over seven years

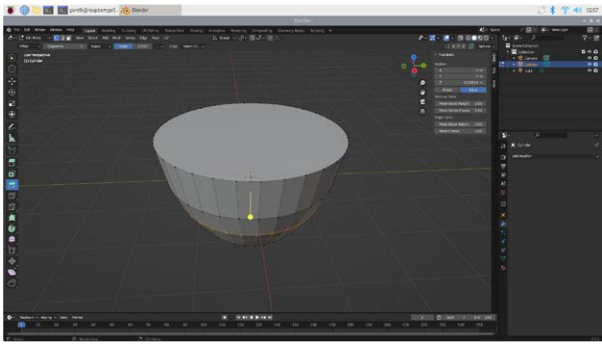
Name Nicola King
Occupation Freelance writer/sub-editor
Community role Crafter and maker
URL @holtonhandmade

Nicola is a name you'll have seen grace the pages in the various publications by Raspberry Pi for a long time now, and currently she's our resident craft tutorial expert. Nicola covers everything from making paper to computer-programmed embroidery – and this month she's making soap with a tech twist.

"My mum taught me to sew when I was maybe six or seven, and I remember hand-sewing dresses for my Sindy doll (that dates me!)," Nicola says. "I learnt to knit shortly after that, and it's just something that sticks with you, even if you don't knit anything for a while; it's like riding a bike. I taught myself crochet around ten years ago using YouTube, and it's absolutely addictive once the penny drops. My dad has always been very practical and hands-on, and my sister is a secondary school textiles teacher, so it's engrained. I've always turned to making when I need to switch my mind off from other things. I've tried many crafts now, not just soft crafts, and have quite the collection of paraphernalia in the office!"

When did you first learn about Raspberry Pi?

I learnt about Raspberry Pi through my husband, Phil (a tech journalist for decades). Phil was already working for *The MagPi* magazine and was always tinkering at home with Raspberry Pi computers in some capacity, so the whole family has had a lot of exposure to Raspberry Pi over the years. I heard about the sub-editing role on *HackSpace* magazine and, luckily, I began working on it soon after that. Sub-editing both *HackSpace* and *The MagPi* was a real eye-opener in



▶ As seen in this issue – 3D printing and soap making go hand in hand

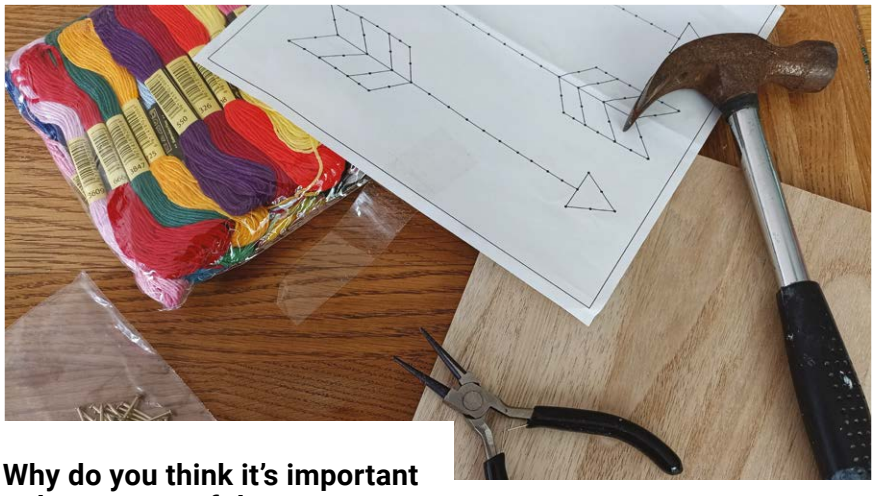
terms of learning about the flexibility of Raspberry Pi and the multitude of uses that it can be put to. Project showcases, in particular, from makers worldwide have been hugely informative to read. Some of my favourite projects have been made by my good friends Martin and Vanessa at VEEB Projects (**rpimag.co/veeb**). Their coffee robot 'teasmade' and vintage German railway clock projects are particular favourites of mine.

How did you end up doing the crafty tutorials in *HackSpace*?

I was really inspired by some of the makers whose work I was sub-editing on *HackSpace* and *The MagPi*, especially Sophy Wong who had done all sort of things with wearable tech. I then wondered if Ben and Andrew [at *HackSpace*] would be interested in my own warblings on craft, especially if I included a tech angle where possible, and they were thankfully really receptive, so I ended up writing lots of crafty-related pieces – so many that I've actually lost count. I think I may have covered nearly every craft under the sun!

What are some of your favourite projects you've made?

One of my favourites was more of a discussion than a project, but it was called A Stitch in Code, and we examined the idea that an average knitting or crochet pattern is actually just a form of code. Brackets, asterisks, loops, standard notation, etc. all exist in patterns, just as in coding – so, tech and maths skills, creativity, and the ability to catch bugs are needed by pattern writers and coders alike. To help prove the point, we even turned a basic knitting pattern into Python code.



▲ Planning out string art and crochet can be very similar to code

Why do you think it's important to keep some of these crafts alive?

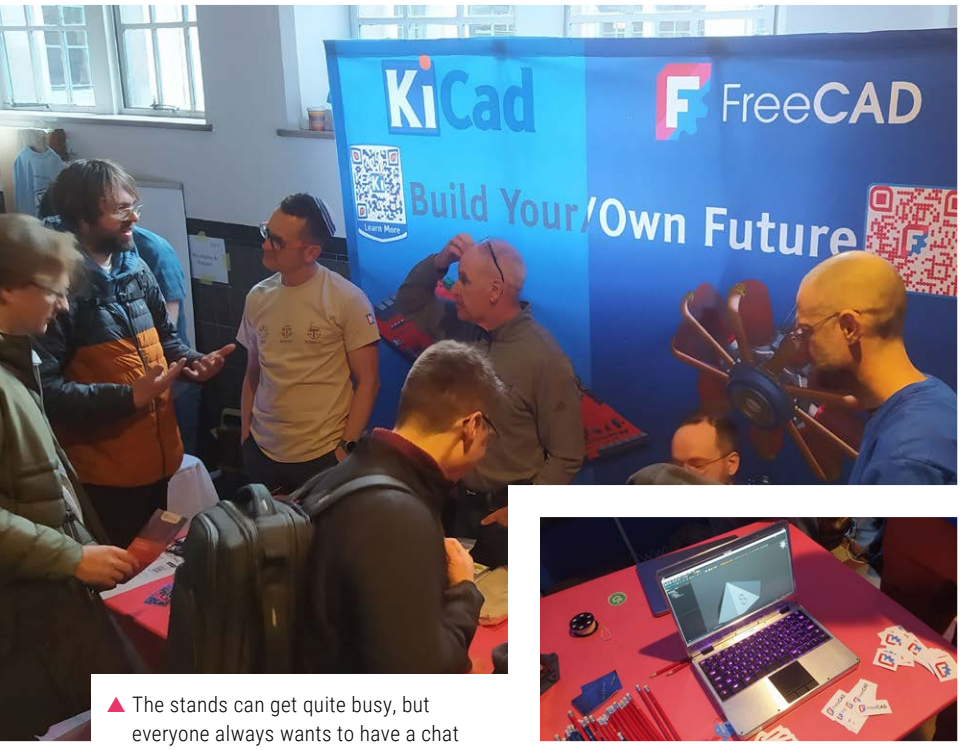
When you preserve a craft of any kind, you are preserving a form of cultural heritage, and are giving future generations a chance to easily link back to that heritage and the beliefs and values of generations that have gone before them. I really can't see the day coming when no one is interested in making things any more; I think it's inherent in us. Keeping crafts relevant and 'cool', if you like, is important. Take crochet… it's surging in popularity, both as a craft and as a fashion trend.

Crafting or making anything is good for the soul. I often bang on about how making things is a 'mindful experience', but it really is true. Making anything can boost your mood, reduce stress, and give you a tangible, usable thing! Our son now towers over me, but the things I knitted or crocheted, wired, stamped into metal, and papier-mâchéd for him while he was little are a way of holding on to memories, passing on skills, and just planting that tiny crafting seed in his head, that hopefully will sprout one day when he's in need of a calming distraction from everyday life.

▲ A lot of crafting projects will use tools common in tech making hobbies

Crafting or making anything is good for the soul

FOSDEM 2025



▲ The stands can get quite busy, but everyone always wants to have a chat

▲ FOSDEM is a great place to chance across cool hardware. Here the MNT Reform v2 laptop prototype is spotted on the FreeCAD/KiCad stand, running FreeCAD!

◀ Everyone is invited to the unofficial after-party, 'Bytenight', at Hackerspace Brussels

Open source is everywhere – yet this blend of software and hardware that keeps the world, and indeed many of our Raspberry Pi projects, running can be hard to see.

If you do want to go somewhere to make this all more visible, then FOSDEM is the place. FOSDEM is the biggest open-source conference in the world, and it takes place across the fabulous Solbach campus of Universiteé Libre De Brussels – and if that wasn't enough to entice you, it's completely free to visit! As such, each year, it attracts a huge number of teams and individuals who work on a vast array of open source projects.

The wide range of organisations represented at FOSDEM includes huge global software/Linux projects, things like Debian (the Linux distribution upon which Raspberry Pi OS is built) and Canonical Ubuntu through to smaller parts of that ecosystem like the Gnome and KDE desktop environments. You'll find totally non-commercial open-source projects like the fabulous Open Flexure – a microscopy project – through more commercial entities like Prusa 3D displaying its latest amazing 3D printers. You'll also get more community stands with broader themes, such as HAM radio stands. We loved chatting with people from the Meshtastic project and the GNU Radio project, which had stands on the same corridor. The list of stands goes on, and you can check out who was there on the FOSDEM site: **rpimag.co/FosdemStands**.

QUICK TIP

There's a wide range of catering at FOSDEM, but it gets busy! Avoiding the peak times of 12–2pm can help, but expect to queue at any time.

▼ The array of talks is bewildering; make sure to spend a decent amount of time looking through the schedule before travelling to FOSDEM so you don't miss out

Aside from stands, there are lots and lots of talks. The larger keynotes are held in the Janson building, which has a 1500-seat auditorium, and across all the buildings of FOSDEM there are rooms with a talks schedule. Each talk that is delivered at FOSDEM has its own page on the website, where eventually after the event all the captured video of talks and supporting materials will be gathered. It's incredibly impressive.

QUICK TIP

Arrive at the designated room for a talk early; they are often incredibly busy!

This year was the 25th FOSDEM and as such there were, peppered across the site, various posters with information about the event over the years. It made for an additional great aspect while walking around. It's interesting to note how many projects at FOSDEM link to Raspberry Pi, some directly: for example the OpenHAB project was at FOSDEM showing off its Raspberry Pi-powered home automation systems. KiCad, the electronics EDA that's bundled with Raspberry Pi OS, was also represented. But once you start including Raspberry Pi-related projects, the list grows very quickly.

▼ The Mozilla team gave out free cookies (without tracking!) on the Saturday at FOSDEM

QUICK TIP

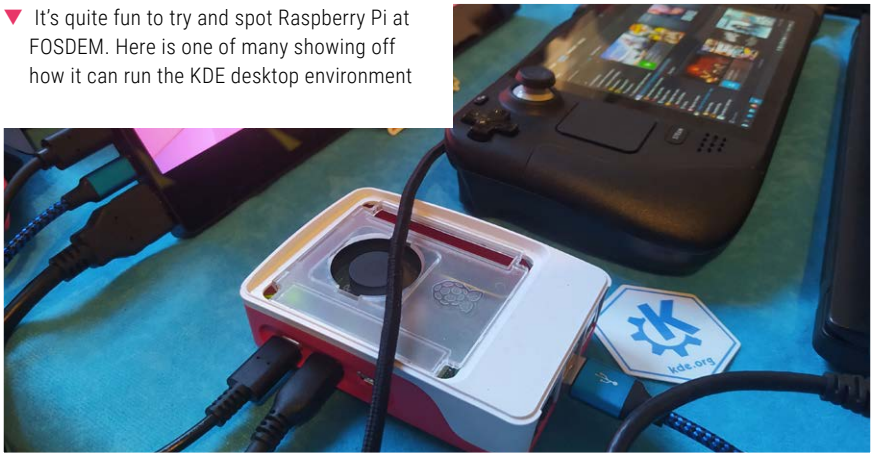
If you want a FOSDEM T-shirt, make that your first port of call as they often run out.

It's often noted that FOSDEM attendees represent a small but significant proportion of the Brussels population on the weekend and indeed you'll find a heap of other events surrounding FOSDEM itself. Many organisations and projects will have meetup days and hackathons around the FOSDEM weekend, either renting small venues or just setting up in their accommodation. There are plenty of evening meetups, with the perennial favourite of beers at Delirium and the Bytenight official FOSDEM after-party hosted by HSBXL (Hackerspace Brussels).

If this all sounds fun, and it really is, we look forward to seeing you out there next year!

▲ For the 25th anniversary of FOSDEM, there was lots of interesting information across the site about FOSDEM in the early days

▼ It's quite fun to try and spot Raspberry Pi at FOSDEM. Here is one of many showing off how it can run the KDE desktop environment

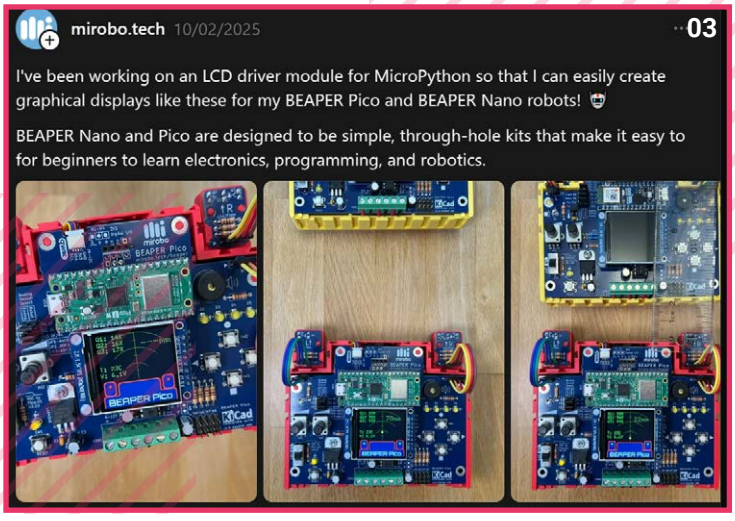


Maker Monday

Amazing projects direct from social media!

Every Monday, we ask the question: have you made something with a Raspberry Pi over the weekend? Every Monday, our followers send us amazing photos and videos of the things they have made.

Follow along to #MakerMonday each week over on our various social media platforms!



01. A simple 3D print, but a nice addition to Stewart's model railway

02. As everyone who has played a Game Boy knows, this would have been a game-changer in 1990

03. Ooh, tiny LCD driver modules? Colour us intrigued

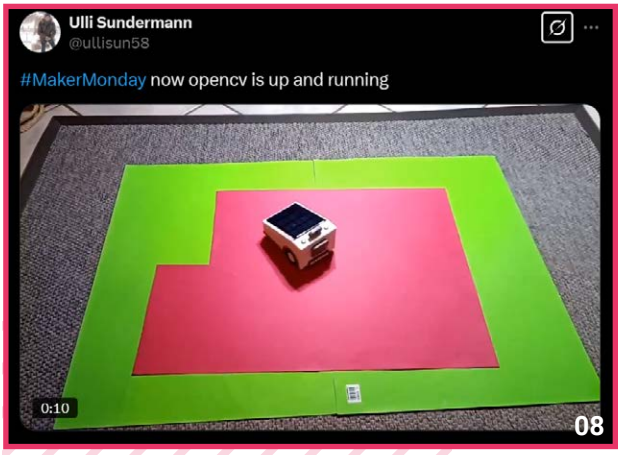
04. A very neat and tidy test rig; we like it

05. Extremely tidy little setup for this Raspberry Pi server rack

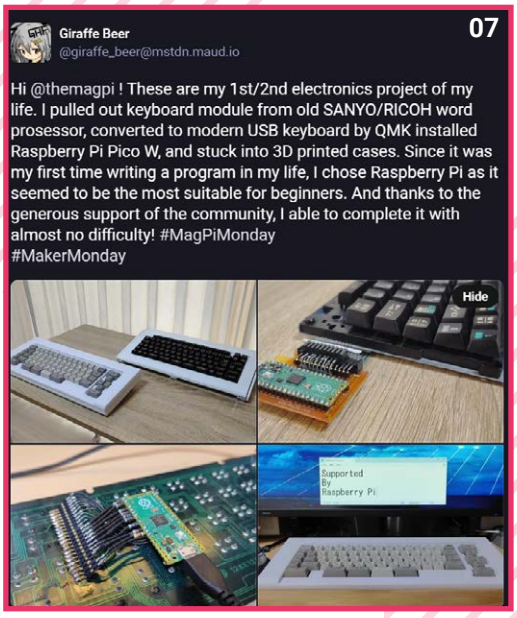
06. We knew nuggies were good, but we were unaware of their musical prowess

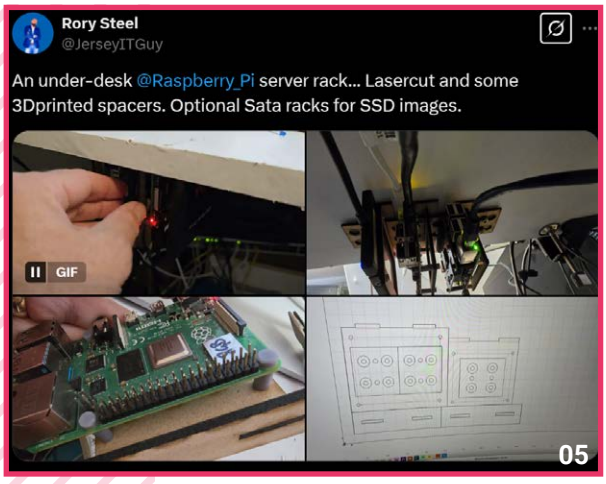
07. Keyboard upcycles are a great project – especially when you can get some old clacky variants

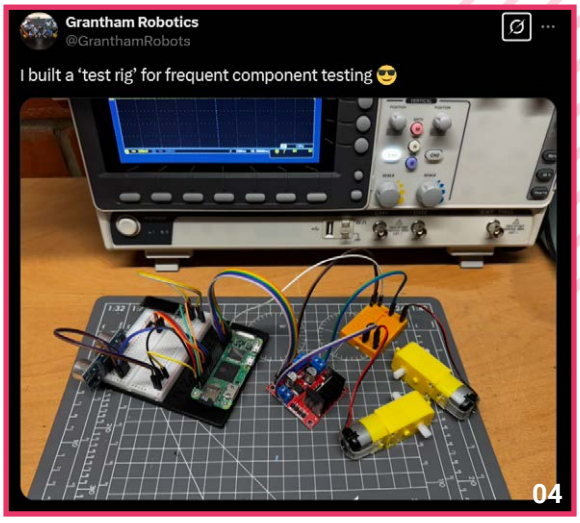
08. This solar-powered robot can now see with a bit of computer vision


Ulli Sundermann
@ullisun58
#MakerMonday now opencv is up and running
0:10
08


Kevin McAleer Robot Maker
@kevsmac
06
I created a Pico Powered chicken nugget piano -
NUGGET PIANO
Chicken Nugget Piano
From kevsrobots.com


Giraffe Beer
@giraffe_beer@mstdn.maud.io
07
Hi @themagpi ! These are my 1st/2nd electronics project of my life. I pulled out keyboard module from old SANYO/RICOH word prosessor, converted to modern USB keyboard by QMK installed Raspberry Pi Pico W, and stuck into 3D printed cases. Since it was my first time writing a program in my life, I chose Raspberry Pi as it seemed to be the most suitable for beginners. And thanks to the generous support of the community, I able to complete it with almost no difficulty! #MagPiMonday
#MakerMonday
Hide


Rory Steel
@JerseyITGuy
An under-desk @Raspberry_Pi server rack... Lasercut and some 3Dprinted spacers. Optional Sata racks for SSD images.
GIF
05


Grantham Robotics
@GranthamRobots
I built a 'test rig' for frequent component testing 😎
04

Raspberry Pi Pico Ticket Game

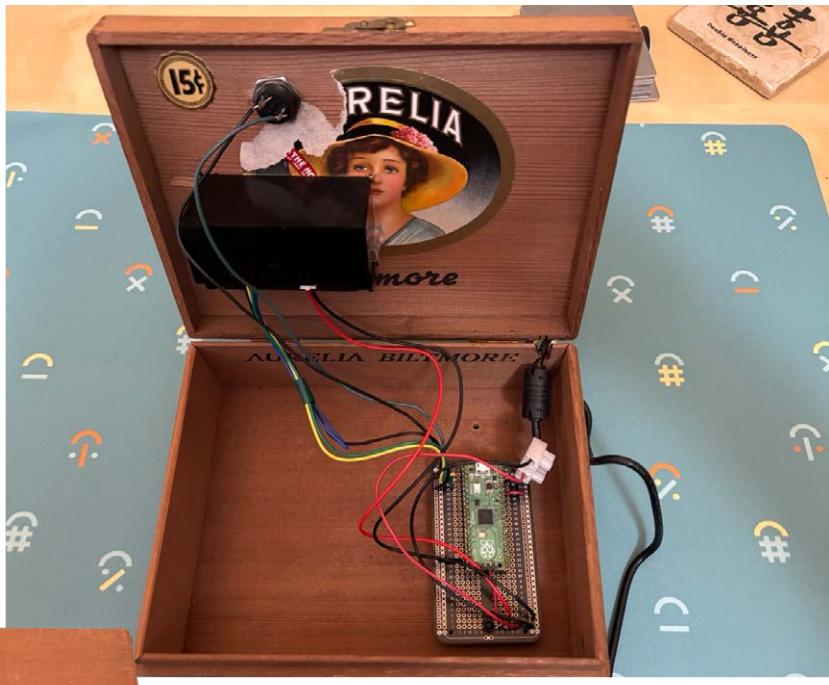
Break the ice with this cute little conversation starter

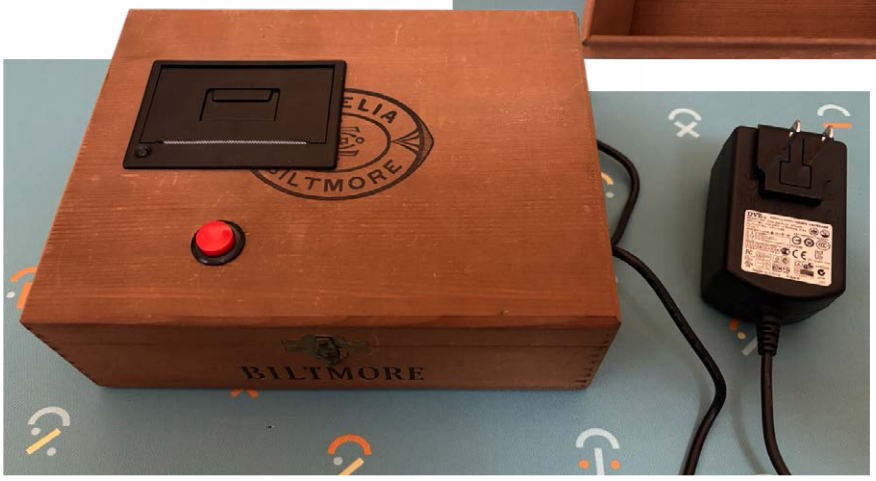
▲ Names and questions can be changed in the code very easily – it is MicroPython, after all

Chris emailed us a little while ago (sorry, Chris!) about his fun little Raspberry Pi Pico project which he describes as "a simple stand-alone Q&A game or ice-breaker for a party, using a Pico, a thermal printer, and a big red button" – although we'd say the button is medium-size compared to the 100 mm ones we've seen/used in the past.

According to the GitHub page for the project (**rpimag.co/ticketgame**, which includes the build instructions too), it was made for a New Year's event, and is easily modifiable.

"I used a cigar box for the build, but it can fit into any suitable project box," Chris says. Although we quite like the box ourselves.





▲ Due to the overall size of Pico, the insides are mostly empty

◀ A thermal printer inside the box prints out questions at the push of the red button

Crowdfund this

Great crowdfunding projects this month

ECHOBLAST

A very fun project based on a classic toy from the previous century, it runs on a Raspberry Pi Pico and is fully customisable to use your own sounds – so they don't have to sound like you recorded them underwater any more.

▶ **kck.st/3QNXEEj**

Edin's Garden

A new idea for a community garden using Raspberry Pi-powered towers to monitor and control urban farms. We do like automated farming, and Raspberry Pi has been proven to be a perfect controller for these kinds of builds in the past.

▶ **kck.st/43ftvVR**

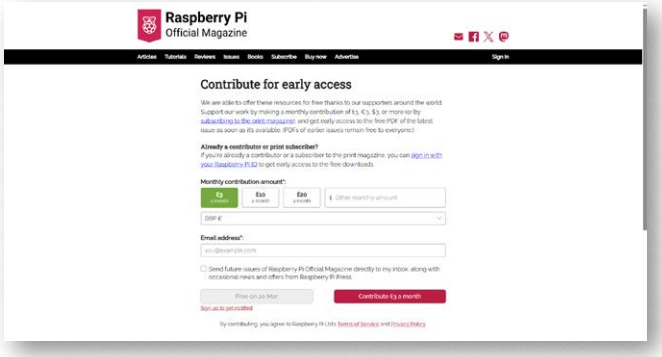
Your Letters

On the bookshelf

Is there a plan to update the Bookshelf app now that *The MagPi* is *Raspberry Pi Official Magazine*? Thanks in advance.

Jack via the blog

The Bookshelf app on Raspberry Pi OS was technically updated the moment the new issue with the new name was released! As the PDF doesn't appear on the app until three weeks after launch, it will take a little while for the changes to be apparent, though. Of course, if you'd like the PDF earlier, making a contribution on the *RPOM* website (**rpimag.co**) will grant you access to the PDFs from day one, and print subscribers also get day-one access to the PDFs.



▲ The best way to get the PDFs on day one is to contribute

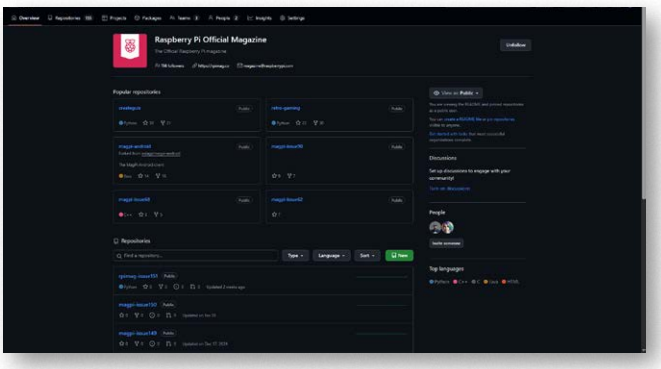
Link retention

With the change to the magazine URL, I hope something has been put in place to make sure the old links in old articles still work. Would be a shame if they suddenly stopped working!

Harlan via email

We've set up a redirect that should make sure everything still works as it did before – including old shortlinks.

One of the reasons we kept the numbering is to make sure the legacy is remembered and properly maintained. That being said, if you notice an issue with an older link, do let us know via email.



◀ Things like GitHub will stay on the same domain, but everything else will redirect

Readability

[Regarding the redesign,] I appreciate the very slight increase in the font size!

There *are*, however, a few times when I've really struggled. Is the body text 'black' black, or is it 'grey' black? The bold bit at the start is fine, but the body text is a little hard on the eyes.

There's also a thinner font version that's used in a few places that is difficult to read.

But that's just me with my old(er) eyes.

Mike via the forum

Yes, stuff like contrast and font sizes in places is something we plan to tweak a bit. We've been scouring the PDFs and printed versions to see where we think improvements can be made – hopefully you can already see some in this issue already.

We're also looking at getting alt text on images into the digital version of the magazine, so watch (or screen-read) this space.

▲ *Raspberry Pi Official Magazine* is very new, which means we're still debugging bits of it

Contact us!

- rpimag.co/twitter
- @rpimag
- rpimag.co/facebook
- magazine@raspberrypi.com
- forums.raspberrypi.com

Community Events Calendar

Find out what community-organised Raspberry Pi-themed events are happening near you...

01. Melbourne Raspberry Pi Makers Group Meetup

- **Sunday 6 April**
- **Docklands Makerspace and Library, Melbourne, Australia**
- **rpimag.co/mrpmgm152**

This meetup is open to everyone with an interest in electronics, robotics, home automation, 3D printing, laser cutting, amateur radio, high-altitude balloons, space tech, etc. Makers are invited to bring along their projects and project ideas, and come connect with other makers. Get your questions answered, show off the work you are doing, and get support to resolve nagging issues.

Riverside Raspberry
Raspberry Pi Users Group
Let your computer play in the real world!
www.meetup.com/Riverside-Raspberry

02. Riverside Raspberry Pi Meetup

- **Monday 14 April**
- **3600 Lime Street, Riverside, CA, USA**
- **rpimag.co/rrpm152**

The purpose of Riverside Raspberry is to share knowledge related to Raspberry Pi hardware in particular, and to promote interest in tech development in the Inland Empire in general. The group is currently meeting on the second Monday evening of each month.

03. Hobby-X

- **Thursday 1 May to Sunday 4 May**
- **Kyalami Grand Prix Circuit, Johannesburg, South Africa**
- **rpimag.co/hobbyx**

Raspberry Pi Approved Reseller PiShop is hosting an exhibit at Hobby-X, a trade and consumer show that showcases a variety of hobbies and crafts. At Hobby-X, visitors can explore the latest products and supplies related to their favourite hobbies and crafts, learn new techniques, and connect with other hobbyists and experts in their field.

Hobby-X

04. Raspberry JAM @ MILL

- **Saturday 17 May**
- **MILL, Lisbon, Portugal**
- **rpimag.co/rjmill152**

MILL (Makers In Little Lisbon) invites everyone to another Raspberry Jam Lisboa! Come and enjoy a day of conviviality as you get to know this revolutionary minicomputer, Raspberry Pi!
The group will share projects, help those just starting out on their journey, give presentations, and much more.

FULL CALENDAR
Get a full list of upcoming community events here:
rpimag.co/events

05. Gitex Africa 2025

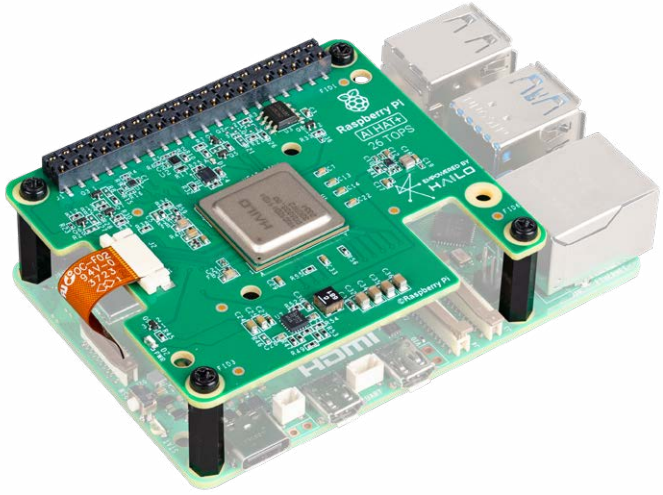
- **Monday 14 April to Wednesday 16 April**
- **Bab Jdid, Marrakech, Morocco**
- **rpimag.co/gitex2025**

The Raspberry Pi team is delighted to be returning, for the second consecutive year, to Marrakech, Morocco, to attend Africa's biggest tech and startup show: Gitex Africa 2025. There you'll be able to meet our team and experience the full range of our technology, including Raspberry Pi single-board computers (up to Raspberry Pi 500), the Raspberry Pi Pico family, and RP2350-based solutions, as well as our AI products, cameras, and latest industrial device: Compute Module 5.

Win 1 of 3

26 TOPS AI HAT+

Unlock the power of AI on Raspberry Pi with the incredible AI HAT+, and follow along with our practical AI special feature. With a built-in neural network accelerator and support for TensorFlow and PyTorch, you'll be able to explore a range of amazing AI applications.



Head here to enter:

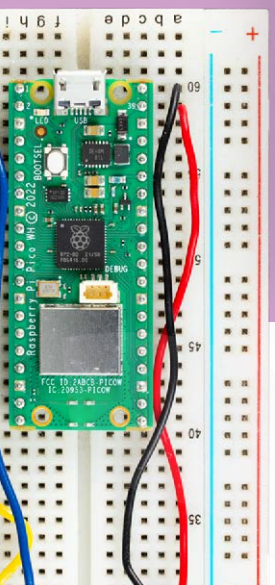
rpimag.co/win

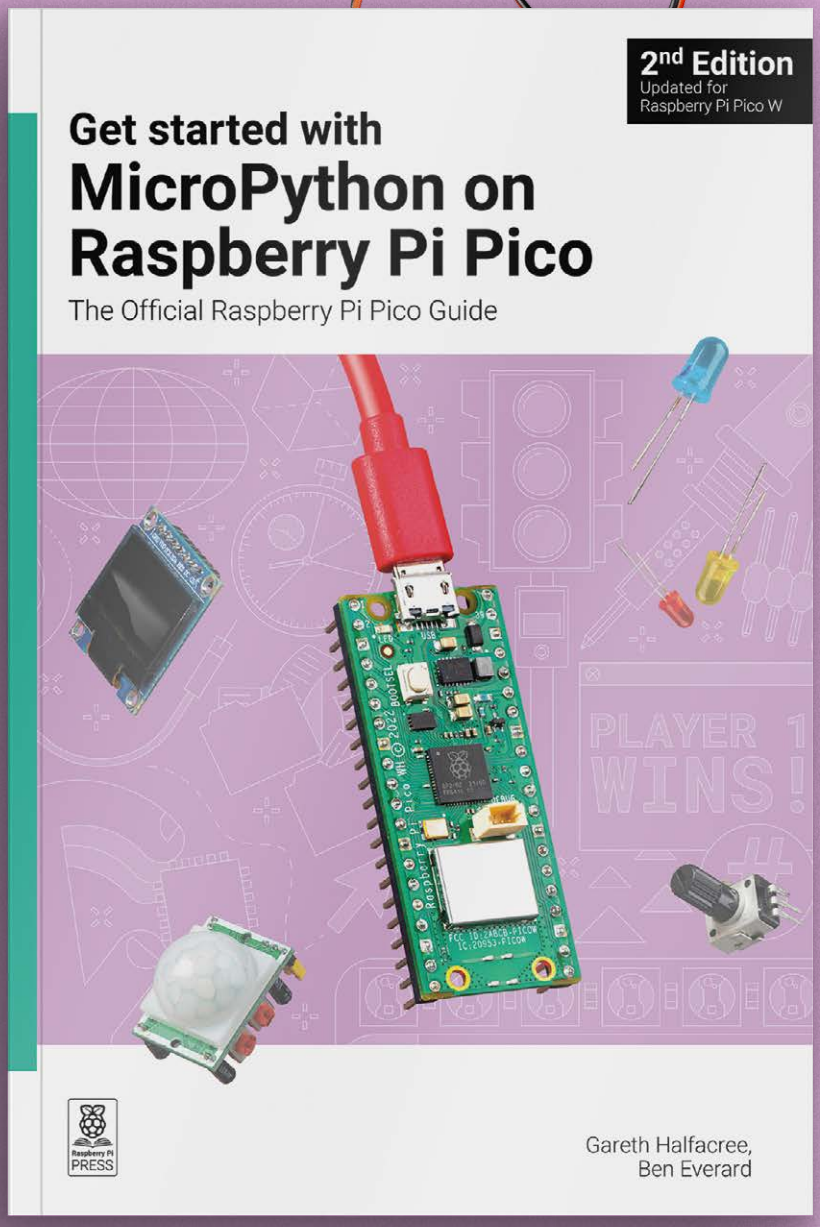
Learn more:

rpimag.co/aihatplus

Terms & Conditions

Competition opens on **26 March 2025** and closes on **24 April 2025**. Prize is offered to participants worldwide aged 13 or over, except employees of Raspberry Pi Ltd, the prize supplier, their families, or friends. Winners will be notified by email no more than 30 days after the competition closes. By entering the competition, the winner consents to any publicity generated from the competition, in print and online. Participants agree to receive occasional newsletters from Raspberry Pi Official magazine. We don't like spam: participants' details will remain strictly confidential and won't be shared with third parties. Prizes are non-negotiable and no cash alternative will be offered. Winners will be contacted by email to arrange delivery. Any winners who have not responded 60 days after the initial email is sent will have their prize revoked. This promotion is in no way sponsored, endorsed or administered by, or associated with, Instagram, Facebook, Twitter (X) or any other companies used to promote the service.





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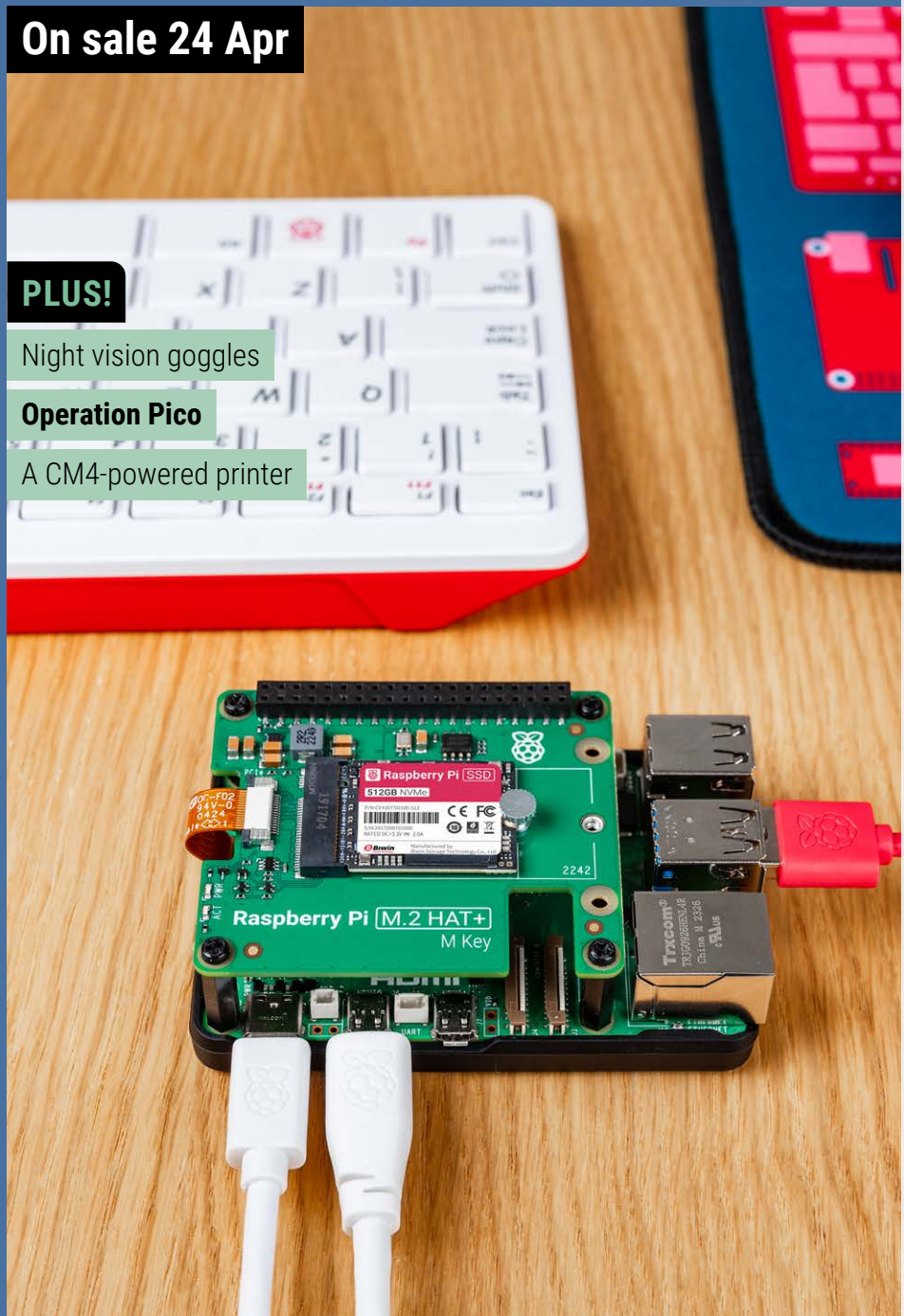

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From one era to another

When a classic computer meets cutting-edge intelligence.

By **Lucy Hattersley**

I'm looking at a Raspberry Pi 500 on my desk. In many ways it's a throwback: like a time machine disguised as a keyboard. It could become my holy trinity of childhood computing: Spectrum, Commodore 64, or the Amiga 500 with which it shares its name. I've turned it into all three at one point.

The design isn't nostalgic, though: it's purposeful. Placing the ultra-powerful Raspberry Pi inside a keyboard produces a modern computer that's supremely hackable. It can be anything I want. A modern Linux desktop, a coding powerhouse, and a platform to experiment with the cutting edge of electronics and software.

> *Sony's use of Raspberry Pi AI Camera on its production line proves this isn't just nostalgic tinkering*

Raspberry Pi isn't – for me – a nostalgia engine. It's a platform to experiment with computing like I did as a child. With wide-eyed wonder at this remarkable new invention that enabled you to create, and control, what you saw on the screen instead of being a passive subscriber. The computer was yours to code, break, and ultimately fix. Also it's red and white instead of beige – a definite improvement.

Next to it is the Raspberry Pi 5 with 16GB RAM, an AI HAT+ and an AI Camera. Here we have a computer that pays homage to the golden era of computing, stacked with a Hailo accelerator capable of performing 26 trillion operations per second. It feels like science fiction today, let alone to my eight-year-old self.

This juxtaposition isn't a contradiction to me. The same ethos that drove home computing drives Raspberry Pi. Democratise technology and make it understandable to people so they can use it for better living through technology. Whether I'm running a simple Python script or training a machine learning model, the goal is the same: demystify the machine.

I have spent the past few weeks experimenting with connecting Raspberry Pi 5 to the AI HAT+ and the AI Camera, investigating object detection models that can identify everything from household items to birds visiting my garden. I've got large language models working (slow but surprisingly easy) and investigated programs that can identify and remember people. Thankfully safely from my desk where I can control the information.

Sony's use of Raspberry Pi AI Camera on its production line proves this isn't just nostalgic tinkering (**rpimag.co/aitrios**). There's serious industrial potential here. But Raspberry Pi remains a tool that ensures you understand technology rather than deploying something made by other people. (At least as best you can with the black box that is an AI model.)

Raspberry Pi reminds me that progress doesn't require abandoning your values. You can embrace the new while standing on the shoulders of giants (and honouring them in the process). I've got more AI models and code to play with and hope to have something new every month.

Lucy Hattersley – Author
Lucy is editor of *Raspberry Pi Official Magazine* and is wondering what Dizzy would look like upscaled by AI.

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