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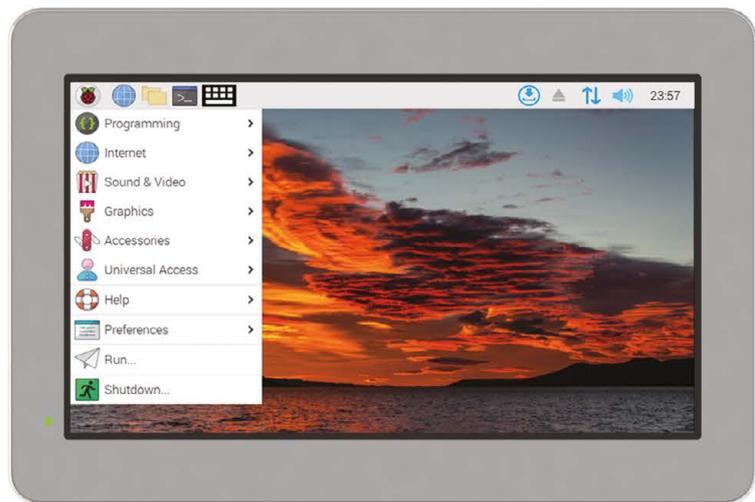
The ComfilePi is a touch panel PC designed with high-tolerant components and no moving parts for industrial applications. It features a water-resistant front panel, touchscreen, color LCD (available in various sizes), RS-232, RS-485, Ethernet, USB, I2C, SPI, digital IO, battery-backed RTC (real-time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

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COMFILE TECHNOLOGY

Welcome to Raspberry Pi Official Magazine

Editor
Lucy Hattersley

Lucy is trying to make RPOM a thing! If we say it enough; it will happen. RPOM!

rpimag.co

This is an incredibly important edition of the magazine formerly known as *The MagPi.* We've now got full official status and are now known as *Raspberry Pi Official Magazine.*

I love change, but it's important to remember where you are from. So we're keeping everything else familiar to those of you who see this as the 151st edition of *The MagPi.* If you appreciated our old magazine, you'll love *Raspberry Pi Official Magazine.* It looks different but is packed with the same amazing Raspberry Pi projects, tutorials, and features.

We've got a huge troubleshooting guide updated for Raspberry Pi OS with Debian Bookworm. Armed with this guide, you'll be a better Raspberry Pi maker and builder. We tapped into the Raspberry Pi engineering team for advice and feedback so you can be sure everything works as intended.

Rob has written a complete guide to building your own maker space. So if you want a cave for all your tools, this is the way to do it. And Andrew has been chatting to the maker of an amazing synth with hexagonal keys.

I hope you enjoy the new-look magazine and find it both refreshing and familiar at the same time. We really can't do this without our readers and subscribers. Thank you for spending time with us.

Lucy Hattersley – Editor

Mission critical

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Win 1 of 5 PiFi Kits

Raspberry Pi finds a new home

Versatile enclosure for Raspberry Pi B+

The new UCS Universal Case System is now available with ready made cut-outs for the 7" touch display and standard connections of the Raspberry Pi B+ single board computers. The 237 x 195 x 47mm housings are available in black or grey and are suitable for wall or desktop mounting

For additional information call 01952 681700 or visit

https://phoe.co/ucs-series

RP2350 Hacking Challenge

How Raspberry Pi is improving security through transparency and an open approach to security engineering. By **Lucy Hattersley**

▲ The RP2350 based badge handed out at DEF CON, containing a secret value

Raspberry Pi has announced the winners of its recent RP2350 Hacking Challenge.

To coincide with the DEF CON hacking conference in August 2024, where RP2350 featured on the conference badge, a prize of $10,000 was offered to the first person to demonstrate the ability to bypass the chip's security architecture and read a secret value from the on-chip one-time-programmable (OTP) memory. The prize was later doubled to $20,000, and the deadline extended from September to December 2024.

On 14 Jan 2025, Eben Upton, Raspberry Pi co-founder and CEO, stated: "We're pleased (ish) to announce that we received not one but four valid submissions."

The winners

The winners are: 'Hazardous threes' created by Aedan Cullen, 'USB bootloader single-instruction fault with supply-voltage injection' by Marius Muench, 'Signature check single-instruction fault with laser injection' by Kévin Courdesses, and 'Extracting antifuse secrets from RP2350 by FIB/PVC' by IOActive. More details on each hack can be found in this article.

"We'd like to thank everyone who participated in the challenge," says Eben. "While the rules specify a single $20,000 prize for the 'best' attack, we were so impressed by the quality of the submissions that we have chosen to pay the prize in full for each of them.

"As expected, we've learned a lot," Eben continues. "In particular, we've revised downward our estimate of the effectiveness of our glitch detection scheme; the difficulty of reliably injecting multiple faults even in the presence of timing uncertainty; and the cost and

Security through transparency is here to stay

complexity of laser fault injection. We'll take these lessons into account as we work to harden future chips and anticipated future steppings of RP2350."

While this challenge is over, another one will soon start. Raspberry Pi is working on an implementation of AES which is hardened against side-channel attacks, and expects to offer a prize for the first person to demonstrate the ability to extract an AES key via differential power analysis or other non-invasive methods.

Says Eben: "All vendors have security vulnerabilities in their chips." He adds, "We are unusual because we talk about them, and aim to fix them, rather than brushing them under the carpet. Security through transparency is here to stay." ▣
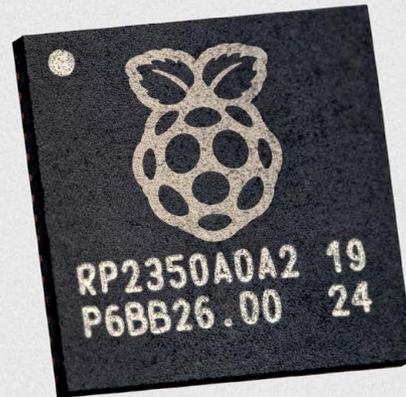
▲ Raspberry Pi RP2350

Hazardous threes – Aedan Cullen

RP2350 features "antifuse" OTP (One Time Programmable) memory. An antifuse is the opposite of a fuse, in that a permanent low-resistance connection is created when a voltage is applied between two points on the chip.

When RP2350 turns on it reads security-critical settings from OTP memory. To ensure that the OTP is correctly powered before reading security critical settings, it first checks that it can successfully read a fixed "guard word", with the value 0x333333.

If the power is unstable, the guard word check should fail. However, the OTP remembers the last successful read. If the attacker cuts power at the right time – just after a guard read has occurred – the chip reads 0x333333 instead of the real setting, which allows an attacker to disable security protections.

More information can be found on Aeden's GitHub page: **rpimag.co/hackingrp2350git**. He also explains the method in a video: **rpimag.co/hackingrp2350vid**.
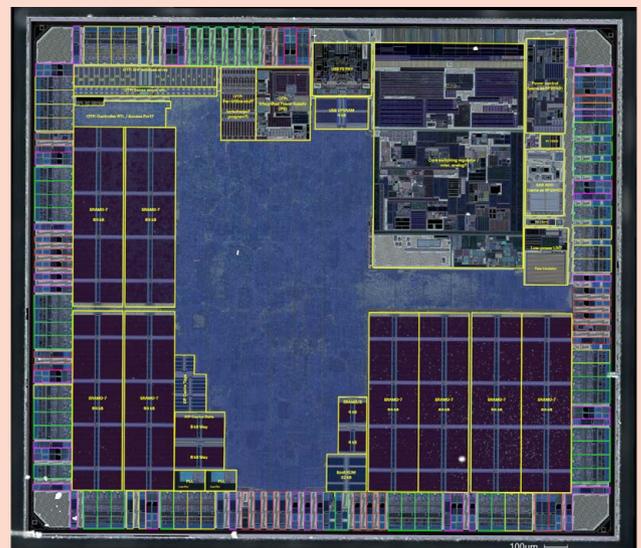
▲ Hazardous threes. Image courtesy of Aedan Cullen

USB bootloader single-instruction fault with supply-voltage injection – Marius Muench

A foundational security feature of RP2350 is secure boot. This restricts RP2350 to only run code signed with a specific private key.

Marius' attack tricks RP2350 into running malicious unsigned code by first loading the code into memory, before rebooting the system and glitching the power supply at a precisely chosen moment to skip an instruction. This tricks RP2350 into selecting a special reboot mode, which restarts at a user-specified memory location – in this case the location of the malicious code.

RP2350 is consequently tricked into executing the malicious code loaded into the system beforehand.

Marius says: "While this break may seem straightforward in retrospect, reality is quite different. Identifying and exploiting these types of issues is far from trivial. Overall, this hacking challenge was a multi-month project for me, with many dead-ends explored along the way and countless iterations of attack code and setups to confirm or refute potential findings. Nonetheless, I had plenty of fun digging deep into the intricacies of the new RP2350 microcontroller, and I would like to thank Raspberry Pi and Hextree for hosting the challenge!"

Signature check single-instruction fault with laser injection – Kévin Courdesses

RP2350 contains glitch detectors which aim to prevent attackers from skipping instructions by glitching the power supply. Kévin's attack, however, uses lasers to skip an instruction without disturbing the glitch detectors, bypassing parts of the boot security system.

Kévin's laser applies a brief pulse to the back of the die, which has been exposed away by grinding parts of the package. Injecting a single precisely timed fault – just after the firmware to be validated loads into RAM – causes the hash function to be computed using a different image from that which is to be executed.

Detailed information can be found in Kévin's paper here: **rpimag.co/rp2350laserinj**. "No mitigation is available for this attack, which has been assigned erratum number E24," says Eben. "It is likely to be addressed in a future stepping of RP2350."
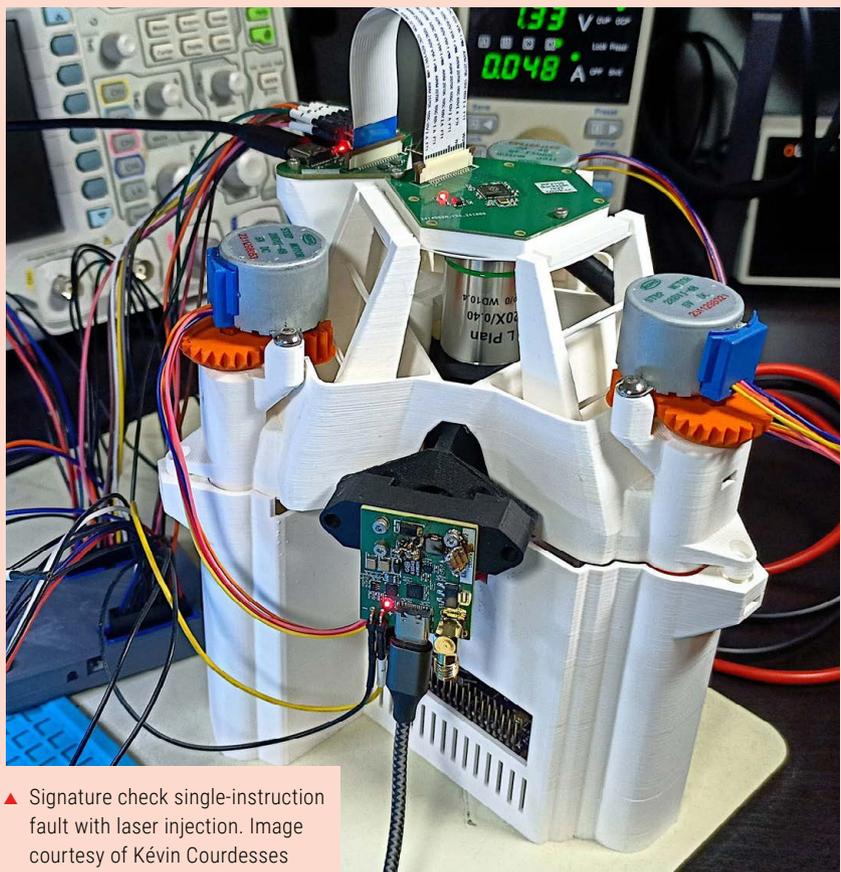
▲ Signature check single-instruction fault with laser injection. Image courtesy of Kévin Courdesses

Extracting antifuse secrets from RP2350 by FIB/PVC – IOActive
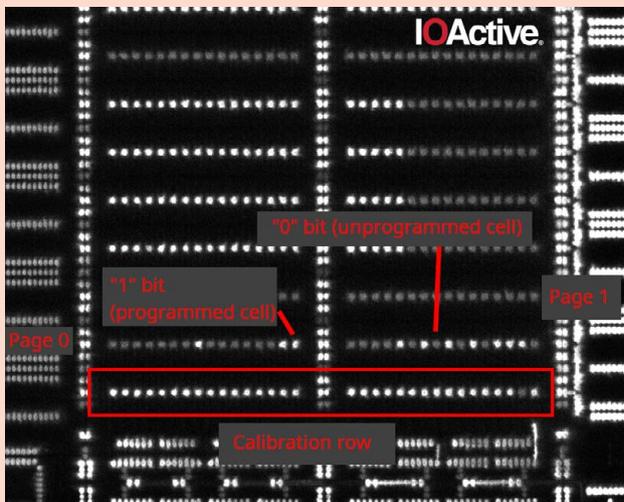
▲ Extracting antifuse secrets from RP2350 by FIB/PVC.
Image courtesy of IOActive

This attack attempts to extract information directly from the OTP memory using an analysis technique called Passive Voltage Contrast (PVC) with a Focused Ion Beam (FIB).

Unlike other attacks, which glitch the system into revealing its secrets, this attack physically examines the system to recover hidden data.

The attack has limits. It currently recovers the bitwise OR of two physically adjacent memory cells. "With some per-bit effort it may be possible for an attacker to separate the even/odd cell values," speculates Eben.

This attack is believed to have broad applicability to all antifuse-based memories. Dr Andrew Zonenberg, who led the technical team on this project along with Antony Moor, Daniel Slone, Lain Agan, and Mario Cop, commented: "Our team found a unique attack vector for reading data out of antifuse memory, which we intend to further develop. Those who rely on antifuse memory for confidentiality should immediately reassess their security posture."

Glitch detector evaluation, and OTP read double-instruction fault with EM injection – Hextree
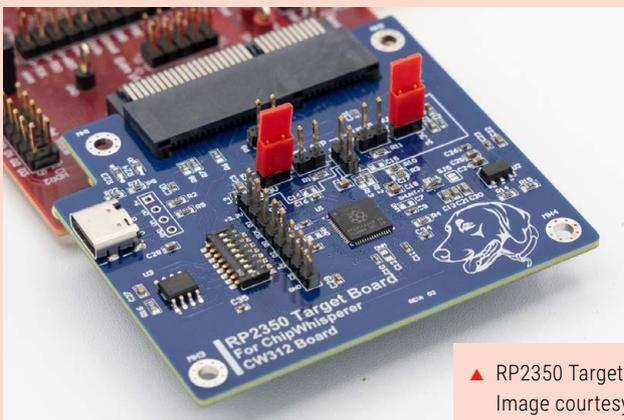
▲ RP2350 Target Board for ChipWhisperer.
Image courtesy of NewAE and Fritz

Raspberry Pi also commissioned the Hextree team (**hextree.io**) to evaluate RP2350's secure boot process. They found that the glitch detectors can detect many voltage glitch attacks, but the rate of undetected glitches is high enough to make attacks feasible (albeit with some effort).

Raspberry Pi would also like to express gratitude to Colin O'Flynn and his team at NewAE (**newae.com**) for collaborating with both us and Thomas Roth / Hextree on this advanced silicon security research, as well as enabling us with their fantastic ChipWhisperer kit (**rpimag.co/chipwhisperer**).

Steam Link updated

Updated version of Steam Link for Raspberry Pi is now available. By **Lucy Hattersley**
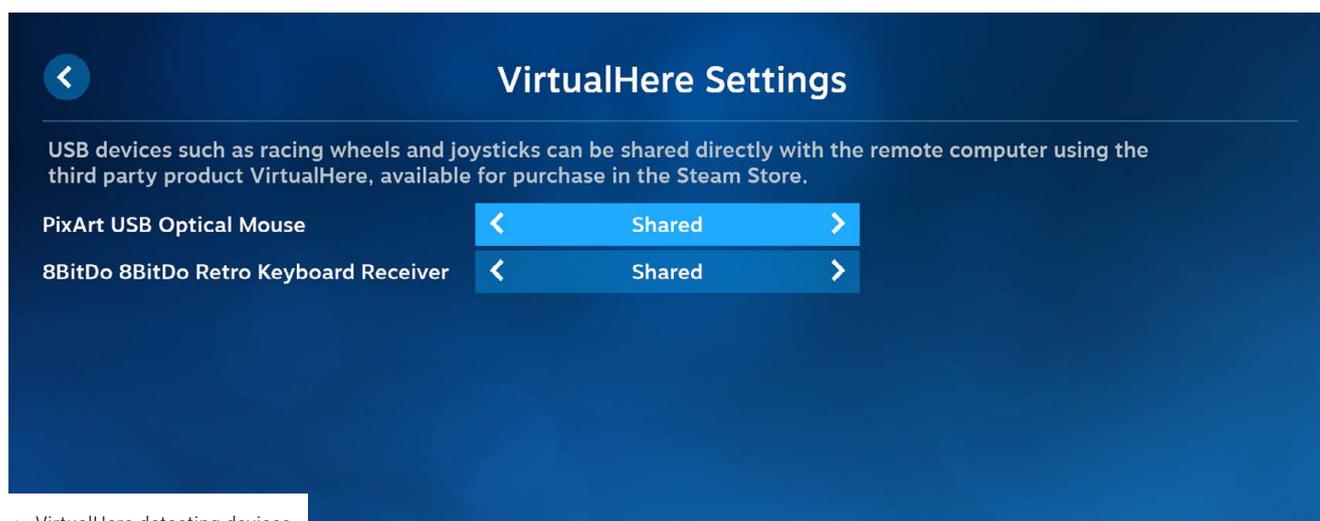
▲ VirtualHere detecting devices in Raspberry Pi OS

> *Stream video games from any computer on your local network*

Steam Link, the popular video gaming streaming software, has had a series of updates for Raspberry Pi. The latest 1.3.5 BETA version was released on 8 February and introduces support for VirtualHere in Raspberry Pi OS Bookworm.

With Steam Link software installed on a Raspberry Pi, you can stream video games from any computer on your local network or over the internet running Steam software. In effect, this extends your PC video games to stream at any location in the house. It's especially useful for streaming video games from a PC (located in the house) to a console-style Raspberry Pi connected to your home television.

We tested it out with a Steam Deck handheld device and a Raspberry Pi 5 running Steam Link software.

VirtualHere is a Steam Link device upgrade that enables you to use the Xbox One Wireless Controller alongside "steering wheels, microphone, headphones, flight sticks, PS3 controllers, Bluetooth adapters, and many other USB devices directly on your Steam Link device."

Settings

Computer   Controller   VirtualHere   Streaming
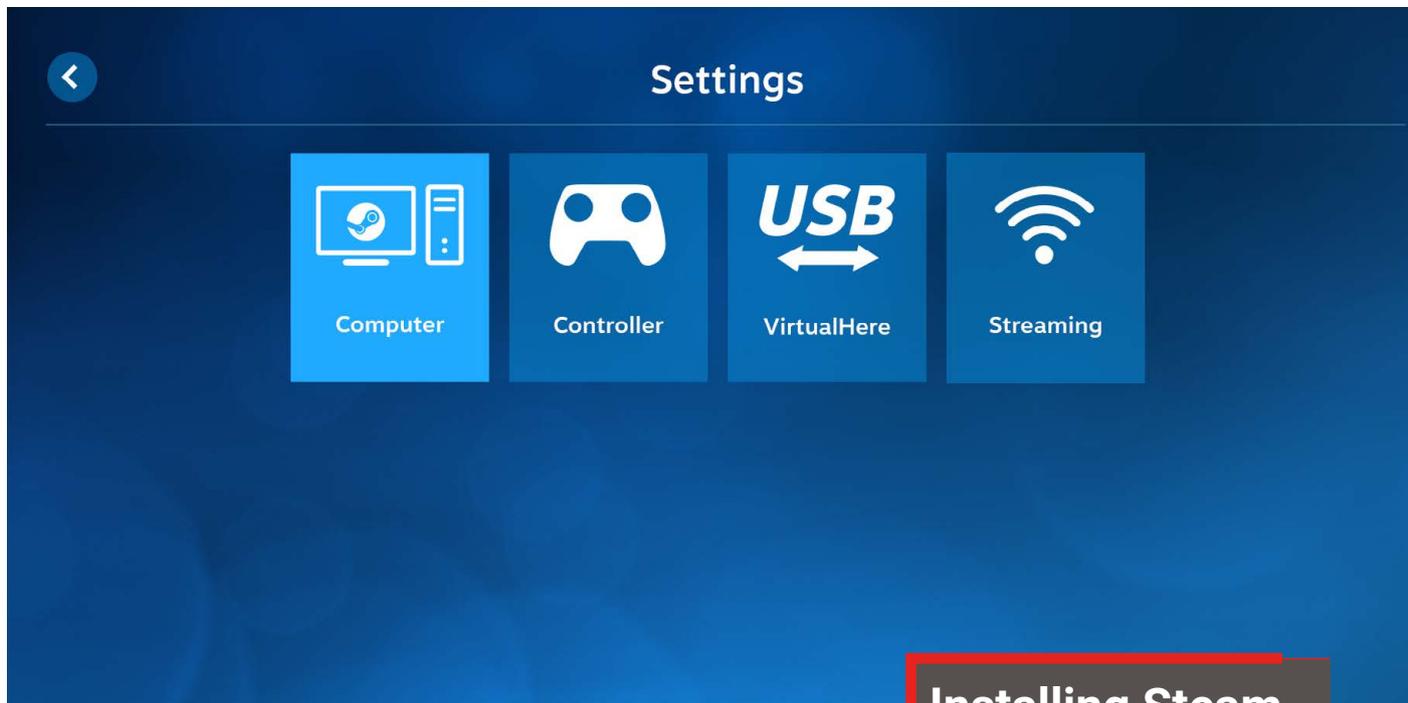
It improves the compatibility of gaming controllers because it transmits the actual USB signal between Steam Link and the remote computer. The remote computer (in this case our Raspberry Pi) thinks the gaming controller is local to it.

In our test, it detected an 8BitDo Retro Keyboard and the Raspberry Pi Official Mouse.

A difficult challenge

Writing on the Raspberry Pi blog in December, Raspberry Pi CTO (Software) Gordon Hollingworth explained how Steam Link was integrated into his household. "With Steam Link, our kids can – OK, we can – play PC games on any computer in the house, without having to lug the PC around. And now, you can run Steam Link on your Raspberry Pi 5!

"Steam Link is tackling some quite difficult challenges to enable us to play graphics-heavy games remotely," explains

▲ VirtualHere activated in Steam Deck on Raspberry Pi

Installing Steam Link

To install Steam Link yourself, grab yourself an up-to-date Raspberry Pi OS image and type:

```
sudo apt update
sudo apt upgrade
sudo apt install steamlink
```

Double-click the Steam Link icon on the desktop to start the software. Click the '?' icon and choose 'Switch to beta build' to view the latest features. Switch back to the 'public build' to use the latest safe version.

▶ Playing Pacific Drive on Raspberry Pi 5 via Steam Deck
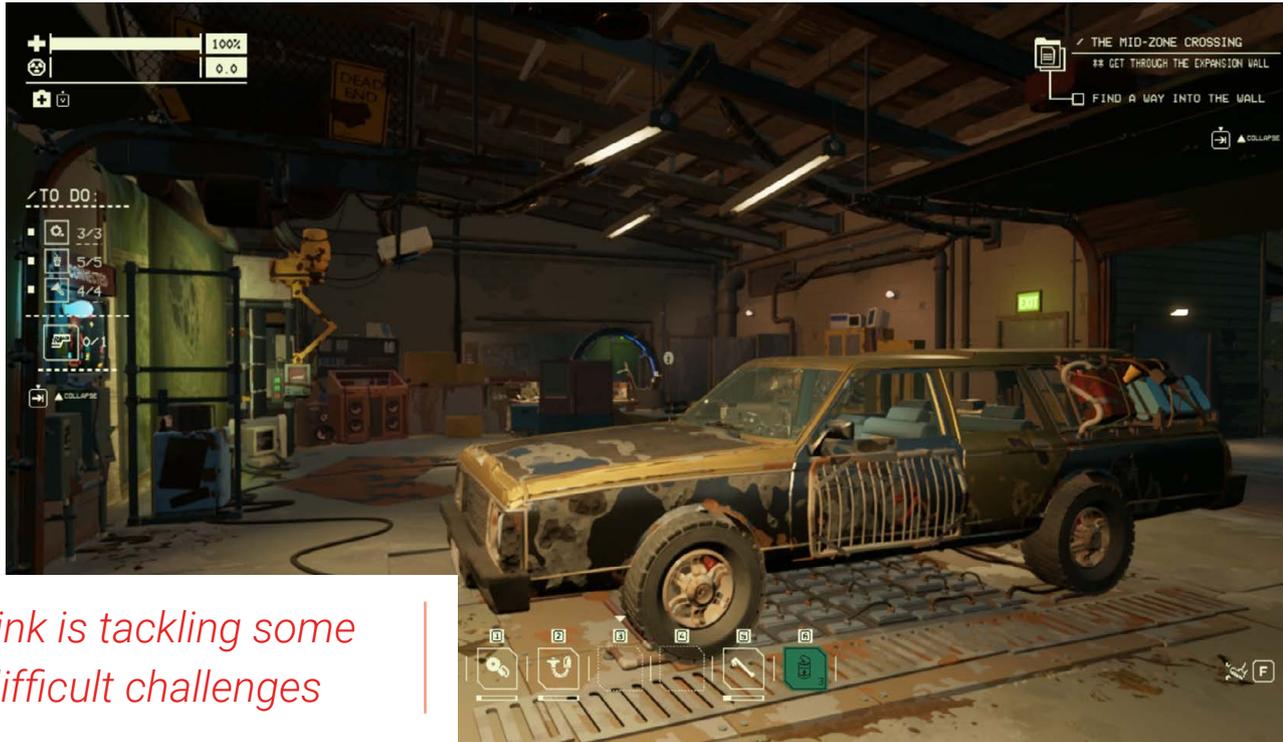
> ## *Steam Link is tackling some quite difficult challenges*

Gordon. "Firstly, screen sharing is not normally optimised for sending high-quality images, since you have to work quite hard to keep both the bitrate and the latency down; you also don't normally transmit audio as well as video, and you need to do a bit of magic to talk to game controllers. So the smart folks at Valve have successfully solved quite a few hard problems to bring this into being."

Valve senior software engineer Sam Lantinga has been working on getting Steam Link to run on Raspberry Pi 5. "The previous method used to run Steam Link on Raspberry Pi OS no longer worked very well after we moved away from the closed-source Broadcom multimedia libraries," says Gordon. "With Wayland, a different approach was needed. Sam has been working with the Raspberry Pi software team to use our hardware in the most efficient way possible."

Sam has been able to get Steam Link working at some amazing rates on Raspberry Pi 5, including 4Kp60 and even 1080p240 (240 frames-per-second; you'll need a suitable monitor for that.) ◘

▼ Viewing the Steam Deck interface remotely on a Raspberry Pi
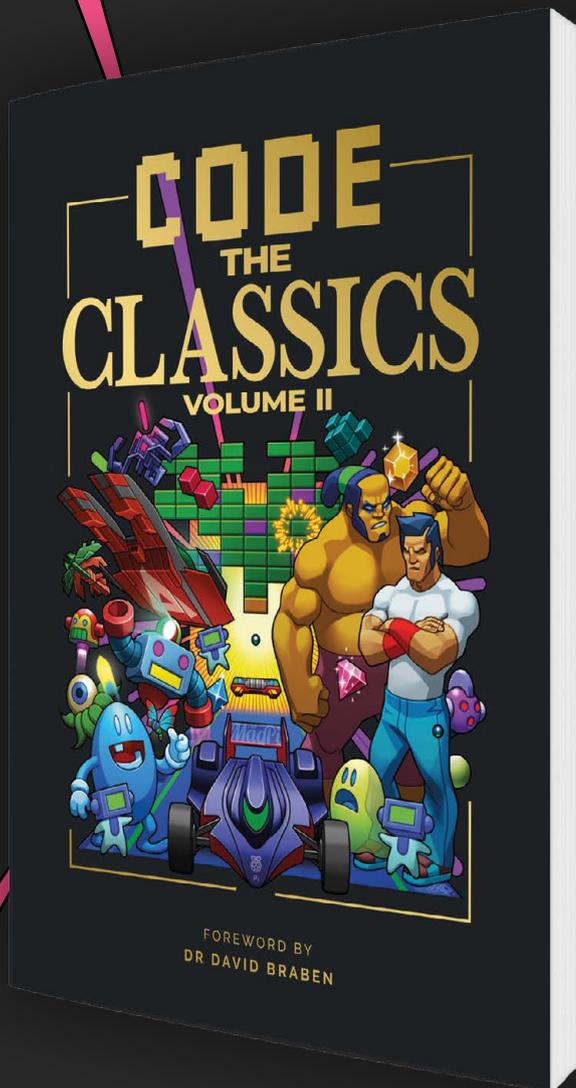
Clever concrete compute

Slump sensor puts Raspberry Pi to innovative use.
By **Chris Boross**

Lately, well-crafted connected devices that feature wireless sensors and reliable, low-cost compute hardware have been revolutionising many 'unconnected' industries, services, and applications. One such industry and service is the delivery of pre-mixed concrete.

Mounting MixPilot

Canadian Raspberry Pi customer Giatec (**giatecscientific.com**) recently launched a unique and very clever product called MixPilot (**rpimag.co/mixpilot**). MixPilot gets mounted to concrete delivery trucks and, through the use of sensors and algorithms, can monitor various aspects of concrete being delivered, including a property known as its 'slump'. This is measured
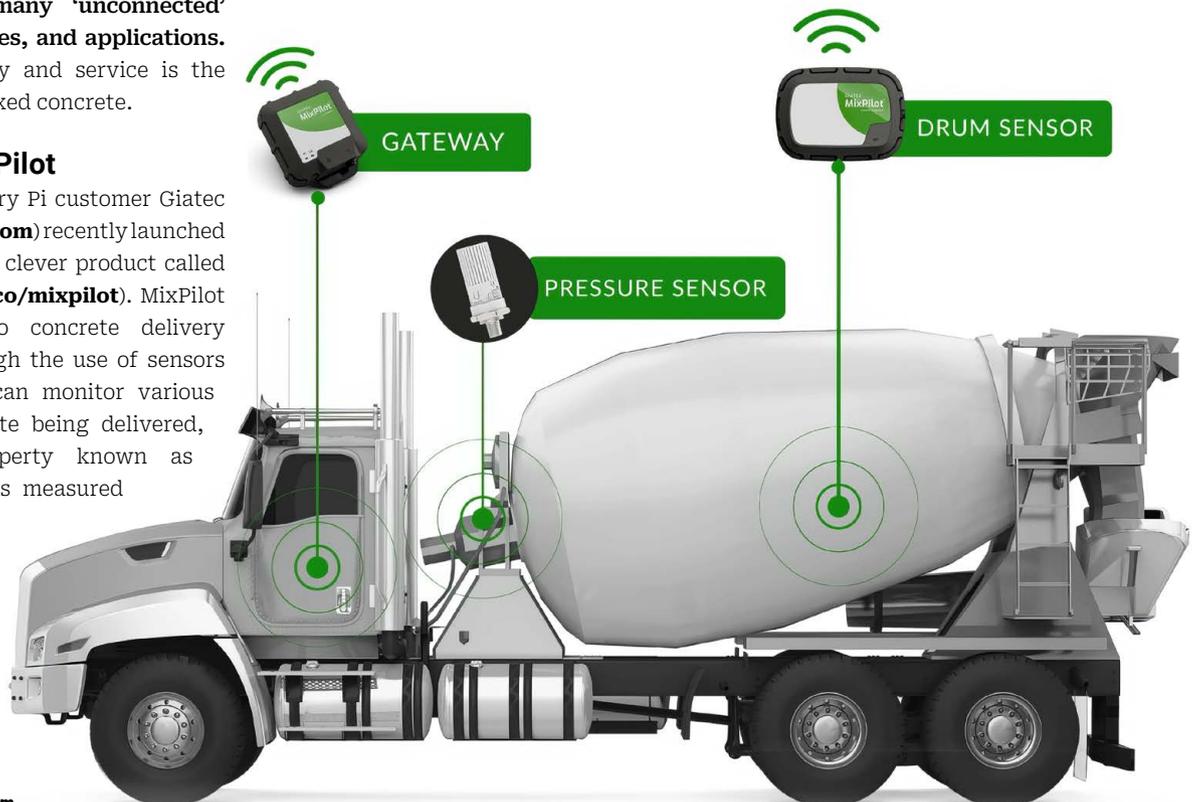
▶ Two sensors send data to a gateway. Image via *giatecscientific.com*

GATEWAY

DRUM SENSOR

PRESSURE SENSOR

MixPilot gets mounted to concrete delivery trucks

to ensure the quality of the concrete and give the fleet operators more visibility into the trucks and their payload, as well as bringing other new operational benefits. Part of the product's charm is that it's easy to install on the truck: it's 'set and forget', and doesn't require much maintenance.

Slump is a measurement of how well concrete flows when it's poured. It is important for the slump to be in the right range when the concrete is poured into a form or mould, as otherwise it might not flow correctly to fill the volume, leaving voids – bad news if you want a structurally sound construction.

To deliver MixPilot, Giatec built a highly reliable wireless gateway based on Compute Module 4 and paired it with two custom sensors that wirelessly send their sensor readings back to the gateway, where the data is processed and the concrete payload's status is displayed to the truck operator. The gateway is then connected to Giatec's cloud via cellular, allowing for further data processing as well as providing the end customer with a cloud console to enable useful features, such as alerts and fleet-wide stats. ▣

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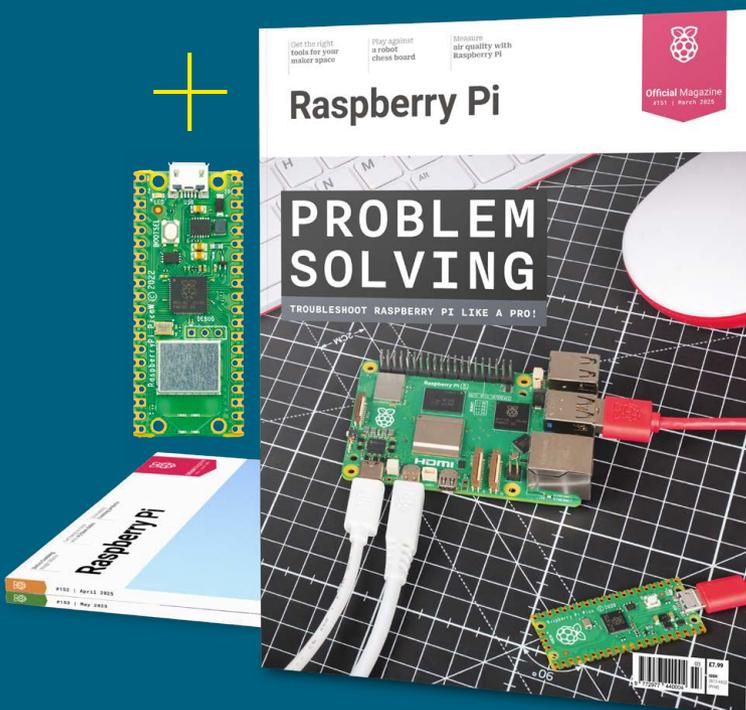
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HexBoard

A unique way to make music.
By **Andrew Gregory**

Maker
Jared DeCook

Stay-at-home dad of two wonderful (and very small) kids. I primarily work on my projects during nap time, but I love finding parts we can work on together.

shapingthesilence.com

Musical instruments are dependent on physics and maths for their sounds. A guitar string changes pitch when its physical properties change, be that string thickness, tension or length. A note from a saxophone, or any wind instrument, changes according to the length of the instrument that the air is vibrating through. Any physical instrument needs to have some physical property that the player must interact with in order to play music, and this naturally limits who can play, and what can be played.

At least, that's how it always was. With MIDI and computers, this no longer has to be true. The instrument that you play is nothing more than an input device, like a keyboard and a mouse, and as such, it can be any shape or size that the maker wants. In this case, the maker Jared DeCook, maker of the HexBoard, has chosen to make a grid of hexagonal keys and RGB LEDs, all controlled by a Raspberry Pi RP2040 chip.

Custom controller

"The HexBoard is primarily a MIDI instrument, which means that it sends note information to software or hardware sound generators that play the sounds based on the notes you play," Jared tells us. "It has a USB-C connector for connecting to MIDI software on a computer and a TRS MIDI jack for connecting to hardware MIDI devices. It has a very basic built-in sound generator that can play over headphones or built-in speaker, which is nice for when you want a quick and simple setup. All the unused pins from the RP2040 are exposed as headers on the board for ease of hackability for those interested in taking the hardware farther."
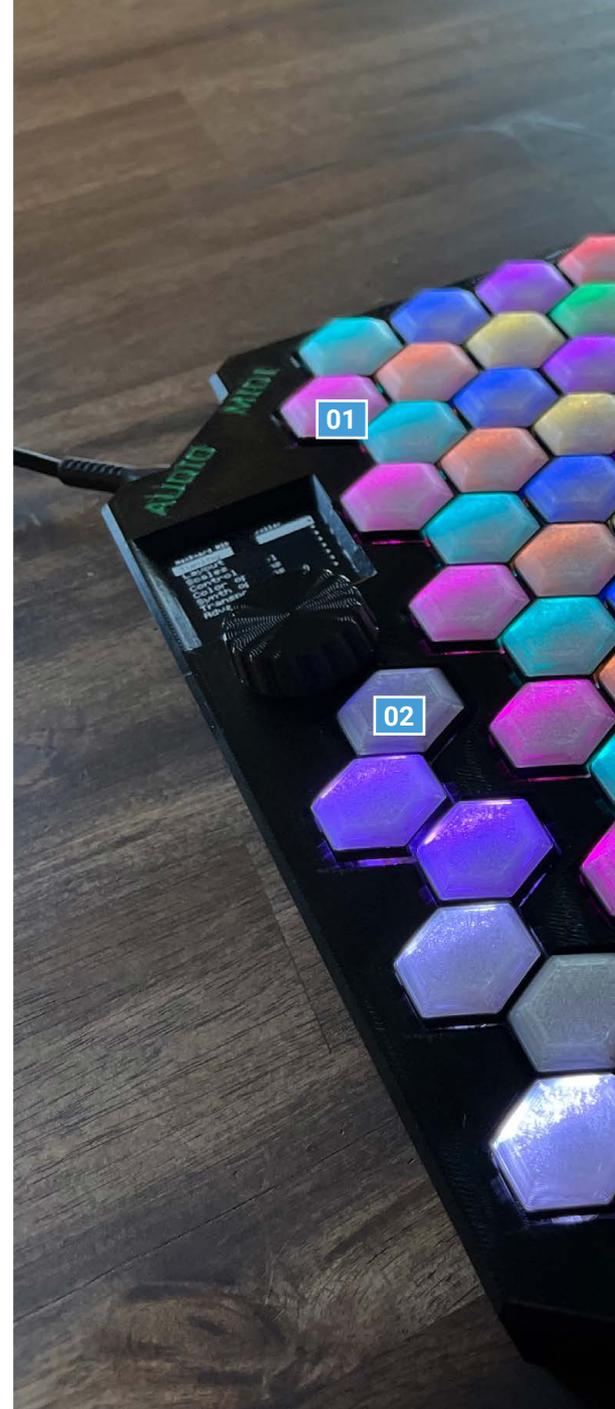
On a piano, each key has two notes on either side of it; on the HexBoard, each key is touching six further keys, so you can physically reach more notes with one hand – which is useful if you don't
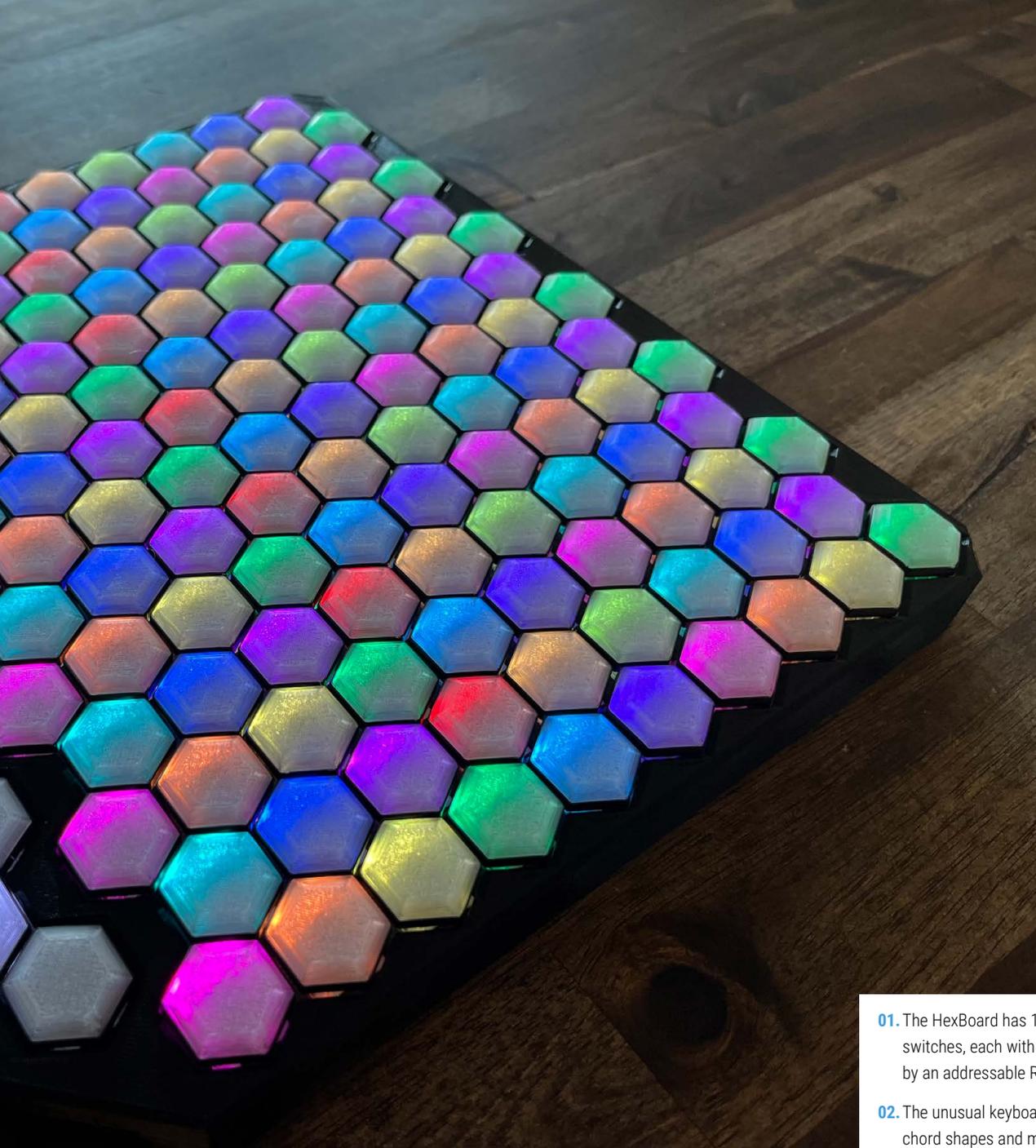
01. The HexBoard has 140 individual mechanical switches, each with a 3D-printed keycap lit by an addressable RGB LED

02. The unusual keyboard gives rise to unique chord shapes and melodic ideas

have massive mitts like Franz Liszt or Jimi Hendrix.

"The lit-up hexagonal keys allow for many different note layouts while indicating which note is which using colours," says Jared. "The different layouts included make it easy to play chords using simple finger shapes that don't change depending on the key, unlike an instrument like the piano. I designed the keycaps in TinkerCAD and designed the frame in Blender. I print everything on the Bambu Lab P1S, which just barely fits the frame into the build area."

Why use an RP2040?

"The RP2040 chip is the brains of the whole project," he adds. "It reads the buttons, sets the lights, updates the screen, sends MIDI data, and generates simple sound waves. No proprietary software is needed to run this as it's all handled by the RP2040.

"I appreciate how I can use PIO to handle updating the LEDs without blocking the CPU. I selected this chip for this project as it had all the I/O my project required with a good amount of headroom for future developments.

▼ Jared launched the HexBoard in May 2023, and has since overhauled the design to make it easier to assemble and repair, and to add new features

> *I come up with different ideas on the HexBoard than I do on a standard musical keyboard*

That, plus it was very available during the big chip shortage that occurred in the early stages of this project."

While big companies may relentlessly focus group products to make sure they find an audience, Jared originally made the HexBoard for a pretty small audience: himself. We reckon argue this might have enabled him to focus on making the HexBoard awesome.

"Originally, I made it for me and my brother," he recalls. "I wanted a fun, hackable instrument that looked cool and was relatively easy to learn. I'm quite happy with where I am on that, so I'd say the maker/hacker/musician is my primary target.

"As the project has advanced, it's become useful to a variety of people. A beginner musician can use it to start learning basic chords and melodies. Any given melody or chord has the same shape/movement no matter what key you are in, so in many ways it has a simpler learning curve.

"A music producer can use the various layouts to spark inspiration as each different layout gives a unique way to consider the relationships between notes. I know for me, I come up with different ideas on the HexBoard than I do on a standard musical keyboard.

"With the latest update, it's now a useful tool for those experimenting in microtonal music. The compact size and wide range make it very useful for musicians who want access to a large number of keys while still being able to easily carry it around in a backpack. Beyond this, the colourful lights and animations make it plain fun for anyone to play around with." ▫

Quick FACTS

- Jared built a similar device in 2013, inspired by the Axis 49 instrument…

- …when this started to fail in 2021, he began work on the HexBoard

- It originally used a Teensy LC board as the source of the processing power…

- …but this was replaced with an RP2040-based module designed by Jared

- HexBoard is still under development, with new features being added all the time
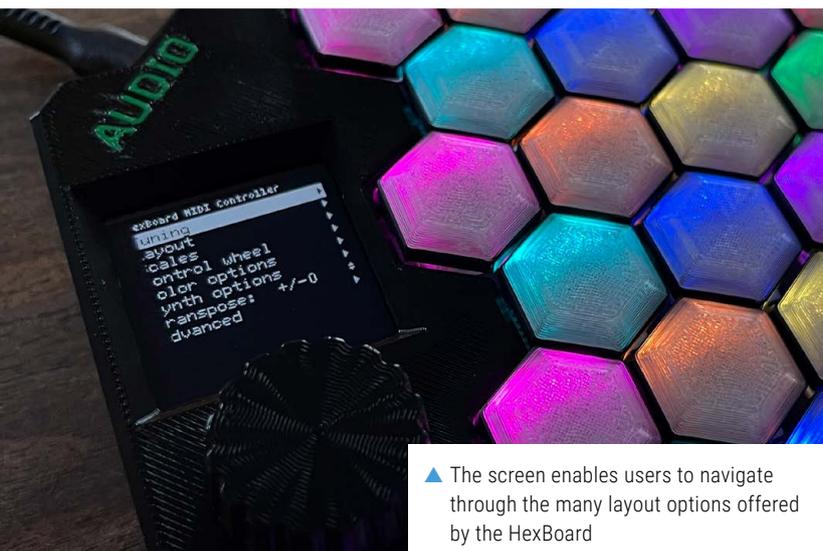
▲ The screen enables users to navigate through the many layout options offered by the HexBoard

How to build a HexBoard

1. Design a custom PCB with all the ports you need, breakouts to the RP2040 module, and room for 140 mechanical switches.

2. Solder the switches in place, then fire up the 3D printer and get to work creating a grid of tessellating hexagons.

3. Meanwhile, create your own custom RP2040-based board – add this to the PCB to handle all the ins, outs, and programming.

Mini Air Hockey games table

Offering a physical workout as well as a tactical one, this Raspberry Pi-controlled games table is a fun build. By **Rosie Hattersley**

Maker

Chris Downing

Chris is "a 42-year-old console modder from the backwoods of central New Hampshire" while CrashBash is a fellow modder and software engineer.

downingsbasement.com

For the past 15 years, Chris Downing has been part of a community that takes old TV console games and turns them into portable versions using original hardware wherever possible, posting details on his site, Downing's Basement (downingsbasement.com). Raspberry Pi had "always been in the scene", with many hobbyists using it to make portable emulation handhelds, "which in its own right was very cool", says Chris, even though it was against the group's "purist original hardware culture". Nonetheless, when it came time to create his own Doom-playing Mini Air Hockey Table and scoreboard, he instinctively turned to Raspberry Pi.

Multicoloured swap shop

A change of company gave Chris access to bigger and more robust CNC routing tools and large flatbed printers, while a Yankee swap at the office party netted him a kids' mini air hockey table that went down a storm with his 5- and 7-year-old children. This spurred Chris on to create his own, using the Raspberry Pi 2B he'd bought for a portable project that had never materialised.

Given his interest in retro gaming, Chris didn't want a plain vanilla air hockey table, instead envisaging one with a DOOM theme and plenty of additional gameplay options. He's "a designer and fabricator at heart" with plenty of technical knowledge from his retro games builds. As well as the mini air hockey table, Chris already had a suitable ATX power supply, a fan to cushion the pucks, and scoreboard screens. He used CAD software to design

▶ The Hyperion lights mimic the action when a games console is attached

01. Flashing lights in the legs and a celebratory sound are triggered when a point is scored on this Raspberry Pi Zero air hockey table

02. A video wall of LEDs underneath the 1/8-inch thick acrylic playing field are controlled using a Raspberry Pi build of Hyperion open-source software

and 3D-print parts for the screen housing and other structural elements. However, he needed an LED controller and an OS for the scoreboard interface and automatic score-detecting puck traps.

Play to your strengths

Chris says coding is his biggest Achilles' heel. "You play to your strengths the best you can, but when they fall short in an area, having someone who can bridge the gap is invaluable." In this case, Chris's modding buddy CrashBash was immensely more experienced with Raspberry Pi and able to offer professional software engineer input. "This project would not have gotten anywhere near my vision without his help," says Chris.

There was one slight problem: the two men live more than 800 miles away from each other in different US time zones and would have a single weekend to work on the air hockey/DOOM project

in person. As a result, recalls CrashBash, "the theme of the software-side was to, an extent, to make it able to be hacked together in such a way that it could be mostly completed in a weekend".

Raspberry Pi was used for the puck trap sensors and scoreboard inputs. CrashBash quickly realised that the 'Hyperbian' Raspberry Pi build of the Hyperion Ambilight LED controller

> *Raspberry Pi was used for the puck trap sensors and scoreboard inputs*

would be ideal and could be easily integrated using a Bash script that executes at boot. They would later add a Raspberry Pi Pico and use leftover GPIO pins and a serial port to have lights flash on the scoreboard struts too.

Hockey rink and DOOM hockey modes use Python and the Ambilight Hyperbian effects API to generate static along with dynamic images such as DOOM's fire mode. Hyperbian even includes the option to create a video wall in which the LEDs recreate the images from a composite video capture card. "You get a rather low and somewhat lagged live representation of what is being played down on the main deck," says Chris, "but it still looks freaking cool!" ◘

▼ Chris demonstrates player modes and other control options in his YouTube video: **rpimag.co/ airhockeyvid**
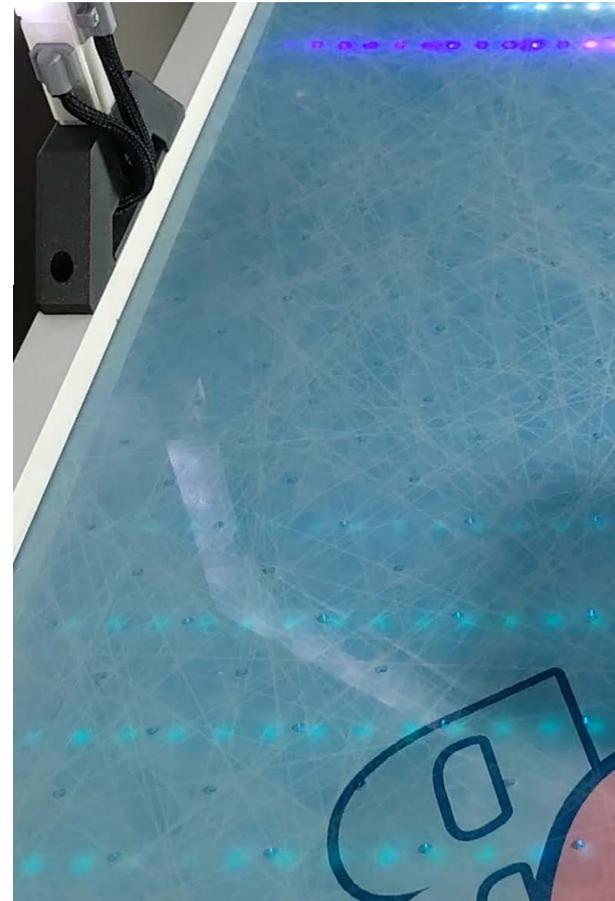
▲ Chris designed and 3D-printed the mode-specific scoreboard display

Ready player one
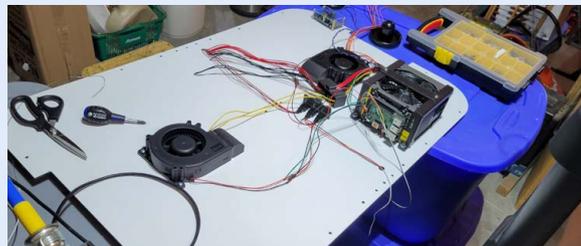
1. Adapt an existing gaming rig or build your own, adding Raspberry Pi, power supply, scoreboard display, fan to make the pucks 'float', and any lights and speakers you wish.

2. Downstall and install Hyperbian (**rpimag.co/hyperbian**), a ready-to-use OS including the Hyperion LED controller. A string of addressable LED lights attached to Raspberry Pi's GPIO pins can be made to respond to the air hockey or gaming action.

3. CrashBash wrote a Python script for Raspberry Pi Pico that recognises when a puck enters the trap, adjusting the score and triggering Hyperion to play celebratory sounds and lights.

Portable Air Quality Meter

Monitor the air for pollutants in real-time with this smart meter. By **David Crookes**

Maker

Arnov Sharma

Arnov describes himself as "just your average maker" but his talents for electronics, embedded systems and PCB designing has led to make some outstanding projects.

rpimag.co/
arnovsharma

When you venture outside and take a deep breath, you expect to be inhaling a heap of fresh air, particularly if you're in the countryside. But in truth, you're just as likely to be filling your lungs with pollutants from dirt, dust, pollen spores, gases, and even lead. There's just no getting away from the fact that a good percentage of air can be deemed unhealthy so being able to monitor it on-the-go with a flick of a switch is almost certain to be welcome news.

Arnov Sharma has created a handheld air quality meter which can use a Raspberry Pi Pico 2 connected to a gas sensor to display the current levels of a host of hazards. "My Air Quality Meter was created with the intention of measuring the degree of air pollution in my city," he explains. "Since we'd just had an air quality issue in New Delhi, where I live, I thought it would be a good idea to try to develop a project to measure the pollution level."

Delhi has suffered record pollution levels of late with the Air Quality Index (AQI) measuring as high as 1500 in November 2024. Toxic air of this magnitude, which led to smog descending over the area, is 15 times the level considered satisfactory for breathing by the World Health Organisation. It was so bad that schools were temporarily closed, construction was halted, and flights were disrupted.

▶ To test the build, Arnov used a breadboard and simply connected the sensor and a Raspberry Pi Pico 2
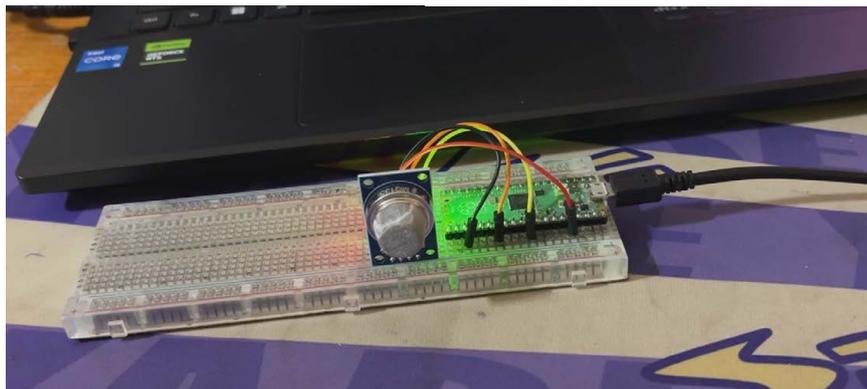
01. The screen displays the current air quality as a number while also explaining what that number means

02. The MQ135 gas sensor pokes out of the top of the device and allows the environment to be assessed

> *We'd just had an air quality issue in New Delhi, where I live*

What's more, it hasn't become infinitely better since, with an AQI reading in January 2025 showing the air has remained poor, albeit at a level of 262.

Turning detective

With his project, Arnov has sought to detect carbon dioxide, smoke, benzene, alcohol, nitrogen oxide and ammonia in the air. In doing so, his resulting device is able to display the levels of gases produced by the incomplete combustion of fossil fuels, wood and coal, as well as some of those pumped out by vehicles and emitted from hazardous waste sites. The detection of ammonia is indicative of the amount of livestock waste, decaying organic matter, and

fertiliser production. It helps to build a general understanding of the air quality in any given location, Arnov says.

So while Arnov's meter doesn't quite go as far as matching an AQI evaluation – which also includes assessing the PM2.5 and PM10 types of particulate matter, along with oxygen, nitrogen dioxide, sulphur dioxide, and carbon monoxide – it's still ultra-useful. What's more, he designed his meter so that it would also be inexpensive, meaning this open-source project should be within the reach of wide numbers of people. It influenced his choice of components.

"I used the MQ135 sensor and found it to be incredibly versatile for pollution control, environmental monitoring, and

checking air quality," Arnov says, of a module that can be picked up for less than £10/$10. "It was handy for various projects where I needed to monitor the air around me, particularly in spotting harmful gases. The best part is that it's super-easy to get hold of. It doesn't burn a hole in your pocket, making it an all-around great pick."

Displaying values

Arnov says planning the project was simple. "I already had an idea of the components I wanted to use, which was the PCBWay MQ135 sensor with Raspberry Pi Pico 2 – Pico is my preferred microcontroller for projects unrelated to wireless LAN. I first created a basic

breadboard setup consisting of the Pico and MQ135 sensor." This allowed him to make use of the sensor's outputs: one that generates an analogue voltage signal based on the gas concentration and a digital signal based on the gas concentration beyond a threshold.

Having written a short program to test the sensor's readings, ensuring it returned both analogue and digital values, Arnov then looked to refine the project further. To be effective, he needed the readings to be displayed on a screen – it shows the specific particle levels in real time – so he chose a tiny, 0.96-inch SSD1306 OLED display, again available for an extremely low price. "I then constructed a body to house all of the components inside a nice enclosure," he continues, explaining that he used the CAD facilities of Autodesk Fusion to complete the task. "This wasn't challenging: I have experience with industrial design, so creating a case was easy enough."

Quick FACTS

- Air quality is measured using the MQ135 sensor

- Readings are displayed on a small OLED screen

- The device detects numerous environmental gasses

- Beginners can easily replicate this open-source project

- The maker wants to reduce the size using an RP2040 chip

Gas panic

At this stage, Arnov made a big decision. He swapped out the Raspberry Pi Pico 2 microcontroller for a Firebeetle 2 ESP32-E, which may sound like sacrilege but he had his reasons. Chief among them was a lack of space in the enclosure that led to a power-related issue. "I was using a lithium cell as a power supply and, in order to charge the lithium cell, Pico would require the use of an additional board," he explains. "Firebeetle has an on-board TP4056 lithium cell charging circuit."

Yet, as he says, "Pico would be just as effective" and he has plans to return to Raspberry Pi. "I will use the RP2040 chip directly on a custom PCB that will also include a lithium cell charging circuit," he explains. As with the Firebeetle, this would resolve the problem of space.

Regardless, the device works well. Arnov used Arduino IDE to write the code and upload it to the board. The program takes the raw analogue value – of between zero and 4095 – and reduces it to a range between zero and 1023 which is needed for an air quality measurement. It then helpfully describes the value as either very poor, poor, moderate, good, or excellent so the user can immediately assess the current state of hazardous gases in the environment.

So how has it fared? In tests, Arnov found that city readings ranged between 550 and 620 regardless of whether he was close to a major road, industrial region, or green space. It's proof, if any were needed, that such gadgets could prove useful in helping people prepare for unsafe environments – and that urgent work is needed to improve matters in some parts of the world. ▣

◀ The casing was
designed to be
3D-printed and,
as well as being
functional, Arnov
added some
aesthetic flourishes

▲ To make it easier to carry and operate, Arnov
made it possible to attach a keychain or ID
card strap to the device

How It Works

1. Although the device has a large orange O and X displayed on the front, these are not operational and they're merely aesthetic. The only actual button is a power one which is placed on the left side of the meter.
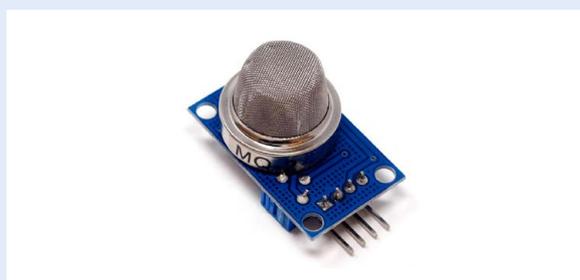
2. When the power button is pressed, the device calls upon the MQ135 highly sensitive sensor, which can be easily connected to Raspberry Pi. It measures gas concentration from 100 to 10,000 ppm and outputs an analogue value.

3. With the information sent to the microcontroller, Arnov's code is able to assess the sensor's data for the current location and use it to calculate the current air quality value which is then displayed on the screen.

Raspberry Pi Chess Board

Teenage strategist Tamerlan created a remote chess board in which a Raspberry Pi-controlled robot arm makes all the moves. By **Rosie Hattersley**

Maker

Tamerlan Goglichidze

High school student Tamerlan has a passion for engineering and innovation and initially taught himself using online videos.

rpimag.co/piboard

California high school student Tamerlan Goglichidze has been coding and building projects since he was 11, teaching himself essential skills using online videos and tutorials before progressing from virtual to physical creations once his knowledge base gave him the confidence. This early focus would be impressive enough in itself, but Tamerlan was also busy taking on all-comers as a chess player who travelled extensively to compete in International Chess Federation matches. His Raspberry Pi Chess Board combines the two interests.

Winning strategy

He chose Raspberry Pi 4 as "the brain of the system, bridging the digital chess world with physical movements on the board", noting its ability to handle advanced and complex systems as well as the versatile OS and accessible GPIO pins. Tamerlan felt it "was the best choice to handle both the chess engine calculations and stepper motor movements."

His Raspberry Pi Chess Board project built on his experience of creating a Raspberry Pi-based MARS rover with a robot arm and a small JARVIS (from *Iron Man*) mechatronic simulation with animatronic servo eyes that move around and also integrated voice recognition and artificial intelligence.

Quick FACTS

- Each chess piece contains a magnet, moved using a stepper motor
- To prevent the stepper motor returning home…
- …Tamerlan created an optimisation algorithm for his 8x8 grid…
- …with 2200 stepper motor steps per chess board side…
- …and a global position variable

Pure magnetism

Seeing DIY but expensive automated chess boards online motivated Tamerlan to create a functional, budget-friendly version with similar capabilities

01. Raspberry Pi 4 remotely controls this Pi Chess Board in which a human player competes against a customisable chess engine

02. The stepper motor glides along a rail, moving chess pieces smoothly along the X and Y axes and deftly mimicking the knight's move
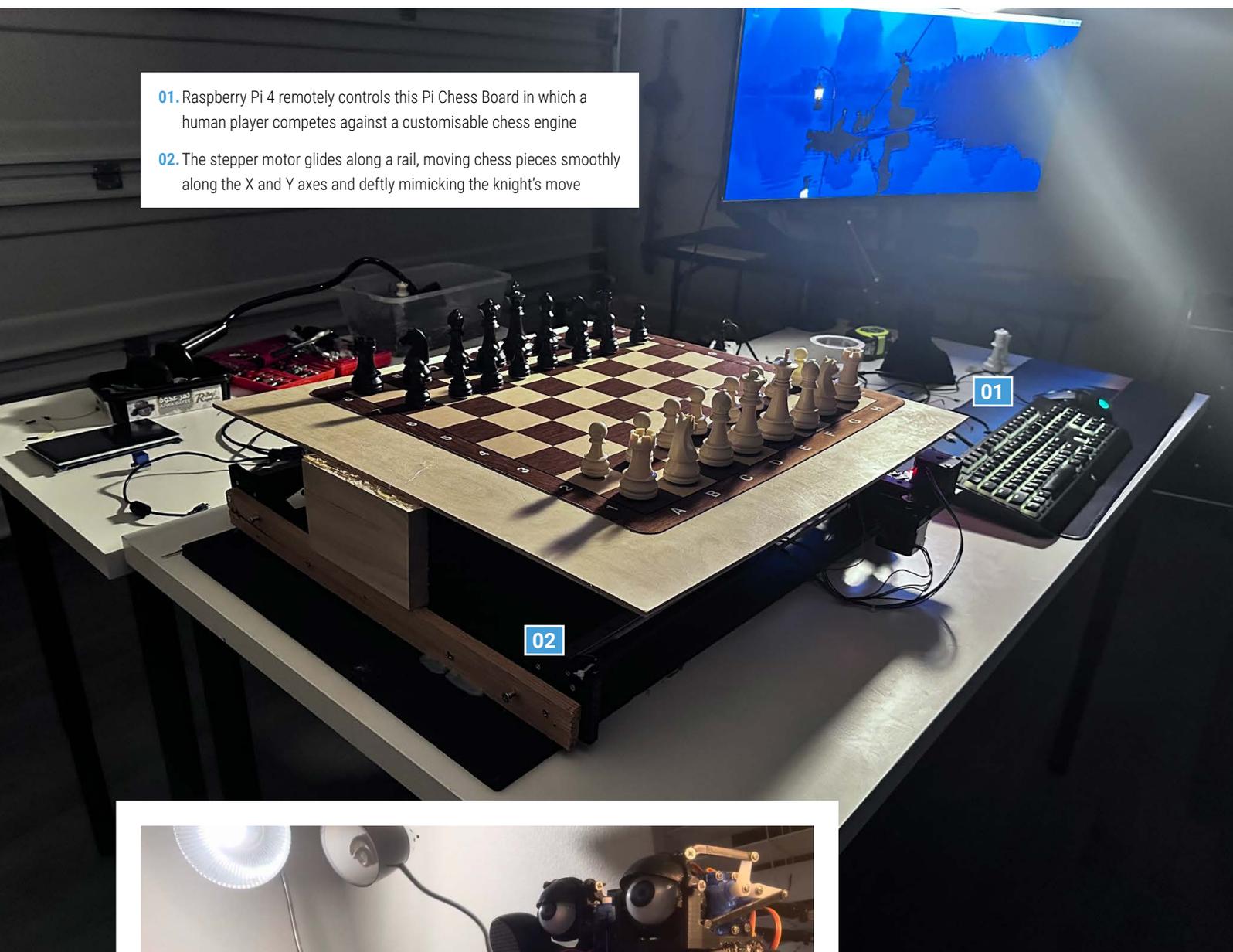
◀ Tamerlan learned all about Raspberry Pi in his earlier Iron Man JARVIS project

▲ Tamerlan pits his wits against his DIY Pi Chess Board
▶ Tamerlan's impressive website shows his Pi Chess Board in action
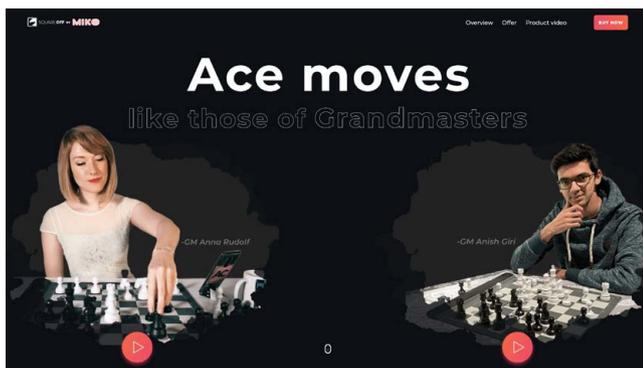
▶ He was partly inspired by commercial chess games such as Square Off

that would capitalise on his growing engineering skills. He designed most aspects using Fusion 360 and used a standard chess board, cutting wooden boards as a base in his parents' garage.

Challenges for the automated chess system included accurately weighing each chess piece so the XY stepper motor mechanism and magnets could seamlessly move them across the board. Tamerlan tracked down an algorithm to minimise the stepper motor's power consumption. He used a servo linear actuator with a magnet to move each chess piece, rather than an electromagnet, having calculated it would be more power-efficient. "To generate a strong enough magnetic field to lift or attract objects, high current is typically required, demanding a robust power supply and generating heat, which must be managed," he explains. "In contrast, a servo linear actuator needs power primarily during movement,

with significantly lower standby power consumption."

Using magnets moved by a stepper motor rather than a robot arm allowed Tamerlan to make the chess board as compact as possible. He wrote Python code to control each piece, translating the coordinates for each of the board's 64 squares into steps the stepper motor could execute. Raspberry Pi calculates the best moves according to player input and translates text such as 'b3b5' into moves. "Castling is straightforward and can be handled by writing two different functions to cover the four possible cases and executing them accordingly."

> *Seeing DIY but expensive automated chess boards online motivated Tamerlan*

He also needed a way to move pieces without pushing others out of the way, in particular the knight's dog-leg movements. His solution has the knight do a half-step between squares, follow its move, and then reverse the half-step.

Peer approval

Players can specify difficulty levels and whether to play as black or white pieces against the computer chess engine, and there is a web option for remote play against other chess fans. The project quickly garnered interest and plaudits online. Buoyed up by the success of his Raspberry Pi Chess Board which "gained remarkable attention" and, after being featured by a number of tech hobbyist sites, led to 40,000 visits to his own website (**rpimag.co/piboard**), Tamerlan has set his sights on a computing or engineering career. ▫

Calculated moves
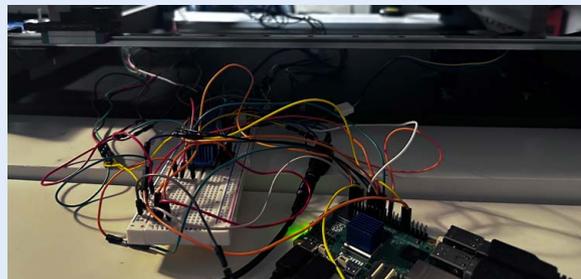
1. The project can be made with a Raspberry Pi 4 or 5 and uses a standard chess board and pieces with a sturdy wooden base to which the electronics will be attached.
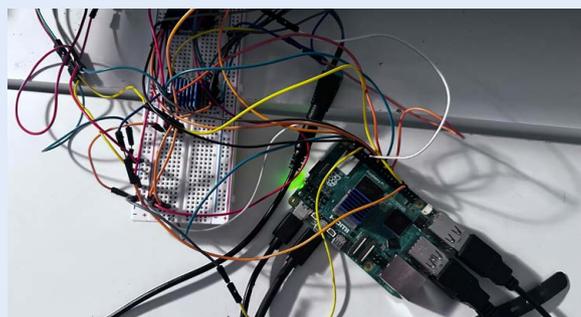
2. Tamerlan used two NEMA stepper motors, a servo, two linear rails, stepper motor belts, and plenty of jumper cables. He 3D-printed parts, designed in Fusion 360, for the mechanism.

3. Tamerlan's website provides details of how to overcome the issue of overheating electromagnets and inaccurate grabbing of chess pieces by mapping magnets fixed to individual pieces and moving them with the stepper motor.

Raspberry Pi Fruitbox Jukebox

Get into the groove and blast out those tunes with this retro jukebox. By **David Crookes**

Maker

Jeremy Childress

Jeremy has a degree in electrical engineering with a background in displays and communications, but he mostly works as a project manager now. He also loves teaching his children how things work.

rpimag.co/fruitbox

It's always good to come across a project that you can really make a song and dance about. And, in the case of this awesome, authentic-looking jukebox based around a Raspberry Pi 4 computer, that's exactly what we've been doing.

Maker Jeremy Childress has harked back to the 1950s for his first Raspberry Pi project, producing a machine that makes great use of a popular customisable MP3 player called Fruitbox. He's done so at a fraction of the price it would cost to buy and fix up a retro jukebox while having lots of fun in the process.

"My mom has always wanted a vintage jukebox and several years ago, my parents bought an old Seeburg DS160 that never worked right," Jeremy says. "I tried messing with it a few times, but I could only get it to play a random record and only one at a time. So, I wanted to give my mom a working jukebox and, seeing the expense of a fully functioning vintage one, I thought I could do better for far cheaper."

Golden grooves

To begin, Jeremy researched jukebox software to see what was available. "Most of it was for Windows and didn't

▲ The cabinet is completely modular. The marquee, monitor, button board and back panel bolt to the sides so it can be easily disassembled and moved if necessary
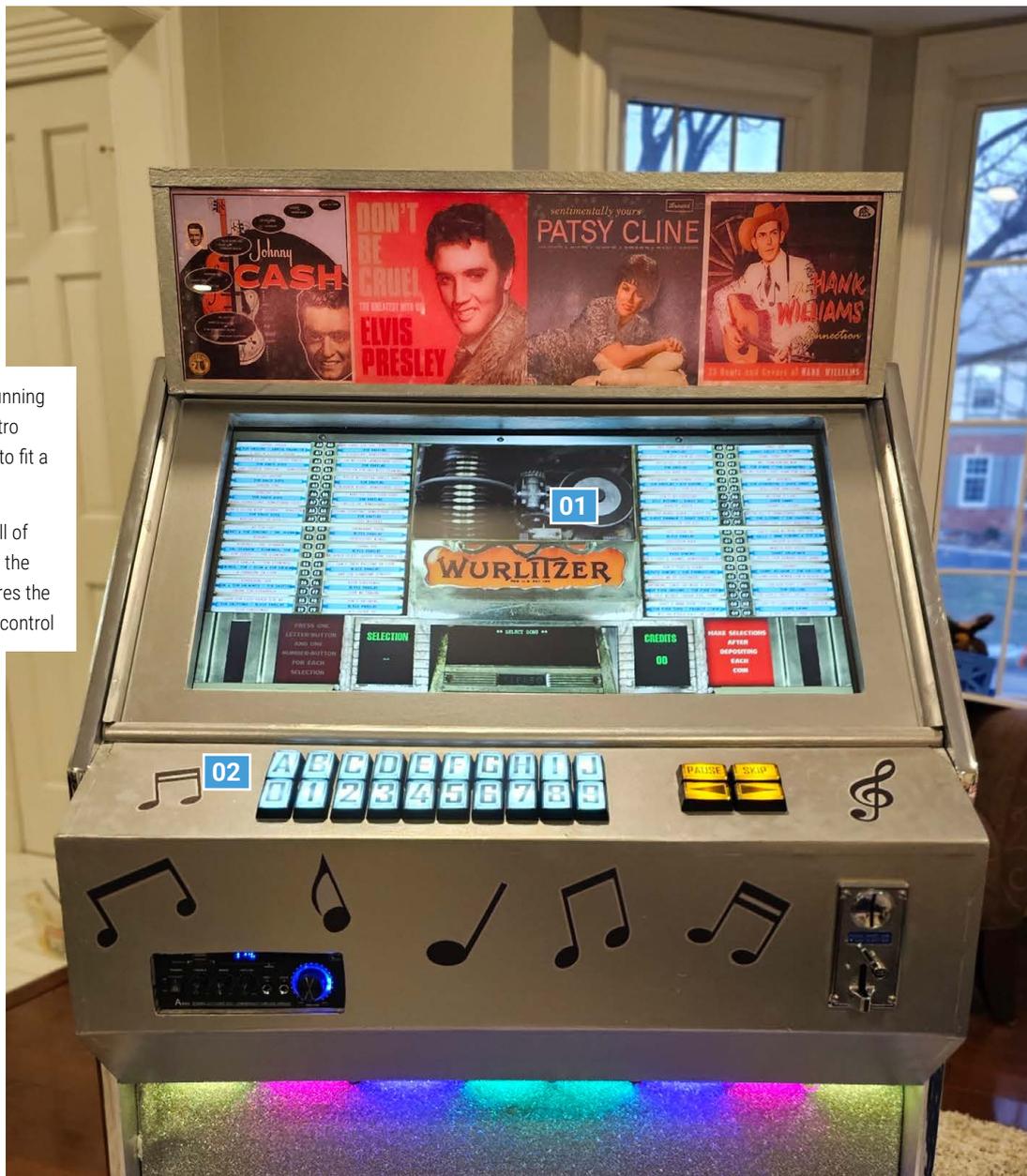
01. The 32-inch monitor, running at 1080p, displays a retro Fruitbox skin modified to fit a larger display

02. The cabinet contains all of the components within the front section and ensures the amp is visible for easy control

fit what I was looking for," he says. "I then happened to think about seeing if there were any Raspberry Pi jukebox projects I could work with and came across Fruitbox." Excited, he went to his local Micro Center to pick up a Raspberry Pi 4 Model B 1GB computer. "I didn't have plans to buy any other hardware until I was sure the software was going to work like I wanted it to," he says.

Luckily, it fit his needs. "It had the vintage look and feel that I was looking for," Jeremy explains. "Once I got it up and running, it was pretty easy to figure out, although I had some initial problems getting it up and running with the latest version of Raspberry Pi OS Bookworm. It was missing a library dependency that I had to install separately and I thought it was all running smoothly until I tried to get it to autostart at boot.

"Then I found the Fruitbox4dummies site which had a big notice saying there were issues between the latest version

of Fruitbox and Bookworm. It suggested using a specific version from March 15, 2024 so I reinstalled everything and it all went smoothly from there. Just using Fruitbox with the keyboard, it appeared to function like I had hoped and the Fruitbox4dummies site was an amazing resource, explaining how to configure Fruitbox and customise the skin."

Quick FACTS

- This project uses Fruitbox with a custom skin
- It only took a month to plan and build
- The jukebox will accept quarter coins
- Labelled buttons allow songs to be selected
- There's a swappable light-up marquee

Cabinet craft

With the software in place, Jeremy was able to crack on with the rest of the build. "It was all about making it look as authentic as possible, but after considering buying and gutting an old jukebox, I decided to build my own cabinet," he says.

He based the cabinet around a 32-inch monitor, making the sides, front and back panels out of wood. One of the panels was cut so it could fit an assortment of buttons that could be used to control the jukebox interface. These buttons were connected to Raspberry Pi using the joystick controller, "just because it would save me a lot of time making up wires since the kits already came with wires that connected to the buttons," Jeremy says.

Another panel was made so it could include a coin slot. "I was just going to cut a slot to put coins in and rig up a switch to detect a coin," he explains. He then discovered a programmable coin acceptor – one which only accepts quarters but acts like a button whenever a coin is inserted. Each quarter adds three credits. "The number of credits each coin provides is an option in Fruitbox," Jeremy says. "It's the only way to play songs with my machine besides a secret button on the back to add free credits."

There were some issues connecting the coin acceptor to Raspberry Pi. "I initially wired it to one of the joystick inputs where it caused issues but when I wired it to a GPIO input, it worked as expected," he recalls. The other major issue Jeremy faced was painting. "I tried using metallic paint to look like aluminium, but it was really streaky and it ran everywhere," he says. "I had to sand it down and start over, which set me back a week."

Amp power

To speed things up and make the build a family affair, he enlisted his eight-year-old son, Luke, to help build the cabinet, sand, and paint. His nine-year-old daughter, Charlotte, also helped to modify the skin he used in Fruitbox. "She picked out some of the design elements and I had her program them in the skin," Jeremy reveals.

As expected, aside from the screen, the Raspberry Pi is connected to an amplifier and speakers, enabling the jukebox to fill the air with sounds. "I debated whether or not to leave the amplifier exposed because I thought it took away from the vintage vibe
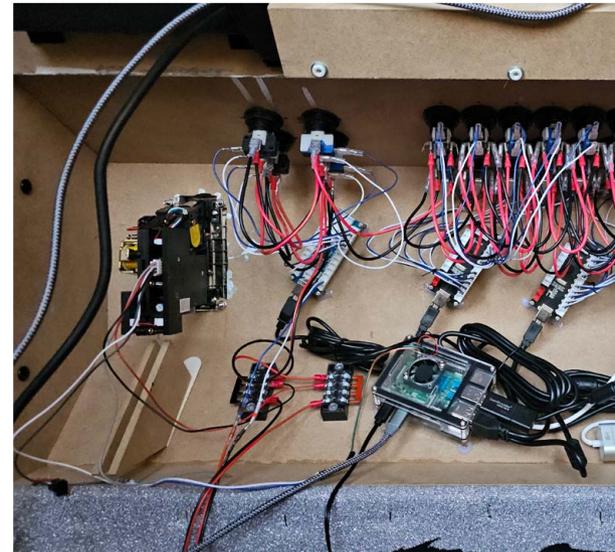
> *It turned out better than I could have imagined*

somewhat," he says. "But I ended up leaving it visible, because you can easily change the volume, it can be controlled by a remote, it has microphone inputs for karaoke, and FM tuner, Bluetooth, and can play MP3s from a USB drive."

As a finishing touch, Jeremy also included a marquee at the top of the jukebox consisting of album covers back-printed on window clings stuck to some 1/8-inch plexi. These are lit using LEDs. More lights were fitted beneath the control panel, ensuring the overall build would look as good as it sounds. With a few extra design flourishes – some notes painted on to the front – it was ready to gift.

"It turned out better than I could have imagined," Jeremy says. "The interface looks great. The buttons look and feel authentic and feel like using a real jukebox. My parents are very excited about it and the kids love to play around with it too." It's enough to make us want to dance with joy.

◀ All of the hardware is housed in the button board. A couple of connections for power and the monitor are needed
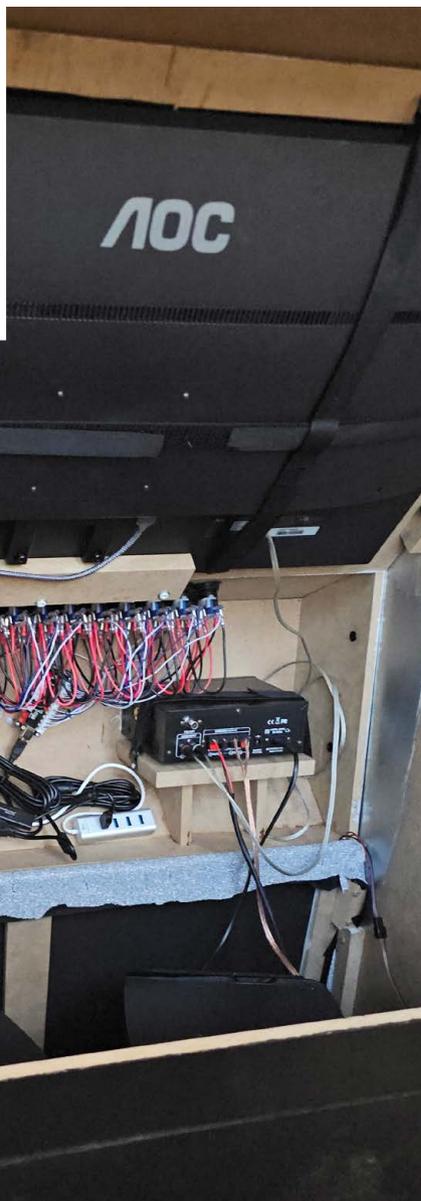
▲ Jeremy says he would use a smaller monitor if he was replicating this build, so he could keep the cabinet under 24 inches wide

How it works
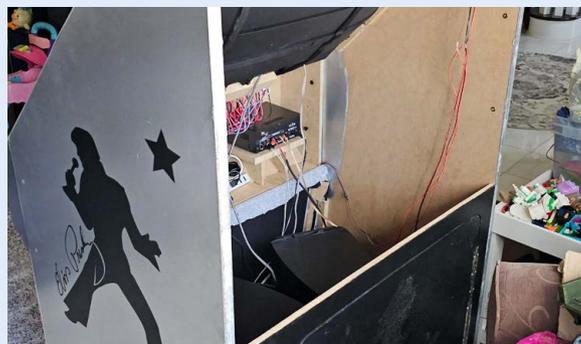
1. Flick a single power switch and the jukebox springs into action. Everything is turned on, from the display to the amp and lights, and the Raspberry Pi 4 computer automatically boots to the MP3 player Fruitbox.

2. There are two ways of playing tunes. You can insert a quarter for three songs or hit the secret button on the back of the jukebox to get five 'free' credits. You're then able to start picking some songs to enjoy.

3. There are 80 songs on each page and there are currently six pages. When a song is selected using the panel buttons, an animation shows the record being picked and played. Up to 20 songs can be queued.
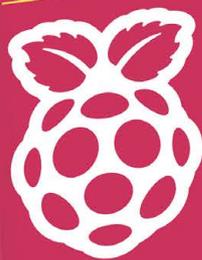
THE *Official*

RASPBERRY PI
HANDBOOK
2025

Olga **Fortune Teller**
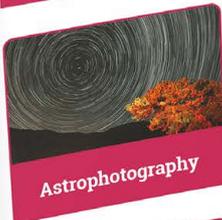
Astrophotography

Exoskeleton

Blue **ROV2**

Emulate a **BBC Micro**

CinePi **XL**
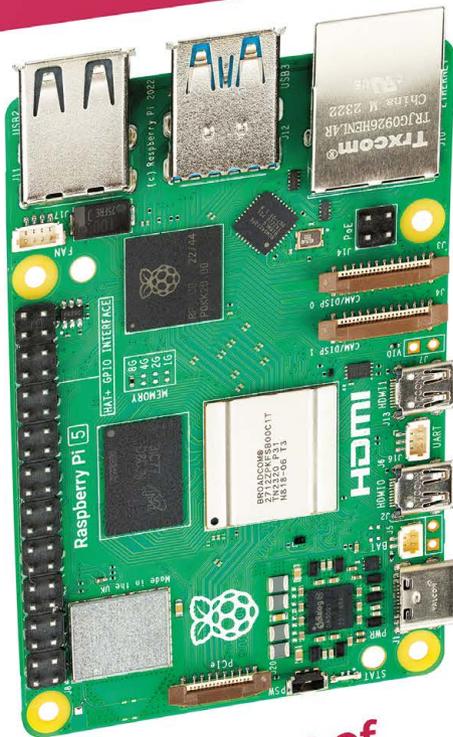
Python **Robots**

200 pages of
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Including
RASPBERRY PI
PICO 2

Stealth Macintosh Portable

By Paul Rickards

rpimag.co/StealthMacintoshPortable

Old hardware is great for repurposing with modern tech. Moore's Law, the trend that makes hardware smaller, better and cheaper over time, means that the hardware that you can buy for pennies today is far better than the bigger, bulkier toys of yesteryear. Add to this the fact that those bulkier electronics need bigger enclosures, and you get a machine such as this: a Macintosh Portable that has had its innards removed and replaced with a much smaller, much faster computer in the shape of a Raspberry Pi 5.

The unit's owner, Paul Rickards, had tried for years to get the original hardware working, to no avail, and so instead he resolved to give it a modern operating system that used as much of the existing hardware as possible, without making any modifications to the case that can't be undone at a later date.

The screen is an LCD module taken from an old iPad, but the keyboard is original (and it is interfaced with the Raspberry Pi 5 via a Raspberry Pi Pico), as is that beautiful trackball (Paul used an ATmega32u4 5V 16MHz Pro Micro to bring this back to life).

Software-wise the machine runs Mini VMac, an emulator for early Mac systems, and it even has a functioning floppy disk drive. It's a real labour of love, and one that will surely have Macintosh old-timers stroking their beards in appreciation.
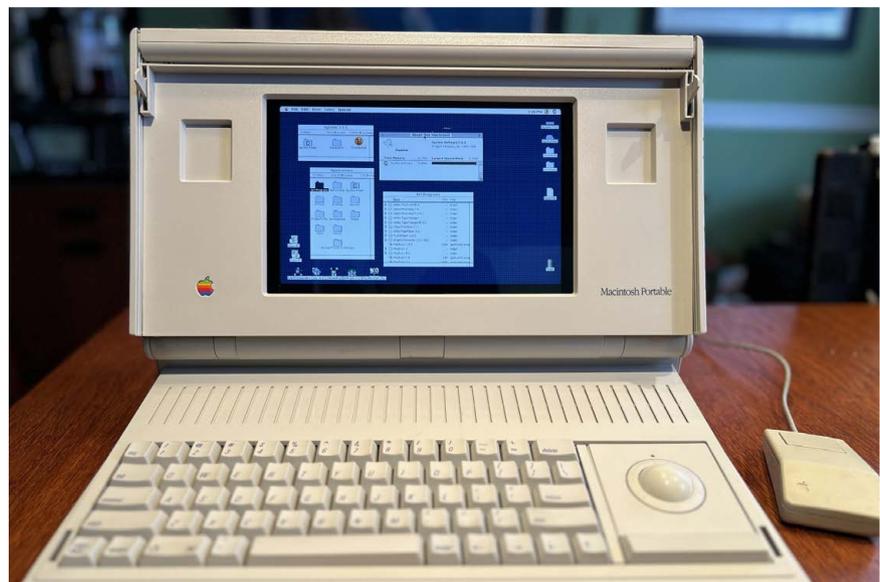
◀ The username in the terminal window says rickards@pi5 – the only clue that this Macintosh isn't all it seems

Whispering wires

By Rootkid

rpimag.co/WhisperingWires

Here's a true work of art: a build designed to be useless; to do nothing other than bring beauty into your life. The maker was looking around a flea market one day, came across an old telephone handset, and wondered to himself: "What if those silent wires could whisper again?" Thus began this wonderful project, called Whispering Wires, which takes a phone and uses a Raspberry Pi Zero W to add poetry.

Maker Rootkid (aka Théo Z V Champion) started with a Socotel model S63, which was the standard issue phone in France in the '60s. This model was built to last and, crucially for our purposes, built to be repaired, so everything can be taken apart and put back together again. He needed the phone to be connected to the internet and to play audio, so he used a Raspberry Pi Zero W, connected to two 1-watt audio amplifier chips and two speakers — one for the body of the phone, and one for the earpiece.

When the phone receiver is picked up, the Raspberry Pi Zero W plays an audio recording of a poem from PoetryFoundation.org, with the sound file ingeniously filtered to make it sound like it's been compressed and sent down a copper wire – in the days of the Socotel S63, phones squished human voices down to a range of 300Hz to 3400Hz, with a sampling frequency of 8kHz.

▼ Théo designed and 3D-printed a support to go inside the phone for the electronics – older equipment often has plenty of room for modern upgrades
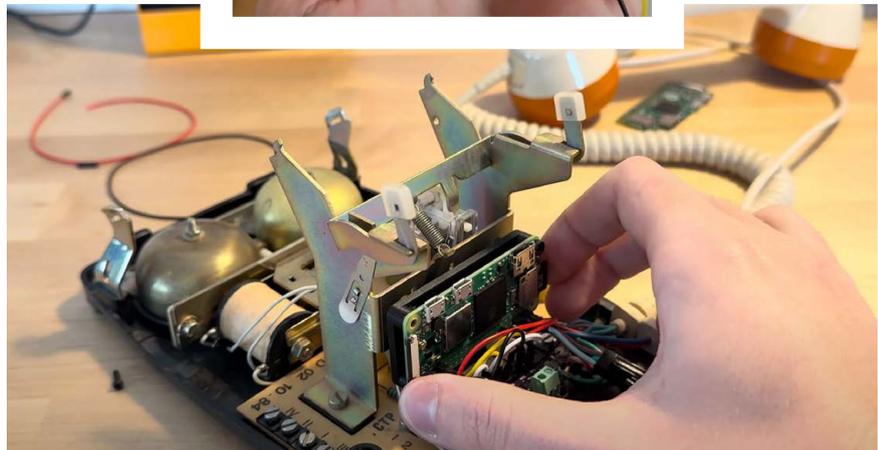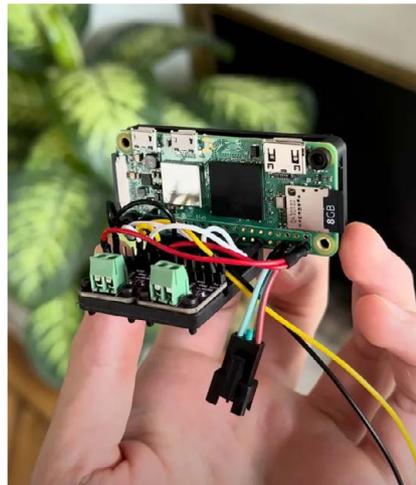
Pomodoro Bot

By CodersCafeTech

rpimag.co/PomodoroBot

The Pomodoro technique is a method of time management named after a kitchen timer in the shape of a tomato. Its adherents break up the day into 25-minute chunks, separated by five-minute breaks. After four of these 25-minute chunks of time have elapsed, you can then take a longer break, typically 25–30 minutes. Fans of the Pomodoro technique say that it helps them to concentrate, as rather than having to negotiate emails, messages, meetings, and whatever else goes on during the day, the comforting ring of the pomodoro timer means that it's time to actually get things done.

Pomodoro timers are also a brilliant subject for physical computing projects. They need a way of counting time, an input method, an audio output of some kind, power management, and a way of tying all the functionality together with a bit of coding. If you've recently got your hands on a Raspberry Pi Pico or something similar and you want to build something

useful, then a Pomodoro timer would be a brilliant place to start.

This example from CodersCafeTech takes the concept of a simple timer and takes it several steps further. For one thing, it's cuter than your average timer: the anthropomorphic little face, the 3D printed body, and the little feet make it something that we'd quite like to have in the office. On the technical side, the makers have added an air quality sensor and an ambient light sensor, to monitor your working conditions and make you even more productive. And since it's built around a Raspberry Pi 5, it has internet connectivity, meaning you can sync it with your work calendar to get reminders of upcoming meetings.

▲ As well as looking cute, this timer monitors air quality index, O_2, and VOC levels

Vertical Runner

By Reeves Media

rpimag.co/VerticalRunner

If this cyberdeck looks like something out of a movie, it's because it is… kind of. The maker initially set out to make a prop for a film they were making, but accidentally ended up learning all about ethical hacking, cybersecurity and Linux, finishing up with a working handheld computer.

The hardware for this build comprises a Raspberry Pi 4 8GB, a Waveshare 3.5-inch touchscreen LCD, a Vilros battery pack, a Fly Way Bluetooth 3.0 keyboard, and a BrosTrend Dual Band Wi-Fi (monitoring/injection) adapter, which is what makes this build something a little different from the normal computer-on-the-go devices: this project was actually built with cybersecurity testing in mind.

It took some work to get the Waveshare screen working with Raspberry Pi OS, and the 3D printing – which looks great — was done in collaboration with Precision Additive. When the machines are rising up and you need to hack an insecure network to shut them down, this is the sort of device you'll need. ◘

▼ This device does get warm when it's running, but the maker reckons they would only use it in short 30-minute bursts anyway

3D print

Brilliant, beautiful creations made out of molten plastic

We often say that with 3D printing, as with programming, if you can imagine it, you can build it. That's all very well, but how on earth do you imagine something like this if you're not a visionary like Ekaggrat Singh Kalsi? He was inspired to build this unique display – which goes by the awesome name of 'Bezicron' — by his daughter's elastic hair bands, and created a mechanism that would use motors, cams, and levers to stretch a length of elastic into the shapes of digits.

The clock is powered by two 20mm geared stepper motors, which each turn two of the four modules. Both motors are controlled by a module featuring an ATmega8 chip, as used in the Arduino ecosystem.

The horizontally stacked cams, and the fact that the levers that shape the digits move horizontally, give rise to the stacked/multilayered look of the clock. As that's how FDM printers lay down material (in layers) the design of this build lends itself to 3D printing. Having said that, we'd love to see this with a chassis made from machined aluminium.
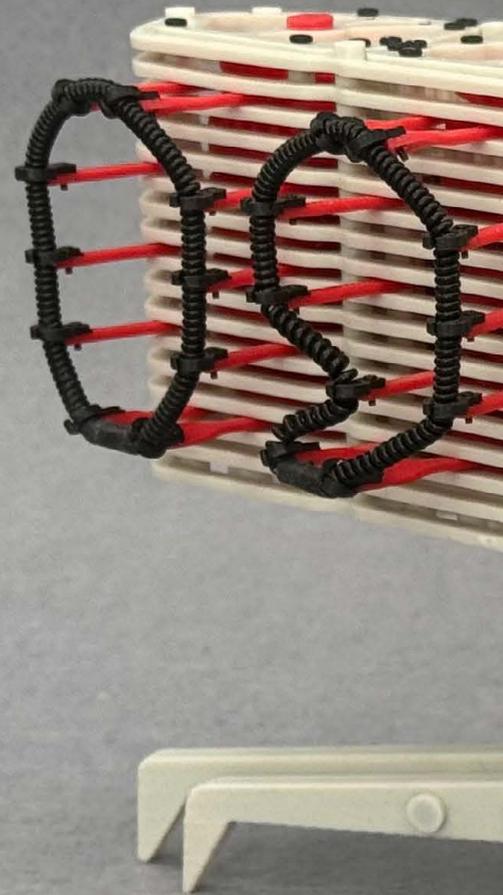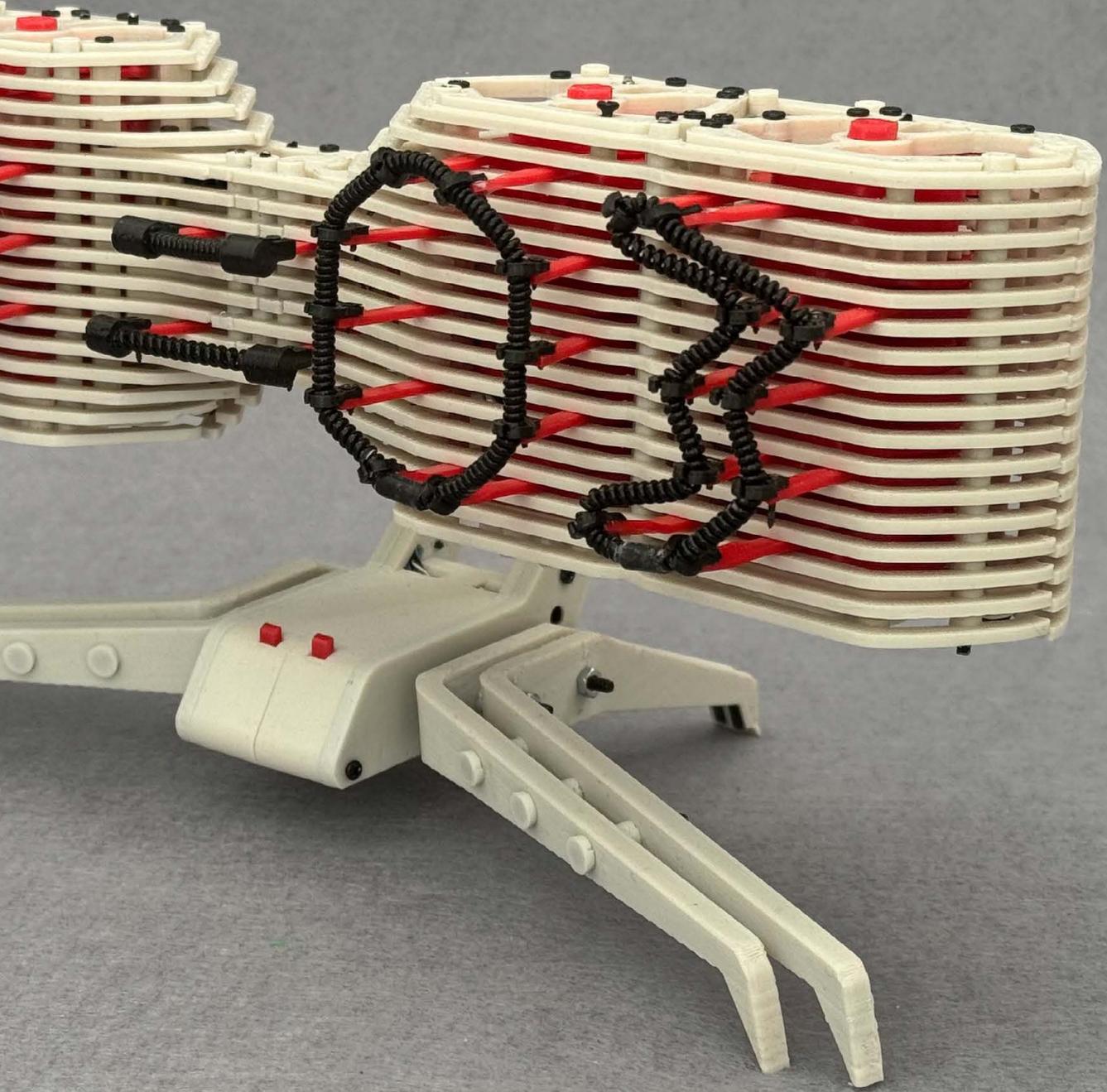
PROBLEM SOLVING

Get better at setting up and taking care of your Raspberry Pi devices. By Lucy Hattersley

*You'll become
a smarter tech
troubleshooter*

Raspberry Pi is the computer for everybody. One group of people that it's especially good for is those of us who really do love computing.

The great thing about Raspberry Pi is you can take it apart, put it together, and start to understand what's going on inside. Unlike the glass and glue slabs that pass for computers, Raspberry Pi is a real computer that you can fix, and break, and fix again.

And that's what this feature is all about. We're going to look at setting up Raspberry Pi, along with some tips for picking the right accessories, and problem solving Raspberry Pi.

There is bound to be something here that you don't know. So read this feature and you'll become a smarter tech troubleshooter.

Power up

The bare minimum you need to get started with a Raspberry Pi computer is a power supply and some form of boot media: typically a microSD card, but increasingly an SSD or USB thumb drive.

Newer Raspberry Pi models, from Raspberry Pi 4 / 400 onwards, use a USB-C connection to provide power; Raspberry Pi Zero and Raspberry Pi 3 (or earlier) models use a micro USB connection. So make sure you have the right cable to hand.

More important is keeping an eye on how much wattage your power supply is capable of. Many Raspberry Pi owners repurpose a power supply from other devices; using a standard phone charger is common.

There are lots of 5V/3A power supplies available that supply 15W (V×A = W), which is enough for a Raspberry Pi Zero model, or Raspberry Pi 4/400 or earlier. The new Raspberry Pi 5/500 models operate best with a 27W power supply and for these we recommend getting a Raspberry Pi Power Supply (**rpimag.co/powersupply**).

It is possible to run a Raspberry Pi Zero / Zero 2 or 4/400 or earlier with 15W of power, you may run into problems with USB attachments that draw power from the device (such as mice, keyboards, thumb drives, or any HAT attached hardware).

If your Raspberry Pi does not power up – or keeps resetting – then the first thing to look at is the power supply. Check it against the 'Recommended power supply' table and if it falls short, pick up an appropriate charger, such as a Raspberry Pi power supply (**rpimag.co/2wpowersupply**).

▶ Raspberry Pi's Official USB Power Supply provides enough wattage to comfortably run the latest models

FIND YOUR RASPBERRY PI

Take a close look at the board and it will tell you what device you are using, such as 'Raspberry Pi 4 Model B' or 'Raspberry Pi 5'. Raspberry Pi Zero has it written on the reverse of the board, as do keyboard models such as Raspberry Pi 400 and Raspberry Pi 500. Head to **rpimag.co/products** to get a visual overview of all Raspberry Pi hardware.
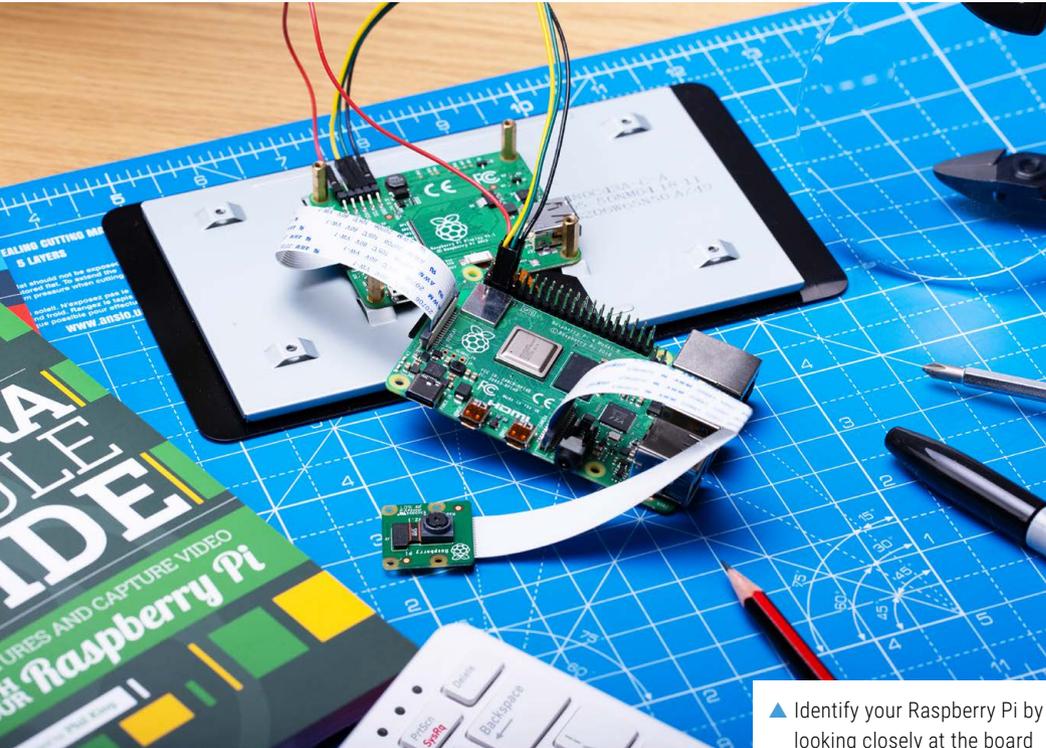
▲ Identify your Raspberry Pi by looking closely at the board

Pick your boot media

Most Raspberry Pi models use a separate storage medium to boot the operating system. Typically, this is a microSD card, which slots into Raspberry Pi and contains an operating system image.

Raspberry Pi OS is the official image, but Raspberry Pi models can run a range of operating systems including Ubuntu and Recalbox.

You can also boot modern Raspberry Pi computers from USB storage, network storage, and via storage attached to the PCI Express 2.0 interface on a Raspberry Pi 5 (typically accessed via the Raspberry Pi M.2 HAT+, **rpimag.co/m2hatplus**).

You will want to use at least a Class A2 microSD card. The speed of the card is likely to affect the performance of the operating system. Raspberry Pi sells its own official SD Cards that are rigorously tested to ensure optimal performance (**rpimag.co/sdcards**).

▲ Raspberry Pi's official microSD card has been rigorously tested

Recommended power supply

Model	Recommended power supply (voltage/current)	Raspberry Pi power supply
Raspberry Pi 5	5V/5A, 5V/3A limits peripherals to 600mA	27W USB-C power supply
Raspberry Pi 4 Model B	5V/3A	15W USB-C power supply
Raspberry Pi 3 (all models)	5V/2.5A	12.5W micro USB power supply
Raspberry Pi 2 (all models)	5V/2.5A	12.5W micro USB power supply
Raspberry Pi 1 (all models)	5V/2.5A	12.5W micro USB power supply
Raspberry Pi Zero (all models)	5V/2.5A	12.5W micro USB power supply

HOW BIG A MICROSD CARD?

We define 'ample space' as at least 8GB to run Raspberry Pi OS with a graphical interface, or 4GB to run Raspberry Pi OS in 'headless' mode (accessible only via the command line or over a network). Only the first-generation Raspberry Pi uses a full-sized SD card; all models from Raspberry 2 onwards support microSD.

Other cables

If you want to use Raspberry Pi directly, you'll also need the following:

- a display
- a cable to connect your Raspberry Pi to your display
- a keyboard
- a mouse

Most of these items are easy to source and many Raspberry Pi owners repurpose old equipment. Raspberry Pi sells its own Keyboard, Mouse, Monitor, and Display Cable if you wish to use official kit (**rpimag.co/products**). You can use any of the USB ports on Raspberry Pi to connect a USB wired keyboard or mouse. It is also possible to connect Bluetooth keyboards and mice from the Raspberry Pi OS interface.

Raspberry Pi models have a range of different display output ports and it is likely you will need to acquire a dedicated display cable. Raspberry Pi 4/400 and 5/500 models require a micro HDMI to HDMI cable (**rpimag.co/microhdmicable**). Raspberry Pi Zero and Zero 2 models need a mini HDMI cable (**rpimag.co/minihdmicable**).

Installing your OS

Raspberry Pi computers check for an operating system on the SD card first, followed by the NVMe/USB boot drive and network drive (depending on the order set in raspi-config).

Raspberry Pi OS should be your first port of call for an operating system. Based upon Debian Linux, it is fast and efficient. Raspberry Pi OS features an effective collection of programming, internet, and desktop applications. And it has links to documentation, reference

▲ Raspberry Pi's official monitor

guides, and a Bookshelf application for reading our magazines and books.

Raspberry Pi has created an easy way to install Raspberry Pi OS onto your SD card using a program called Raspberry Pi Imager (available for Raspberry Pi, Mac, Windows, and Linux computers).

Download the Imager software from **raspberrypi.com/software** and follow the instructions at **rpimag.co/imager**. It is installed in Raspberry Pi OS if you

have another Raspberry Pi up-and-running, or you can install it in terminal:

```
sudo apt install rpi-imager
```

With your card in a USB microSD card reader (**rpimag.co/sdreader**), open the Imager software. Click on Choose Device and pick your Raspberry Pi target device, click on Operating System and select one, then click on Choose Storage.
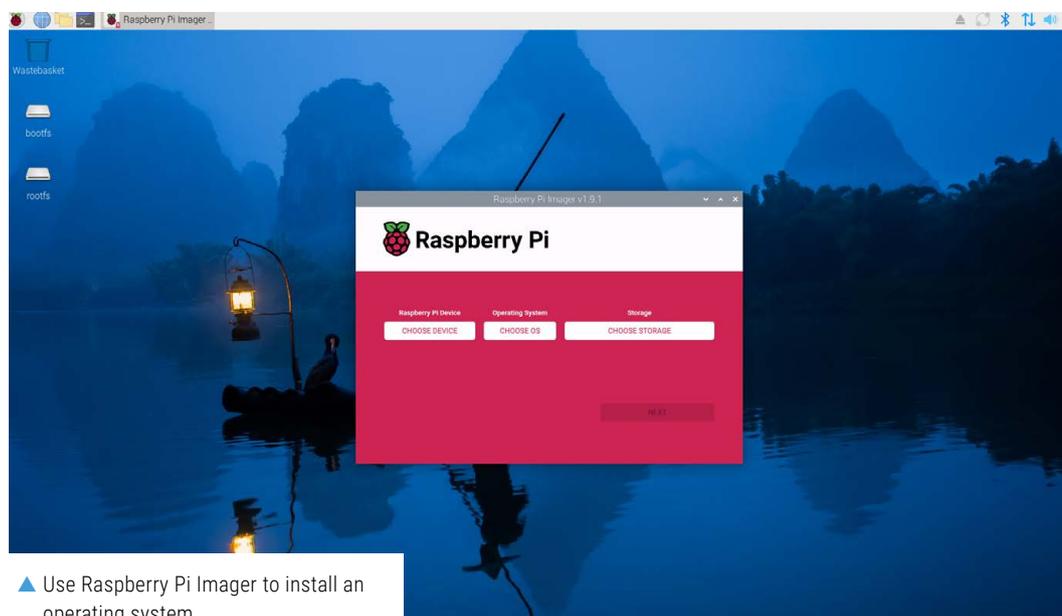
▲ Use Raspberry Pi Imager to install an operating system

Use OS customisation?

Before writing your OS to disk, a pop-up appears asking you if you would like to apply OS customisation settings. We can't recommend highly enough that you click the EDIT SETTINGS button.

Here you will see three tabs:

- **General**. Set a custom hostname, username, and password. Configure the wireless LAN with an SSID and Password and set your locale.
- **Services**. Tick the Enable SSH button if you want to access your Raspberry Pi from another computer. If you already have an RSA key in your SSH configuration, Imager uses that public key. If you don't, you can click Run SSH-keygen to generate a public/private key pair. Imager will use the newly generated public key.
- **Options**. Here are three checkboxes: Play sound when finished, Eject media when finished, and Enable telemetry (**rpimag.co/telemetry**).

Network install

It is now possible to install Raspberry Pi OS onto a storage device using a version of Raspberry Pi Imager downloaded over a network. This means that you no longer require a second computer to install Raspberry Pi OS. The only downside is that you need a reasonably recent model of Raspberry Pi (i.e. Raspberry Pi 4/400 or later).
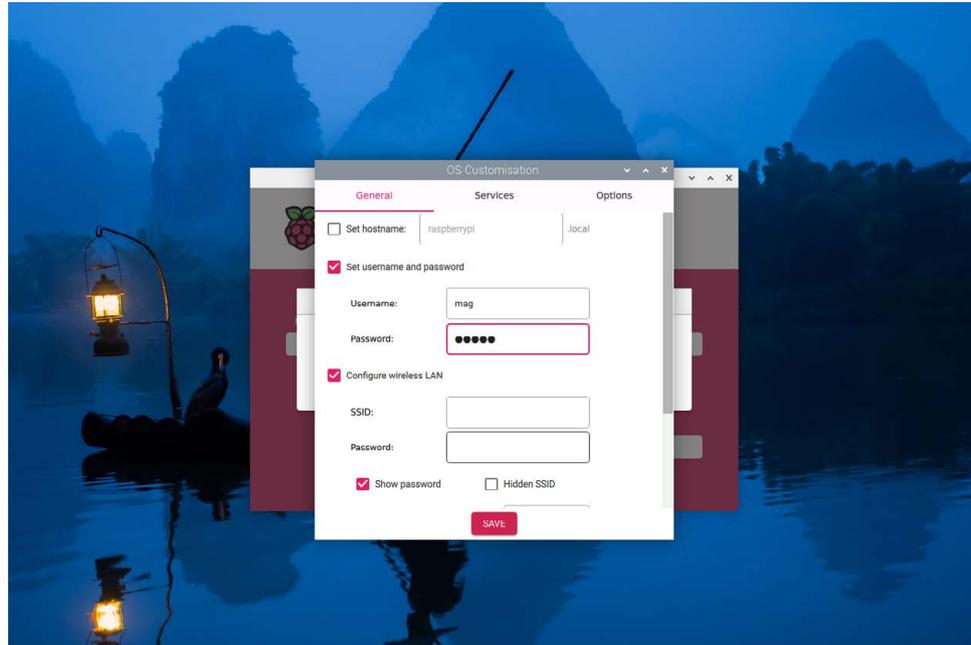
▲ Use OS Customisation to give Raspberry Pi OS custom boot settings

> *Raspberry Pi OS should be your first port of call*

You will also need a wired internet connection via an Ethernet cable, along with a monitor and keyboard.

To launch Network Install, power on your Raspberry Pi while pressing and holding the **SHIFT** key in the following configuration:

- No bootable storage device
- An attached keyboard
- An attached compatible storage device, such as an SD card or USB storage

A red and white screen will appear with 'Install Raspberry Pi OS using Raspberry Pi Imager'. Follow the instructions to download Imager and write an operating system to your storage device.

Boot problems

A Raspberry Pi that is reluctant to boot is a great troubleshooting starter. You'll almost certainly run into this one at some point. Follow these steps:

- **Check the power supply**. First, check that your power supply is connected and that your power supply provides enough wattage for your model of Raspberry Pi computer (see 'Recommended power supply' table). If you have an alternative power supply, try using that one instead.
- **Check LED activity**. If a Raspberry Pi has power but fails to boot, it will – in many cases – flash the LED a specific number of times to indicate what is happening. Take a look at the 'LED Warning Flash Codes' box.
- **Check HDMI cable or network connection**. If you are connecting Raspberry Pi to a monitor, check the HDMI cable is the correct type, and it is correctly inserted. If you have another cable available, try swapping it out.
- **Check boot installation**. Remove the power supply, then carefully remove the storage media and reinsert it. If it still fails to boot, reflash the operating system with Raspberry Pi Imager and double-check you have the correct Raspberry Pi Device selected. If installing Raspberry Pi OS, try using the 'Recommended' version of Raspberry Pi OS. If you are using a different operating system, check with the OS provider that the version you are installing works with your model of Raspberry Pi.
- **Update the bootloader**. Raspberry Pi OS automatically updates the bootloader for important bug fixes. You can manually update the bootloader using a microSD card and Raspberry Pi Imager. Select Misc utility images > Bootloader and select a boot mode: SD Card Boot is recommended; NVMe/USB Boot and Network Boot are the other options. Please see 'Update the bootloader' on Raspberry Pi's documentation for detailed instructions (**rpimag.co/updatebootloader**).

LED WARNING FLASH CODES

If a Raspberry Pi fails to boot for some reason, or has to shut down, in many cases an LED will flash a specific number of times to indicate what happened. The LED will blink for a number of long flashes (0 or more), then produce short flashes, to indicate the exact status. In most cases, the pattern will repeat after a two-second gap.
rpimag.co/ledflashcodes

Long flashes	Short flashes	Status
0	3	Generic failure to boot
0	4	start*.elf not found
0	7	Kernel image not found
0	8	SDRAM failure
0	9	Insufficient SDRAM
0	10	In HALT state
2	1	Partition not FAT
2	2	Failed to read from partition
2	3	Extended partition not FAT
2	4	File signature/hash mismatch – Pi 4 and Pi 5
3	1	SPI EEPROM error – Pi 4 and Pi 5
3	2	SPI EEPROM is write protected – Pi 4 and Pi 5
3	3	I2C error – Pi 4 and Pi 5
3	4	Secure-boot configuration is not valid
4	3	RP1 not found
4	4	Unsupported board type
4	5	Fatal firmware error
4	6	Power failure type A
4	7	Power failure type B

◀ Check for updates using the Raspberry Pi OS GUI interface
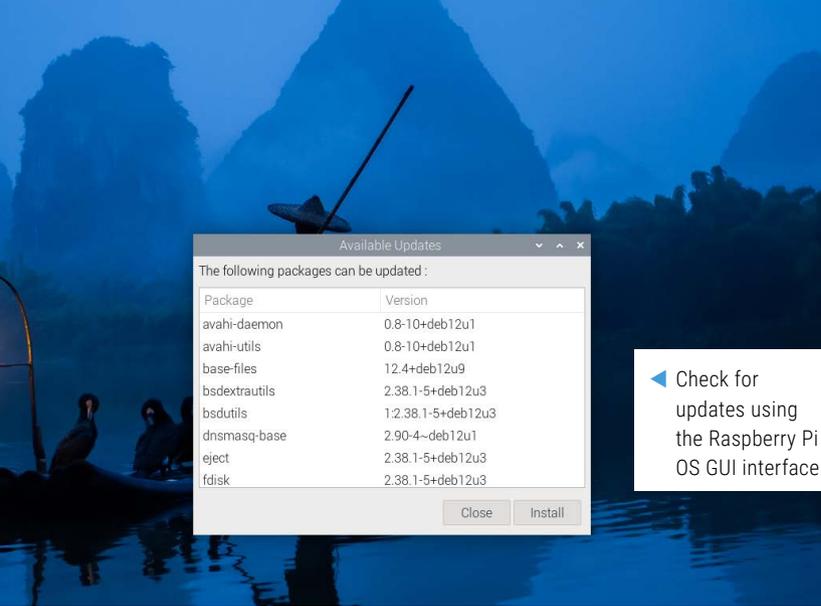
DIG DEEPER!

Click Show Updates to see a list of packages and versions. You can look these up online if you want to get an understanding for what different elements of Raspberry Pi OS and Linux are.

OS update

If you did not use the configuration tool in Raspberry Pi Imager, the operating system will run a configuration wizard on first boot and guide you through the steps of connecting your devices, Wi-Fi or network cable, browser, and guide you through a software update.

Otherwise, the first thing you should do when booting up Raspberry Pi OS is check for updates. If updates are available, an 'Updates are available' icon will appear in the menu bar, click it and choose 'Install Updates'.

If you are running Raspberry Pi OS headless (i.e. without a GUI interface), update using:

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

Remote access

There are three ways to remotely access Raspberry Pi OS and they are all worth learning. Especially if you plan to run your Raspberry Pi without a monitor or keyboard:

- **SSH (Secure SHell)**. You can access the text-based terminal of a Raspberry Pi remotely from another computer on the same network. This is quick to set up and is fast to access, but accessing windows or GUI elements is an arduous process (**rpimag.co/ssh**).
- **VNC (Virtual Network Computing)**. This process enables you to control the desktop of one device from another. VNC relies upon a server program (which will run on your Raspberry Pi) and a client program, which runs on the computer you are using to access Raspberry Pi (**rpimag.co/vnc**).
- **Raspberry Pi Connect**. Raspberry Pi Connect is a service provided by Raspberry Pi that provides free, out-of-the-box access to your Raspberry Pi from anywhere in the world. You activate the service in Raspberry Pi OS and can remote-access your computer from the Raspberry Pi Connect web service in any browser (**rpimag.co/connect**).

SSH and VNC options are both found in the Interfaces section of Raspberry Pi Configuration. Raspberry Pi Connect is found to the right of the menu bar.
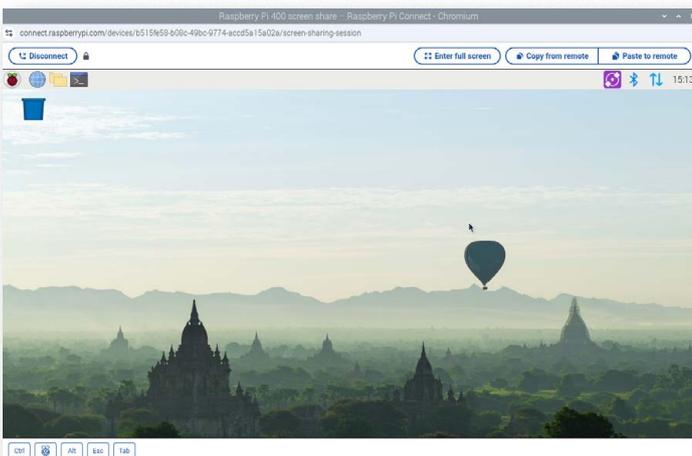
▲ Raspberry Pi Connect enables you to access a Raspberry Pi from a web browser

Update to a new major version

Occasionally Raspberry Pi will introduce a new major version of Raspberry Pi OS; it will be announced via the Raspberry Pi news channel (**raspberrypi.com/news**) and the article will have instructions on how to update to the new version.

To update the operating system to a new major release on your Raspberry Pi, image a second, separate SD card with the new OS release. You can use a USB SD card reader or network storage to copy files and configuration from your current installation to the new SD card. Then, swap the new SD card into the slot on your Raspberry Pi, and boot.

Raspberry Pi Configuration

There are several tools to configure the settings on Raspberry Pi, but Raspberry Pi Configuration on the desktop is the one you should become most acquainted with. Open Raspberry Pi Configuration from Preferences in the main menu.

- **System**. Here you can change your Password, Hostname, Boot, and Login options as well as choose the default web browser (Chromium or Firefox).
- **Display**. Screen Blanking blanks the screen after ten minutes of inactivity (when enabled); the On-screen Keyboard should appear and hide automatically when a touch-display is attached (and can be set to permanently appear here).
- **Interfaces**. Here you can turn on and off various Raspberry Pi OS system interfaces including SSH, VNC, and SPI.
- **Performance**. Click Configure on Overlay File System to enable a read-only filesystem. Here you can also turn the Case Fan on or off (and set the Fan GPIO pin or Temperature).
- **Localisation**. You can configure the UI language, Timezone, Keyboard, and Wireless LAN country code here.

Raspberry Pi Configuration isn't the only tool in Raspberry Pi OS. There's also Appearance Settings, Main Menu Editor, and Mouse and Keyboard settings which are used to customise the OS interface. In addition, Screen Configuration can be used to identify, arrange, and adjust attached displays.

▶ The raspi-config tool enables you to adjust settings from the command-line interface
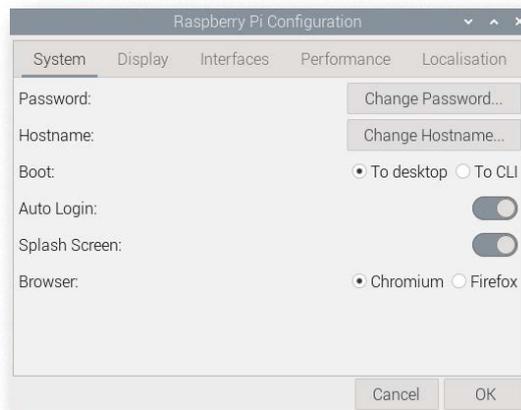
raspi-config

The raspi-config tool helps you configure Raspberry Pi OS from a command-line environment. Open a terminal and enter:

```
sudo raspi-config
```

Changes to raspi-config will modify **/boot/firmware/config.txt** and other configuration files. To navigate the configuration tool from the terminal:

- Use the up and down arrow keys to scroll through the settings list.
- Access the <Select> or <Finish> options using the right arrow or **TAB**.
- Return to the settings list using the left arrow or **TAB**.
- Type a letter to jump ahead alphabetically. For example, type **E** to jump ahead to 'Europe' in the time zone list.

▲ Adjust settings with the Raspberry Pi Configuration tool

TIP!

Some advanced configuration is available in the raspi-config CLI, but not the Raspberry Pi Configuration GUI.
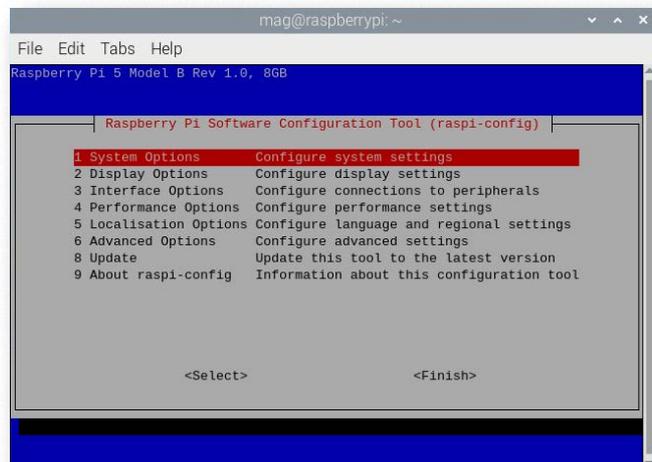
◀ Set the screen resolution in the Screen Configuration tool

config.txt

Raspberry Pi OS uses a configuration file called **config.txt**. Raspberry Pi looks for this special file in the **/boot/firmware/** directory of the file system.

While it is still possible to edit the **config.txt** file directly from your Raspberry Pi OS installation, Raspberry Pi does not recommend this any more. Instead, we would direct you to the GUI configuration tools or raspi-config.

You can view the current active settings by opening a terminal window and using the following commands:

```
$ vcgencmd get_config <config>
```

… displays a specific config value, e.g. `vcgencmd get_config arm_freq`

```
$ vcgencmd get_config int
```

…lists all non-zero integer config options (non-zero)

```
$ vcgencmd get_config str
```

…lists all non-null string config options.

Take a look at the config.txt section of Raspberry Pi's documentation to become familiar with the commands you'll find in **config.txt**.

OLDER VERSION

Prior to Raspberry Pi OS Bookworm, Raspberry Pi OS stored the boot partition at **/boot/**.

Adjust HDMI and display

Raspberry Pi uses the EDID of the HDMI-connected monitor to automatically pick the best resolution. You can manually choose a different resolution with the Screen Configuration tool found under Preferences in the menu. Click on Screens and select your connected display (HDMI-A-1 or HDMI-A-2).

SCREEN BLANKING

If the screen periodically goes blank, it may be that screen blanking is enabled. Check the Display setting in Configurations and ensure Screen Blanking is set to Off.

Command-Line Networking

It is possible to connect to a wireless network via the command line with `nmcli` (command-line tool for NetworkManager). Open a terminal and enter:

```
$ nmcli dev wifi list
```

…to scan for networks, and:

```
$ sudo nmcli --ask dev
wifi connect <example_ssid>
```

…to connect. Enter your network password when prompted. For more commands and information, take a look at the Networking section of Raspberry Pi's documentation.

rpimag.co/networkingdocs

▲ Use SD Card Copier to back up your Raspberry Pi
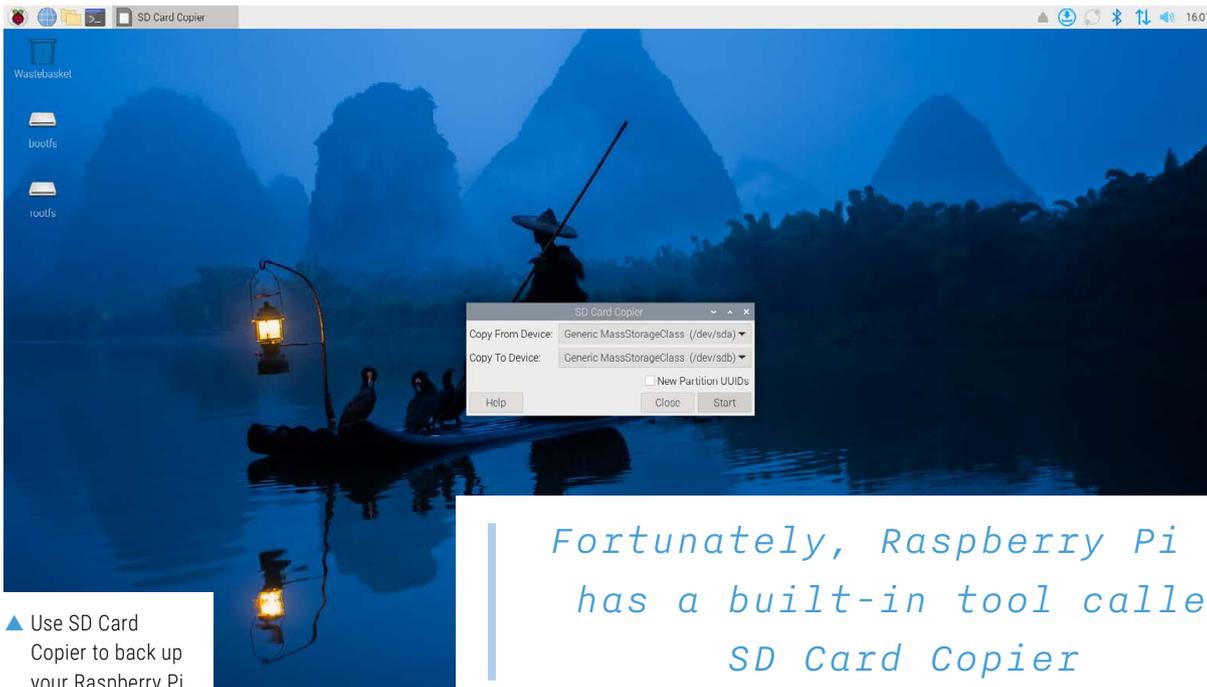
Composite video mode

Composite video can be used to connect Raspberry Pi to CRT displays such as analogue televisions and monitors. In some countries these are widely used, and it's useful for classic retro projects.

To enable composite output, append this to the end of the 'dtoverlay=vc4-kms-v3d' line in **/boot/firmware/config.txt**:

```
dtoverlay=vc4-kms-v3d,composite
```

By default, this outputs NTSC mode. For more information and settings, see **rpimag.co/compositevideo**.

Wayland vs X11

Since Raspberry Pi OS Bookworm (**rpimag.co/bookworm**) was released in 2023, all Raspberry Pi computers use a new display system called Wayland. This performs much better than X11, the system it replaced. You can switch between Wayland and X11 with:

```
$ sudo raspi-config
```

Now choose 6 Advanced Options > A6 Wayland > W1 X11.

Adjust the audio mode

Raspberry Pi has multiple output modes: HDMI, the headphone jack (if your device has one), and USB audio. By default, Raspberry Pi outputs audio to HDMI 1. If no HDMI output is available, Raspberry Pi outputs audio to the headphone jack or USB audio device.

- **Desktop volume control**. Right-click the volume icon on the taskbar bar to open the audio output selector. Available devices will be listed; pick the one you want to use.
- **raspi-config**. To change your audio output from the command line, open a terminal window and enter `sudo raspi-config`. Select System Options > Audio and choose your required mode. Press **ENTER** to choose the mode and then select <Finish> to exit the configuration tool.

Create a backup

Once you have Raspberry Pi OS running to specification, it's a good idea to create a backup. This enables you to restore all your files and system settings.

Fortunately, Raspberry Pi OS has a built-in tool called SD Card Copier that enables you to clone your boot drive. Attach a second storage device that is the same capacity (or larger). Open SD Card Copier under Accessories in the

Model	Composite output
Raspberry Pi 1 A and B	RCA jack
Raspberry Pi Zero	Unpopulated TV header
Raspberry Pi Zero 2 W	Test pads on underside of board
Raspberry Pi 5	J7 pad next to HDMI socket
All other models	3.5 mm AV jack

menu and choose your boot drive from **Copy From Device**. Select your target backup device from **Copy To Device** and click **Start**.

The backup device will be a perfect copy of your boot drive and you can boot your Raspberry Pi from it.

HAT+ and hardware

One of the brilliant things about Raspberry Pi is the ability to attach physical hardware to the GPIO pins. And that there are many, many third-party boards you can use to extend Raspberry Pi's functionality. Everything from motor controllers for robots, to AI accelerators, to audio DACs (and much more besides).

Raspberry Pi has created a HAT+ (Hardware Attached on Top) standard for third-party manufacturers. These HAT+ devices contain an EEPROM chip that holds the board manufacturer information, GPIO setup, and a device tree fragment (this allows Raspberry Pi OS to automatically load up the required drivers). If your hardware is HAT+, it should – in theory – work as soon as it is connected.

You can read more details about the new HAT+ standard in this blog post: **rpimag.co/doublestandards**.

The complete HAT+ specification can be found at **rpimag.co/hatplusspec**.

If you are having trouble with HAT+ hardware, power off your Raspberry Pi and try reseating the HAT+ hardware on the GPIO pins (carefully to ensure it is sitting on the pins correctly). If it still fails, try updating Raspberry Pi OS, updating the firmware, and check your power supply is enough to power both the device and HAT+ hardware.

Raspberry Pi has documentation on all its HATs, which you can find here: **rpimag.co/accessoriesdocs**.

Third-party makers provide their own documentation which you can consult to troubleshoot the device.

Getting physical

Raspberry Pi is hardware and you should take steps to protect it physically as well as on the software layer.

- **Raspberry Pi Bumper**. We love the Bumper! It's a snap-on silicone cover that protects the bottom and edges of the board. It also prevents slippage and can help protect from vibration (**rpimag.co/bumper**).
- **Raspberry Pi Case**. Moving up from the Bumper is the Raspberry Pi Case. These combine high-quality construction with a minimalist design that enables you to quickly remove the lid and access the board. Raspberry Pi 5 models also have an integrated fan (**rpimag.co/case**).
- **Third-party cases**. There are many other cases available that offer a range of features above and beyond Raspberry Pi's official case. The HighPi Pro case offers a large internal volume area for HATs and VESA mount support (**rpimag.co/highpipro**), while ComfilePi offers touch panel cases with high-tolerant parts for industrial applications

COMPOSITE VIDEO PHYSICAL LOCATION

Composite video output can be found on some models of Raspberry Pi computer – see the table on the page opposite. Note: composite video mode is not found on keyboard models.

NEW PARTITION UUIDS

By default, SD Card Copier will clone the partition UUIDs (Universally Unique Identifiers) which means you get an exact copy of the drive. This makes it difficult to mount both disks at the same time. It isn't a problem if you expect to store the backup, but if you want to keep it connected to Raspberry Pi and boot from either device, select the New Partition UUIDs checkbox.

▶ Use a Raspberry Pi Bumper or a case to protect your computer

Raspberry Pi and digital computing is a vast subject

(**comfiletech.com**). Argon offers a popular range for home media that include infrared remote control, DAC audio, and large storage (**argon40.com**)

- **Cooling**. Raspberry Pi computers are designed to operate safely without cooling. If you want to put a Raspberry Pi under stress, then cooling will help it stay at a comfortable operating temperature, even under a heavy load. The official option is a Raspberry Pi Active Cooler for Raspberry Pi 5 that combines an aluminium heatsink with a temperature-controlled blower fan (**rpimag.co/activecooler**). ▫

Getting help

Raspberry Pi and digital computing is a vast subject. You will routinely come across something you don't understand. Don't be afraid to look for help. Here are some places to get started.

- **Help section**. Choose the Help section from the Raspberry Pi OS desktop menu. Here you'll find links to starter guides, Debian reference guides, and projects. Bookshelf is also here, which contains digital PDF editions of *Raspberry Pi Official Magazine*, its predecessor *The MagPi*, and various books.

- **Documentation**. Make sure you look at, and bookmark, Raspberry Pi's comprehensive Documentation portal (**rpimag.co/docs**). Here you will find comprehensive links and you can search by subject (**CTRL+K** accesses the search box).

- **Forums**. Raspberry Pi maintains a vibrant forum user base (**rpimag.co/forums**).
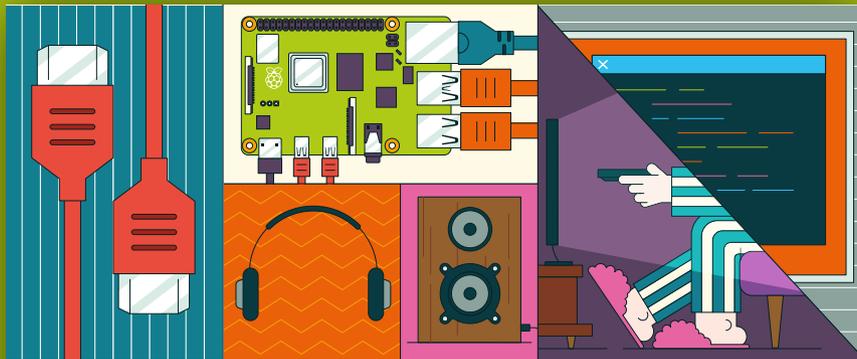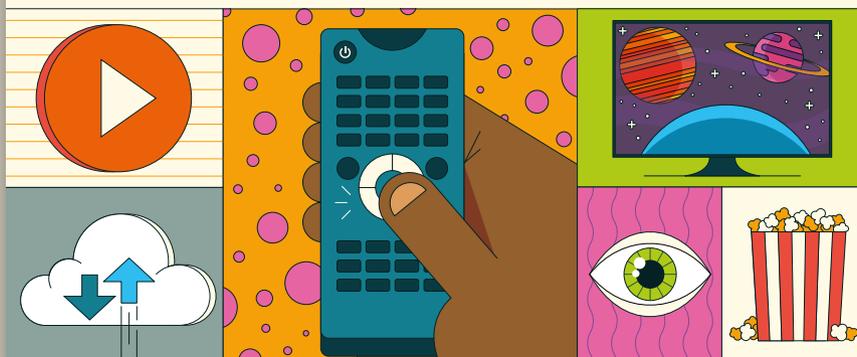
Get started with Sense HAT V2

Learn to make a sparkly simple project with this accessible guide to Raspberry Pi's environment sensing HAT

Lucy Hattersley

Sense HAT brings together some of Lucy's favourite things: space, sparkles, and environmental sensing.

🌐 **rpimag.co**

YOU'LL NEED

- Raspberry Pi computer (any 40-pin model)
- Raspberry Pi Sense HAT V2
  rpimag.co/sensehat

A Raspberry Pi single-board computer (SBC) can do a lot of things thanks to its size, portability, and ability to connect to the internet easily. With the GPIO ports you can control electronics and interact with the world. One of the best ways to get started with interaction is by using an add-on like the Sense HAT V2.

The Sense HAT is a very sophisticated add-on board for the Raspberry Pi. While 'HAT' is an acronym (Hardware Attached on-Top), it does act in a way like a hat for your Raspberry Pi. The Sense HAT contains a suite of sensors that allows the Raspberry Pi to sense the world around it, along with an array of LEDs on top which can be used to display information on what the board can sense, and a little joystick for interaction.

The Sense HAT V2 also includes a TCS3400 RGB colour and brightness sensor.

There is a Python software library called Sense HAT that is used to control the HAT and access information from its sensors. Together this makes a powerful combination.

SENSE HAT PYTHON DOCUMENTATION

Full documentation for the sense-hat Python module can be found on readthedocs.io. It's a good website to bookmark.
rpimag.co/sensehatmodule
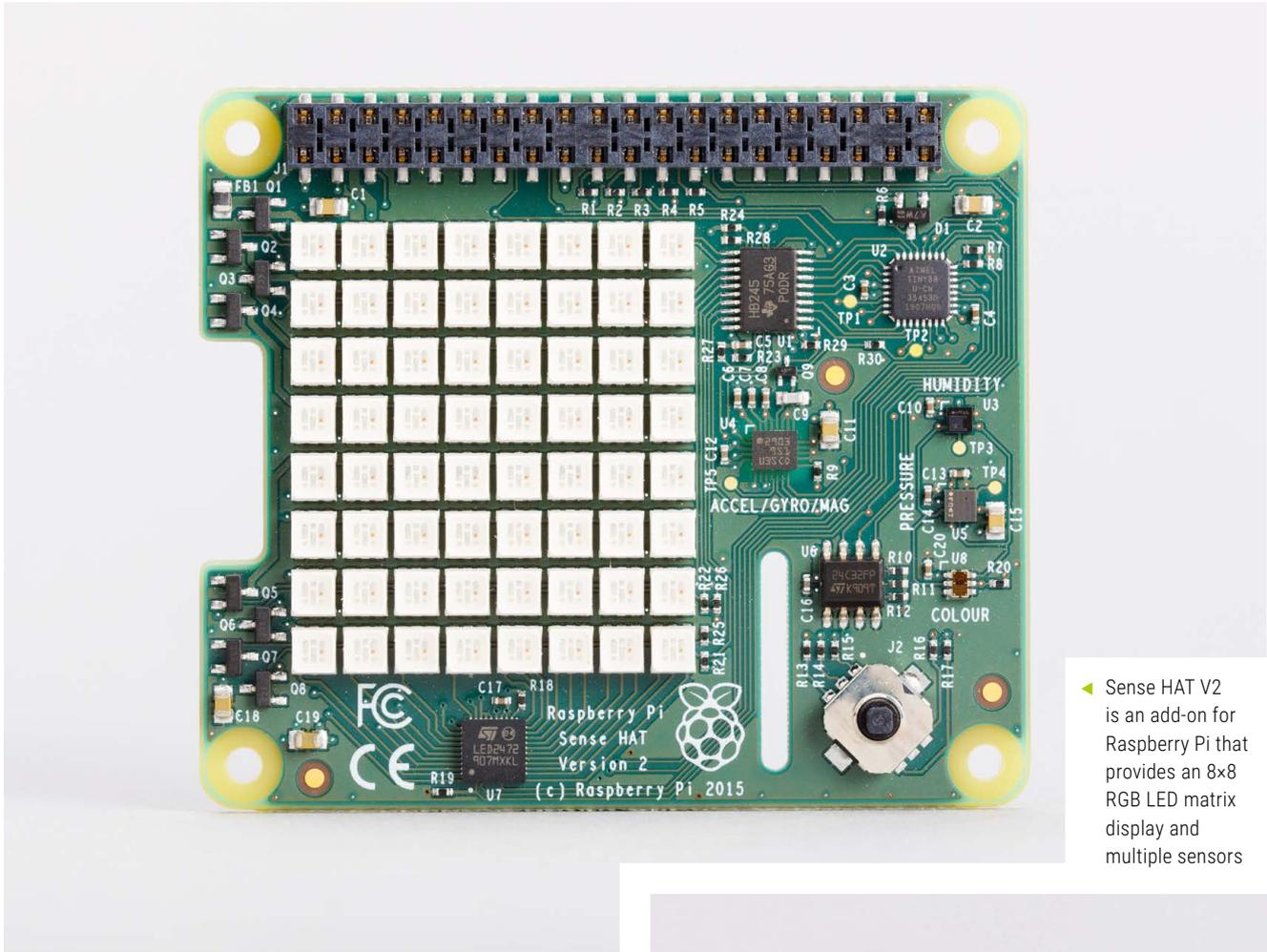
◀ Sense HAT V2 is an add-on for Raspberry Pi that provides an 8×8 RGB LED matrix display and multiple sensors

The Sense HAT is a very sophisticated add-on board for the Raspberry Pi
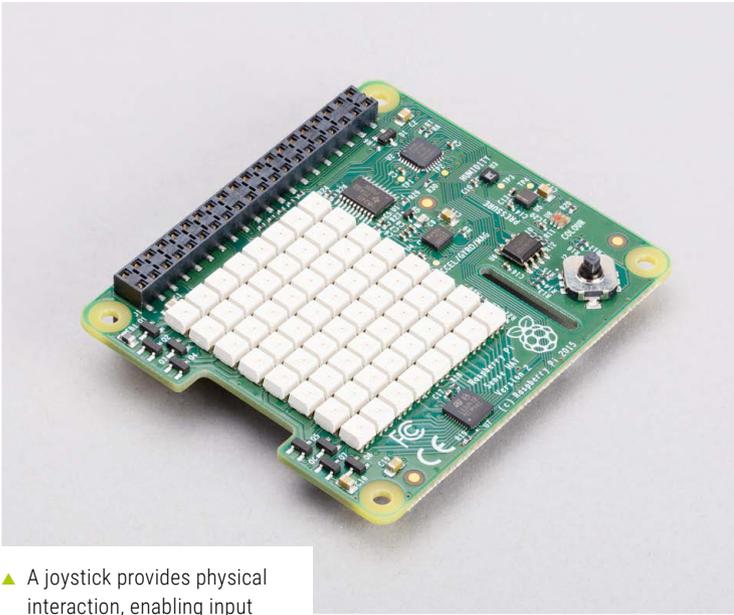
▲ A joystick provides physical interaction, enabling input

The Sense HAT is a vital component of the Astro Pi, the specially adapted educational Raspberry Pi computers which were sent up to the International Space Station with British ESA astronaut Tim Peake to run code created by young students.

You don't need to be in space to make use of the Sense HAT: it works down on Earth as well! In the following tutorials, we will set up the Sense HAT and learn how to code it using the Python programming language.

Assemble the Sense HAT

If you have not yet installed the Sense HAT, now is the time to do so. Do this with your Raspberry Pi shut down, disconnected from the mains, and with all other cables disconnected.

The Sense HAT comes in a silver anti-static bag, along with the following fixtures and fittings:

- 1 × GPIO pin extension header
- 4 × Hexagonal stand-offs (female-to-female)
- 8 × M2.5 screws

Check that these are all present before proceeding.
The diagram in **Figure 1** shows how it all fits together.
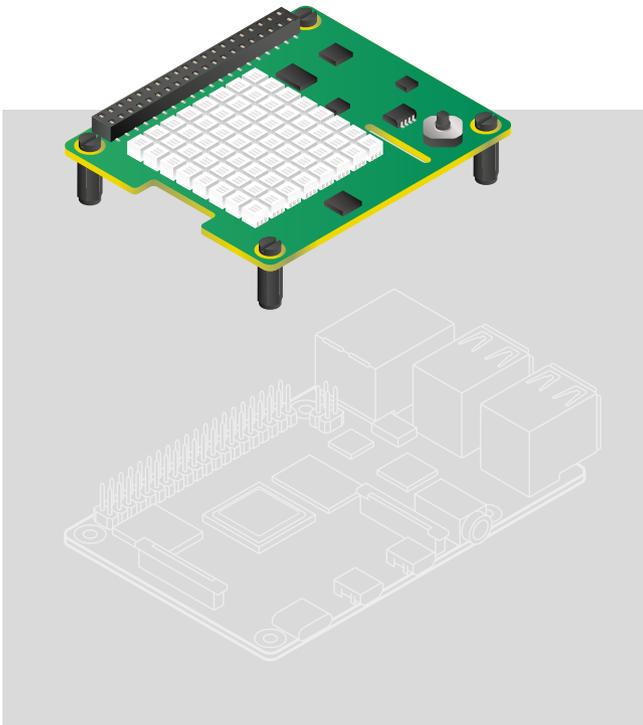
▲ **Figure 1.** Attaching Sense HAT to Raspberry Pi

1. First, put the GPIO extension header block onto the Raspberry Pi GPIO pins.
2. Screw the hexagon stand-offs to the Raspberry Pi itself, by threading the screws through from the bottom and turning the hexagonal stand-offs between your finger and thumb.
3. Next, insert the Sense HAT into the GPIO pin extension header. The corner holes should line up with the hexagonal stand-offs.
4. Lastly, put the remaining screws through from the top.
5. Use a small Phillips screwdriver to tighten each corner stand-off individually. They don't need to be especially tight, just enough to ensure that the HAT doesn't become loose.
6. Now boot your Raspberry Pi to the Raspberry Pi OS desktop and start Thonny, by choosing the Raspberry Pi menu and selecting Programming > Thonny IDE.

When you first boot up the Sense HAT, it will display a rainbow pattern across the LED display, enabling you to confirm power and see that the LEDs work (**Figure 2**).
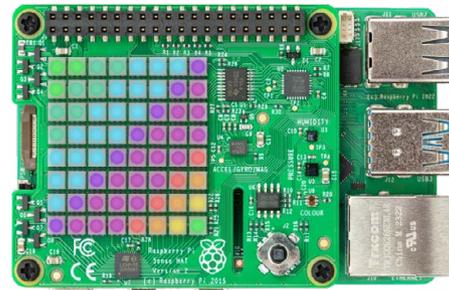
▲ **Figure 2.** The rainbow effect on power-up

For our first trick, we'll display text on the Sense HAT's LED matrix. This program contains two crucial lines of code, which import the Sense HAT software and create a sense object which represents the Sense HAT:

```
from sense_hat import SenseHat
sense = SenseHat()
```

The next line makes the Sense HAT display some scrolling text (**Figure 3**):

```
sense.show_message("Hello, Sense HAT!")
```
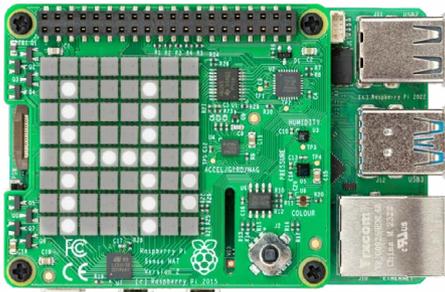
▲ **Figure 3.** The LED matrix displaying an H from our 'Hello World' text

You can easily change the message inside the quote marks to display your own text, but there's much more you can do.

For example, we can expand the `sense.show_message` command to include some extra parameters which will change the behaviour of the message

The following program will display the text 'Astro Pi is awesome!' more slowly, with the text in yellow `[255, 255, 0]` and the background in blue `[0, 0, 255]`:

```
from sense_hat import SenseHat
sense = SenseHat()
sense.show_message("Astro Pi is awesome!",
scroll_speed=0.05, text_colour=[255, 255, 0],
back_colour=[0, 0, 255])
```

You can make the message repeat by using a `while` loop:

```
from sense_hat import SenseHat
sense = SenseHat()
while True:
    sense.show_message("Astro Pi is awesome!!",
scroll_speed=0.05, text_colour=[255, 255, 0],
back_colour=[0, 0, 255])
```

Now we've made our first program, we should save it. Click **Save**, give your program a name like **show_message.py**, then click **Run** or press **F5** to run it (see **Figure 4**). Easy!

Try running the **magic8ball.py** program (shown overleaf) for a more detailed program that uses messages.
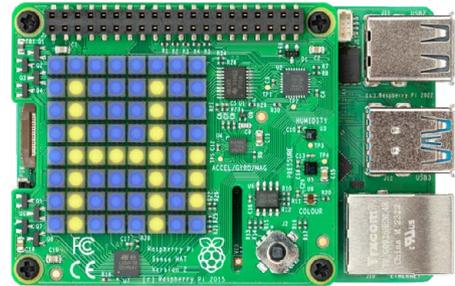
▲ **Figure 4.** The Sense HAT displaying text with using the text_colour and back_colour settings

The LED matrix can also display a single character rather than an entire message, using the `sense.show_letter` function, which has the same optional parameters. For example:

```
sense.show_letter("A", text_colour=[255, 0, 0])
```

This will display a single red A character on the LED matrix (**Figure 5**).
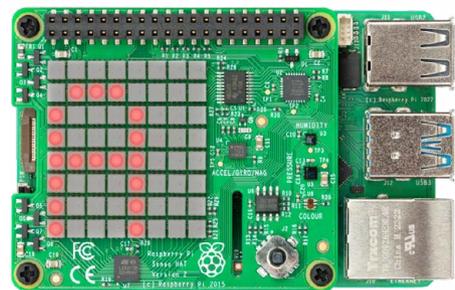
▲ **Figure 5.** Sense HAT's LED matrix displaying a single character

show_message.py

> Language: **Python**

```
001.  from sense_hat import SenseHat
002.  sense = SenseHat()
003.
004.  sense.show_letter("P", text_colour=
      [255, 255, 0], back_colour=[0, 0, 255])
```

magic8ball.py

> Language: **Python**

```python
001.    import random
002.    import time
003.    from sense_hat import SenseHat
004.
005.    sh = SenseHat()
006.
007.    sh.show_message("Ask a question?")
008.
009.    time.sleep(3)
010.
011.    replies = [
012.
013.        'Signs point to yes',
014.        'Without a doubt',
015.        'You may rely on it',
016.        'Do not count on it',
017.        'Looking good',
018.        'Cannot predict now',
019.        'It is decidedly so',
020.        'Outlook not so good'
021.
022.    ]
023.
024.    sh.show_message(random.choice(replies))
```

The sense_show function parameters

Parameter	Effect
scroll_speed	The scroll_speed parameter affects how quickly the text moves on the screen. The default value is 0.1. The bigger the number, the slower the speed.
text_colour	The text_colour parameter alters the colour of the text and is specified as three values for red, green, and blue. Each value can be between 0 and 255, so [255,0,255] would be red + blue = purple.
back_colour	The back_colour parameter alters the colour of the background and is also specified as three values for red, green, and blue.

Displaying images

Of course, the LED matrix can display more than just text. We can control each LED individually to create our own images, and there are a couple of different ways we can accomplish this. The first approach is to set pixels (LEDs) individually; we can do this using the `sense.set_pixel()` command. First, we need to be clear about how we describe each pixel.

The Sense HAT uses a coordinate system; the numbering begins at 0, not 1. The origin (0,0) is in the top-left rather than the bottom-left, as you may be used to. Try the following program (and see **Figure 6**):
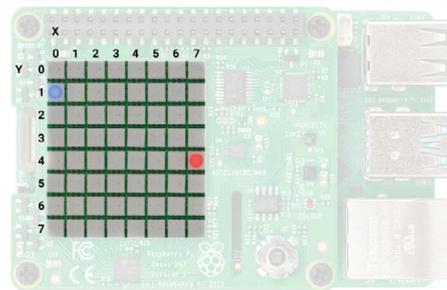
▲ **Figure 6.** The Sense HAT's LED matrix uses a coordinate system

When you first boot up the Sense HAT, it will display a rainbow pattern across the LED display

```
from sense_hat import SenseHat
sense = SenseHat()
sense.set_pixel(0, 2, [0, 0, 255])
sense.set_pixel(7, 4, [255, 0, 0])
```

Setting pixels individually works, but it gets rather complex when you want to set lots of pixels. There is another option, though: `sense.set_pixels`.

This is quite straightforward; we just give a list of colour values for each pixel. We could enter:

```
sense.set_pixels([[255, 0, 0], [255, 0, 0],
                  [255, 0, 0], [255, 0,
0],...])
```

…but this would take ages. Instead, you can use some variables to define your colour palette. In this example we're using the colours of the rainbow:

```
r = [255, 0, 0]
o = [255, 127, 0]
y = [255, 255, 0]
g = [0, 255, 0]
b = [0, 0, 255]
i = [75, 0, 130]
v = [159, 0, 255]
e = [0, 0, 0]  # e is for empty
```

We can then describe our matrix by creating a 2D list of colour names:

```
image = [ e,e,e,e,e,e,e,e,
          e,e,e,r,r,e,e,e,
          e,r,r,o,o,r,r,e,
          r,o,o,y,y,o,o,r,
          o,y,y,g,g,y,y,o,
          y,g,g,b,b,g,g,y,
          b,b,b,i,i,b,b,b,
          b,i,i,v,v,i,i,b ]
```

Once you have the colour and image variables, you can then simply call them by adding:

```
sense.set_pixels(image)
```

rainbow.py

> Language: **Python**

```
001.    from sense_hat import SenseHat
002.    sense = SenseHat()
003.
004.    r = [255, 0, 0]
005.    o = [255, 127, 0]
006.    y = [255, 255, 0]
007.    g = [0, 255, 0]
008.    b = [0, 0, 255]
009.    i = [75, 0, 130]
010.    v = [159, 0, 255]
011.    e = [0, 0, 0]  # e is for empty
012.
013.    image = [ e,e,e,e,e,e,e,e,
014.              e,e,e,r,r,e,e,e,
015.              e,r,r,o,o,r,r,e,
016.              r,o,o,y,y,o,o,r,
017.              o,y,y,g,g,y,y,o,
018.              y,g,g,b,b,g,g,y,
019.              b,b,b,i,i,b,b,b,
020.              b,i,i,v,v,i,i,b ]
021.
022.    sense.set_pixels(image)
```

…but don't forget to start your listing with:

```
from sense_hat import SenseHat
sense = SenseHat()
```

Click **File** > **Save As**, give your program a name, such as **rainbow.py**, then click **Run** (or press **F5**) to run it. What will you display on your Sense HAT?

Setting orientation

So far, all our text and images have appeared the same way up, assuming that the HDMI port is at the bottom. However, this may not always be the case (especially in space), so you may want to change the orientation of the matrix. To do this, you can use the `sense.set_rotation()` method and inside the brackets enter one of four angles (0, 90, 180, or 270).

To rotate your screen by 180 degrees, you'd use this line:

```
sense.set_rotation(180)
```

spinning_j.py

> Language: **Python**

```
001.   from sense_hat import SenseHat
002.   import time
003.
004.   sense = SenseHat()
005.
006.   sense.show_letter("J")
007.
008.   angles = [0, 90, 180, 270, 0, 90, 180, 270]
009.   for r in angles:
010.       sense.set_rotation(r)
011.       time.sleep(0.5)
```

When used in the rainbow program, it would look like this:

```
from sense_hat import SenseHat
sense = SenseHat()

r = [255, 0, 0]
o = [255, 127, 0]
y = [255, 255, 0]
g = [0, 255, 0]
b = [0, 0, 255]
i = [75, 0, 130]
v = [159, 0, 255]
e = [0, 0, 0]

image = [
e,e,e,e,e,e,e,e,
e,e,e,r,r,e,e,e,
e,r,r,o,o,r,r,e,
r,o,o,y,y,o,o,r,
o,y,y,g,g,y,y,o,
y,g,g,b,b,g,g,y,
b,b,b,i,i,b,b,b,
b,i,i,v,v,i,i,b
]

sense.set_pixels(image)
sense.set_rotation(180)
```

Click **File** > **Save As**, give your program a name, such as **rainbow_flip.py**, then press **F5** to run it.

You could also create spinning text using a `for` loop:

```
from sense_hat import SenseHat
import time

sense = SenseHat()

sense.show_letter("J")

angles = [0, 90, 180, 270, 0, 90, 180, 270]
for r in angles:
    sense.set_rotation(r)
    time.sleep(0.5)
```

This program displays the letter 'J' and then sets the rotation to each value in the angles list with a 0.5 second pause. Click **File** > **Save As**, give your program a name, such as **spinning_j.py**, then press **F5** to run it.

You can also flip the image on the screen, either horizontally or vertically, using these lines:

```
sense.flip_h()
```

or…

```
sense.flip_v()
```

With this example, you could create a simple animation by flipping the image repeatedly:

```
from sense_hat import SenseHat
import time

sense = SenseHat()

w = [150, 150, 150]
b = [0, 0, 255]
e = [0, 0, 0]

image = [
e,e,e,e,e,e,e,e,
e,e,e,e,e,e,e,e,
w,w,w,e,e,w,w,w,
w,w,b,e,e,w,w,b,
w,w,w,e,e,w,w,w,
e,e,e,e,e,e,e,e,
e,e,e,e,e,e,e,e,
e,e,e,e,e,e,e,e
]

sense.set_pixels(image)

while True:
    time.sleep(1)
    sense.flip_h()
```

Click **File** > **Save As**, give your program a name, such as **eyes.py**, then press **F5** to run it.

This month we've looked how to set up a Sense HAT with your Raspberry Pi and use Thonny to control the LED matrix. Next month, we will look at how to access the sensors and get information on the temperature, pressure, humidity. ⭘

eyes.py

DOWNLOAD THE FULL CODE:
⬇
rpimag.co/github

> Language: **Python**

```
001.  from sense_hat import SenseHat
002.  import time
003.
004.  sense = SenseHat()
005.
006.  w = [150, 150, 150]
007.  b = [0, 0, 255]
008.  e = [0, 0, 0]
009.
010.  image = [
011.  e,e,e,e,e,e,e,e,
012.  e,e,e,e,e,e,e,e,
013.  w,w,w,e,e,w,w,w,
014.  w,w,b,e,e,w,w,b,
015.  w,w,w,e,e,w,w,w,
016.  e,e,e,e,e,e,e,e,
017.  e,e,e,e,e,e,e,e,
018.  e,e,e,e,e,e,e,e
019.  ]
020.
021.  sense.set_pixels(image)
022.
023.  while True:
024.      time.sleep(1)
025.      sense.flip_h()
```

Build a private cloud server: Getting social

Want to chat to the world on your terms? The Fediverse may be the social service you're looking for

Maker

PJ Evans

PJ is a writer, software engineer, and homelab enthusiast. He's been lost in the Fediverse for many years.

@mrpjevans

YOU'LL NEED

- Private cloud server
  rpimag.co/144
  rpimag.co/145
  rpimag.co/146
  rpimag.co/148

- Domain name

- Static IP (or DuckDNS setup)

There's been a lot of talk about centralised services on the Internet. Companies such as X or Facebook have closed systems and hidden algorithms that control what you see. The Fediverse, backed up by the ActivityPub protocol, was designed as a true decentralised system that no one organisation can control. Mastodon, the Fediverse microblogging platform, has come to the fore as a real alternative for those who take their privacy seriously. In this final part of our private cloud server series, we invite you to join the Fediverse. We'll use CasaOS (**casaos.io**) from the previous instalments and use Docker to create our instance.

01. Introducing GoToSocial

Although Mastodon is typically the server people use for an ActivityPub microblog, it's notoriously difficult to set up and configure. Instead, we're going to use GoToSocial, which is not only compatible with Mastodon but is also available in a Docker container, making installation a breeze with CasaOS. If you're not using CasaOS, you can follow this tutorial but will need to have installed Docker and have some understanding of how it works. CasaOS does not come with GoToSocial in its marketplace (yet), but luckily with a bit of work, we can install any Docker container we want. But first, let's sort the network out.

02. Network setup

Before we install GoToSocial, we will need to ensure that other ActivityPub servers can communicate with it, otherwise it's not very social (although you don't have to federate, if you just want a private microblogging service!). Your server will need

We will need to ensure that other ActivityPub servers can communicate with it
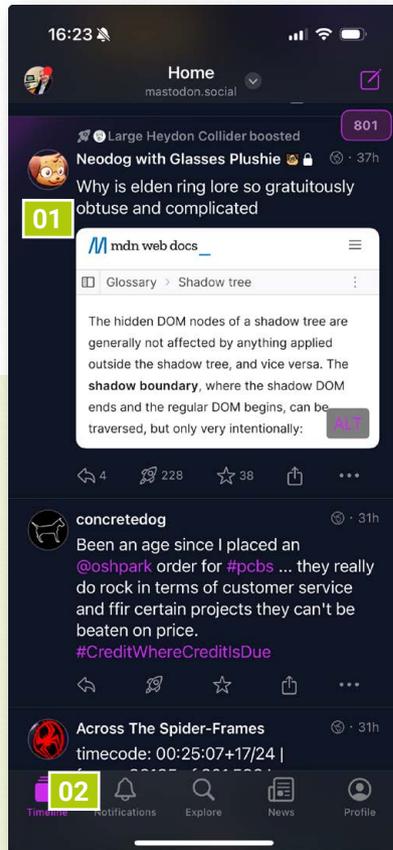
01. Just like other microblogging platforms, Mastodon shows posts from friends and followers

02. Get notifications, send personal messages, and search the Fediverse!
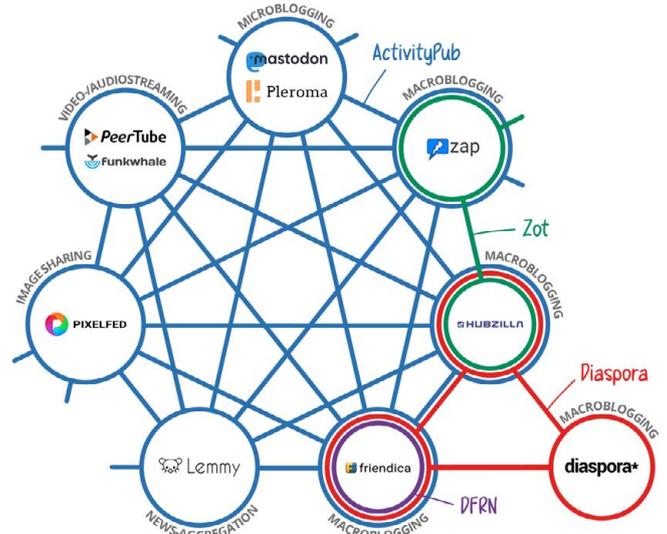
▲ How the Fediverse links different services; each service can be made up of many instances. **Credit:** Imke Senst & Mike Kuketz CC-BY-SA

a unique domain name. A typical approach is to use 'social' as a subdomain. We are using 'social.mkraspberryjam.org' in our examples. On your domain name provider's site, create this subdomain as an A record and point it towards your static IP address (you should already have port forwarding configured on your router from previous tutorials).

03. Domain proxy

In previous instalments of this tutorial we covered installation and configuration of Nginx Proxy Manager, a way of hosting multiple services on a single server and providing SSL security. See issue #146 (**rpimag.co/146**) for more details on this. Open up Nginx Proxy Manager and add a new Proxy Host. Configure it with your new domain name and forward it over HTTP to 127.0.0.1 port 8083 (change the port if it's already in use). Now click on SSL, select 'Request a new SSL certificate' and select 'Force SSL'. If your DNS is OK, your secure connection should now be set up; loading the URL should give a 'Bad Gateway' error (as opposed to no response). Return to CasaOS.

04. Installation

Docker containers often come with a 'Docker Compose' file: a set of instructions on how the container should be run and what access it has. CasaOS can import these files, saving us time and complexity. Start by getting the official GoToSocial compose file from **rpimag.co/gotosocialyaml**. In CasaOS on your cloud server, click the '+' icon in the top-right of the screen and select 'Install a customised app'. Ignore the settings for now and click the 'Import' arrow in the top-right of the dialog. You can now paste in the compose file. There's no need to make any changes yet.

05. Configuration

You'll go back to the settings dialog where we need to provide some extra info. Give the service a name (Hint: 'GoToSocial' might be a good choice for this!) and set the icon URL to **https://gotosocial.org/assets/logo.png**. Next, set the WebUI address to the new domain (e.g. **social.mkraspberryjam.org**), select 'https' and leave the port blank. Change the host port
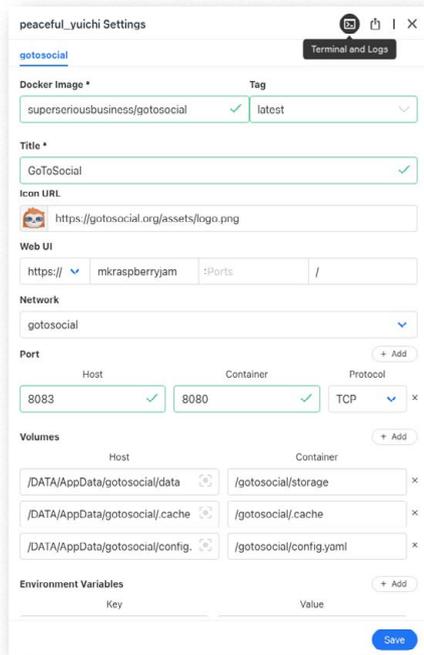
▶ The customised app setup in CasaOS takes all the pain out of installing and configuring Docker apps

to **8083**. Then, under environment variables, set **GTS_HOST** to your new domain name. Next, add a new variable called **GTS_TRUSTED_PROXIES** with the value **127.0.0.1**. Finally, reduce the memory limit to 1024 (GoToSocial is not memory hungry) and click 'Install'.

06. Testing

We're not quite done yet, but your ActivityPub server should now be live! Click the cute sloth icon on CasaOS (or just visit your new domain name) and you should see an 'About this instance' page. If not, go back and check your Nginx Proxy settings are OK and you have used the correct port numbers. Congratulations, you are now a part of the Fediverse. However, nobody knows about you yet, so you will not be exchanging messages (or 'federating') with other servers. Before we get to that, we need to do a little more configuration.

07. Final configuration

Now we know we have a working server, we can add in a few features to help it run smoother. First we want a dedicated config file that persists if the Docker container is restarted.

Explore the Fediverse

Now you have a Mastodon service running, don't forget that the Fediverse has many more aspects. Have a look at Pixelfed for an Instagram alternative, or Loops for your own TikTok.

Docker?

Docker is an elegant solution to the age-old problems of hosting multiple services on a single server. To avoid clashes of software versions and configurations, Docker wraps up a service in its own OS environment called a container.

Open CasaOS's Files app and browse to AppData > gotosocial. Click 'Upload or create' > 'New file' and name it **config.yaml**. Now go to the settings page for GoToSocial in CasaOS and add two new volumes:

```
/DATA/AppData/gotosocial/.cache
                        /gotosocial/.cache
/DATA/AppData/gotosocial/config.yaml
                        /gotosocial/config.yaml
```

Now add the following environment variables:

```
GTS_CONFIG_PATH         /gotosocial/config.yaml
TZ                      Europe/London
```

(Change the TZ value to suit your locale). Finally, click 'Save' and GoToSocial will restart.

08. Create the first user

Time to get a first user on our server and promote them to administrator. Not all functions are available in the web interface, although the makers are working hard on this. In this instance, we need to create the user on the command line. Go back into GoToSocial's settings and click the 'Terminal and logs' icon in the top-right. When you have the prompt, enter the following command:

```
 $ ./gotosocial --config-path ./config.yaml
admin account create --username pj --email
pj@social.mkraspberryjam.org --password
'mysupersecretpassword'
```

Make sure you change the values above to match your instance! Once created, promoted the user to administrator like this:

```
 $ ./gotosocial --config-path ./config.yaml
admin account promote --username pj
```
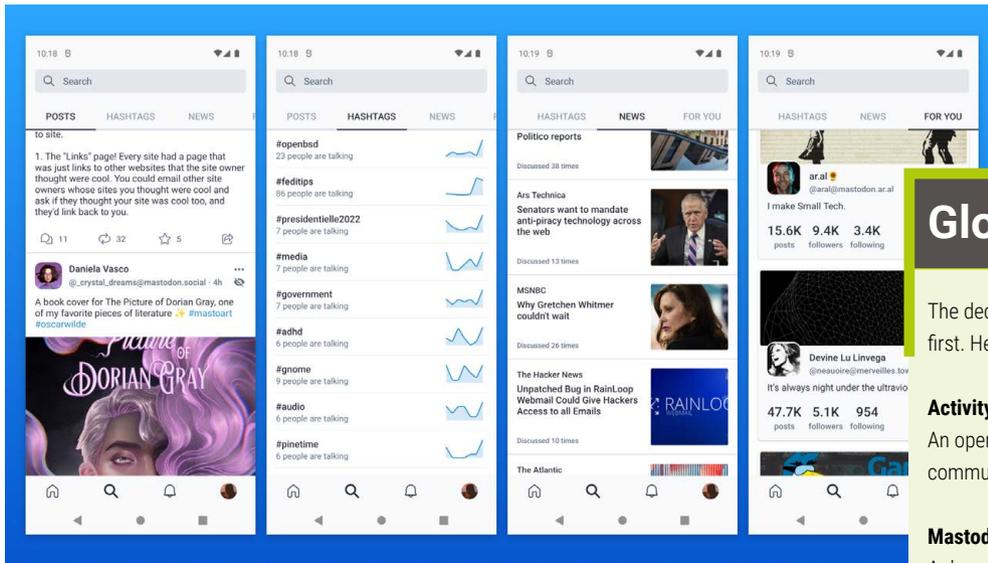
▲ The Mastodon platform provides a rich experience to rival commercial alternatives

Now restart the server (three dots > circle with arrow) and the user is ready.

09. Personalise your server and profile

We can now log in! Browse to your server's URL with '/settings' at the end (e.g. **social.mkraspberryjam.org/settings**) to get to your profile page. Accept the instance, enter your username and password then authorise the app to access your account. If you can see three different sections on the left-hand side, you're an admin! GoToSocial has many settings, far too many to cover here. It is well worth your time browsing through them and deciding what features you want to enable or disable. At a bare minimum, set your name, profile pic and bio so that people can recognise you when you start posting.

10. My first toot

GoToSocial does not come with a user client, it is a server only with some user controls. Luckily, the Fediverse is such that there are many clients available, most of them open source. The easiest one with which to get started is the browser-based Elk (**elk.zone**). Go to the site and add your account. Enter your server URL when prompted and you'll be redirected to your own server to log in (this is a secure method of authorisation called OAuth). When you come back, you'll be ready to post! Try it. Just post 'Hello world!' or something. You should see your own post appear in your timeline (and yes, posts on Mastodon are known as 'toots').

11. To the Fediverse!

So, you now have a working microblogging platform but no-one to talk to. It's time to federate. The easiest way to do this is to follow someone you already know on the Fediverse. Search for them in Elk (using the full **@username@domain** format)
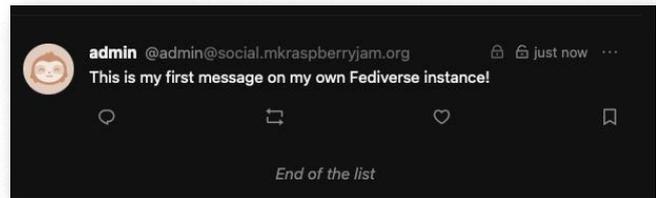
▲ Your first post on your very own personal Fediverse instance

then follow them. Your server will now be federating with their server. The more people you follow, the more servers you will be able to exchange messages with. With a bit of work and patience, your timeline will soon fill up with messages from all over the world.

12. That's all folks

This brings our series on running your own private cloud server to a close. We could go on for months about the other things you could do, but it's time to let your own curiosity take over. CasaOS provides an excellent platform for experimentation, using Docker's capabilities to avoid bricking your server as every new service is isolated, so don't be afraid to try something new! One final note: a server that isn't backed up should not be considered to exist. Try to back up at least the **/DATA** directory in CasaOS, which contains all the config and data files for your services, ideally somewhere in the cloud. Enjoy your private cloud server!

Build a home recording studio with Raspberry Pi 500

Here's what you need to know to equip your new studio, from micro to medium budgets

Maker

K.G. Orphanides

K.G. is a game developer, tinkerer, writer and sometime musician. Check out their SoundCloud.

rpimag.co/
dungeonsynth

Continuing from last month's guide to setting up an acoustically treated recording space at home, it's time to get to the hardware. Quieter than an actively cooled Raspberry Pi 5 setup in most cases, Raspberry Pi 500 is a great studio computer (other Raspberry Pi 4, 400 and 5 models also work well, if you use a silent case or no fan), but you'll need a little more equipment than that.

Audio interfaces

You'll need an external audio device. For basic voice recording, we've successfully used a pocket-sized consumer USB DAC (AudioQuest DragonFly Red, £135) and a USB microphone. This is enough, with the right software and driver setup, to handle vocal and spoken word recording, editing, and mixing without any quality or latency issues.

More sophisticated productions require more gear. A guitar can also be connected via a USB guitar lead, and USB XLR microphone leads are also available. These generic devices are available from brands including t.bone, Lindy, and Behringer for around £13, and they're functionally interchangeable. If you have a condenser mic that requires 48V phantom power, you'll need an additional power unit.

This is a point in favour of dedicated audio interfaces, such as the Focusrite Scarlett 2i2 (£159), currently in its 4th generation, which has two powered XLR inputs, two TRS or TS inputs, a stereo pair of TRS outputs, a TRS headphone port,

> *For vocal work in a sound-treated room, we recommend a large-diaphragm condenser mic*
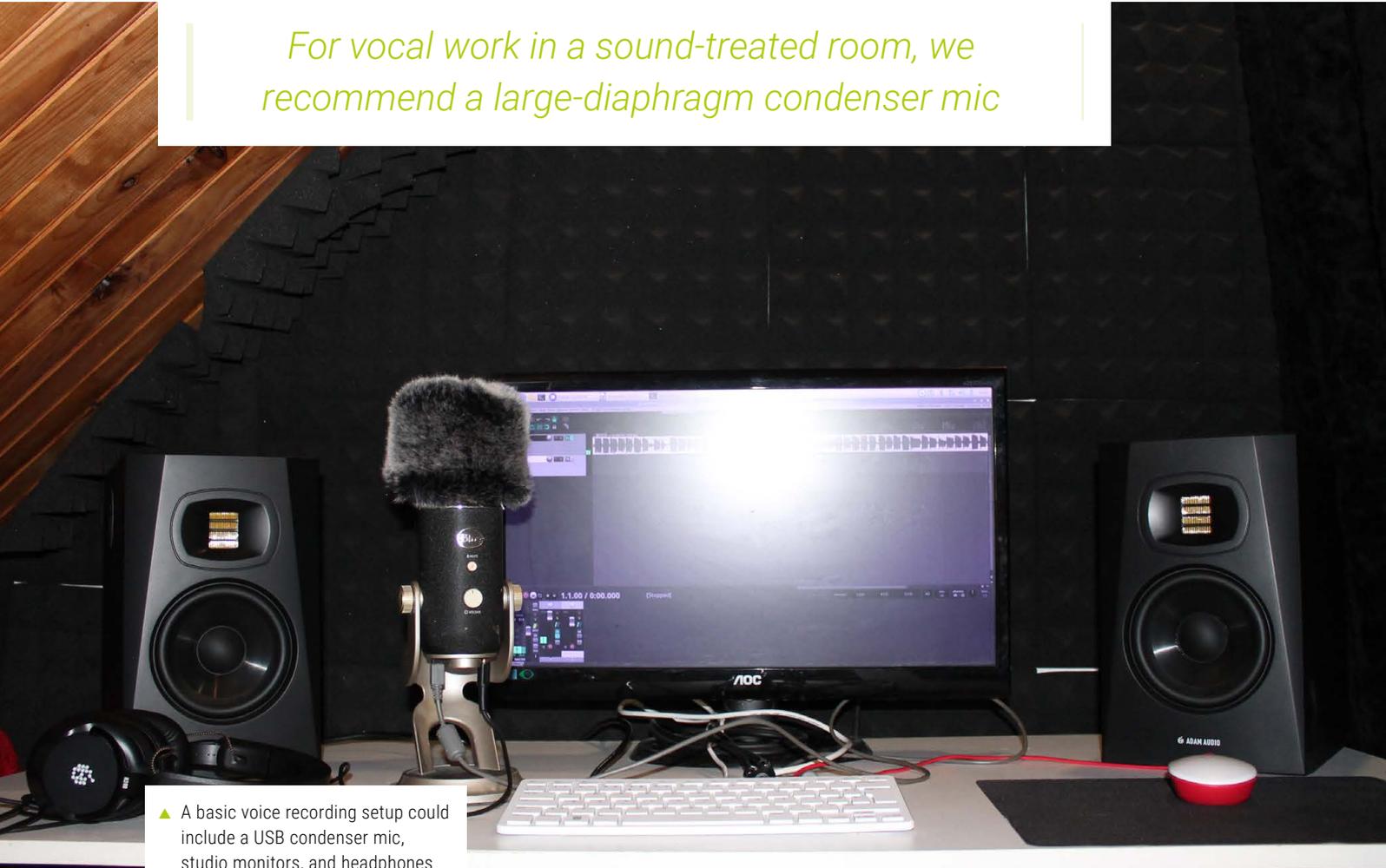
▲ A basic voice recording setup could include a USB condenser mic, studio monitors, and headphones

and can record two live inputs at once. You can save money by getting an older model, and even those with software controls are supported thanks to a Linux driver project. Other good entry-level audio production interfaces are made by Behringer, Presonus, Steinberg, and Roland.

Instruments

Assuming you already have the instruments you play, you'll mostly either need to consider mic'ing up acoustic instruments and making sure you have an interface with the right connectors for your electric instruments.

If you primarily compose using MIDI step entry and plan on mostly working with loops or in your DAW's notation or piano roll interface, you don't necessarily need any instruments, although a MIDI keyboard can come in handy. We opted for a lightly weighted, 49-key Novation Launchkey 49 Mk4 (£222),

designed for use as a DAW controller. MIDI instruments can be connected via integrated USB, Wireless USB, or traditional MIDI ports assuming your audio interface has them – our Focusrite Scarlett 2i2 doesn't, so we used USB.

Make sure that you have enough space for any instruments you need, add floor- or wall-mounted instrument stands as required, and ensure that your audio interface is equipped to handle them.

Microphones

Dynamic microphones use a magnetic coil to pick up sound, while condenser mics use a lighter, thus more sensitive, electrostatically charged diaphragm. Dynamic mics are robust, highly directional, and well suited to the rigours of a stage environment. They're not favoured for studio use, as they're less sensitive to sound than condenser

mics and have a narrower frequency response. But if you frequently have background noise in your environment, the reduced sensitivity of a good-quality dynamic mic could result in a better-sounding overall recording. We use a Shure SM-58 for vocals and SM-57 for mic'ing amps and instruments, as these live workhorses sound great and border on indestructible.

For vocal work in a sound-treated room, we strongly recommend a more responsive large-diaphragm condenser mic, connected via either USB or XLR. Entry-level favourites include the Audio Technica AT2020 XLR mic (£75), Logitech's Blue Yeti USB/XLR mic (£120), and the Rode NT-1 XLR mic (£135 including shock mount).

Headphones

Headphones allow you to monitor – i.e. listen to – whatever you're recording and let you listen to previously recorded parts that you're trying to accompany. Closed-back studio headphones won't leak sound for live mics to accidentally pick up their sound.

We used Adam Audio H200 headphones (£135) for this. Shure's SRH440s are a little cheaper, and also good for the job. However, you can use whatever you happen to have, as long as they don't leak noise and have a fairly neutral sound profile. So if you have a favourite pair of sound-isolating earbuds, they'll do perfectly well if you don't want to shell out for new cans straight away.

Avoid the kind of open-backed cans that are aimed at hi-fi enthusiasts (these tend to have a great soundstage but least sound) and on-ear headphones.

Studio monitors

Eventually you'll also want studio monitors: speakers with a neutral audio profile designed to make the job of mixing music easier – no bass boosts or hi-fi EQ tweaking.

We're using Adam Audio TV5 (£135 per powered speaker – £270 for two), which are about as big as our desk will comfortably hold, measuring 290 × 180 × 270mm. These are near-field monitors, designed to accurately reproduce the full frequency spectrum of your music at a low volume, close to your head, so you don't need to blast your ears apart.

We've also run with larger monitors: Behringer's Truth B2030A monitors (£281 for a pair) are much larger powered loudspeakers, measuring 317 × 214 × 211mm. Their sound is a little less precise than the Adams, but is still appropriately neutral at low volumes and is a solid choice if you're working in a larger space.

▲ If you just need to connect a single guitar or bass, generic USB interfaces are conspicuously cheap and work well

▶ We're using a desk mic here with a solid stand with a heavy anti-vibration base, plus a mic cover

If you're on a budget, Mackie's compact CR5-X speakers (£159) fall between computer speakers and monitors, and are reasonable choice for the money if you're not doing high-precision work.

Other equipment

To go with your microphone, you'll need a mic stand or boom arm. Options include desktop mic stands, booms with screw clamps to hold them to the edge of your table, ceiling-mounted booms, and a variety of floor-standing mic stands. Most condenser mics are threaded, but you'll need a microphone clip to attach to the stand if you're working with a traditional dynamic stage mic, while condenser mics will benefit from shock mounts.

Another consideration for your mic is a pop shield or cover to soften plosives (hard consonants such as p, k, and t).

You'll need the appropriate cables – there's nothing more frustrating than buying cool new gear that you can't use – and any relevant adapters, such as 3.5mm to 1/4-inch TRS stereo adapters for headphones, if yours don't come with one. ◙

Glossary: audio encoding terms

PCM – pulse-code modulation. A digital representation of analogue sound sampled at a specified rate and bit depth. Uncompressed file types used for PCM include WAV and AIFF.

Sample rate – or sample frequency. The average number of samples taken in one second to digitise analogue sound. CD audio has a sample rate of 44,100 kHz (44,100 samples per second), allowing it to accurately reproduce audio frequencies of up to 22.05 kHz – the upper threshold of human hearing. High-resolution audio formats use sample rates of up to 192 kHz, but higher sample rates are most often used during production. 48 kHz is sufficient to capture all audible frequencies in principle, but if you have sensitive recording equipment and an interest in psychoacoustic theory, you may have a reason to record at higher frequencies. Note, though, that high-frequency recording results in rapidly ballooning file sizes.

Bit depth – the number of bits used to encode each sample. CD bit depth is 16-bit, but lossless digital formats such as FLAC are typically 24-bit. Higher bit depths can capture a broader dynamic range.

Glossary: hardware audio encoding and decoding

DAC – digital-to-analogue converter: converts data into sound that you can listen to via speakers or headphones.

ADC – analogue-to-digital converter: captures an analogue sound and digitises it at a specified sample frequency and bit depth.

CODEC – a single-chip audio coder and decoder including the features of both a DAC and an ADC.

Custom CNC machine

Last issue we dived into developing a custom CNC machine – now we'll turn it into a prototype carbon filament winder

Maker

Jo Hinchliffe

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, robots and much more besides, he often releases designs and projects as open-source.

concretedog. blogspot.com

I n the first part of this two-part mini series, we set out designing various parts for a custom CNC machine that is intended to act as a carbon filament winding machine for making custom carbon-fibre tubes. We got as far as creating a machine bed and frame from aluminium extrusions and then created a sliding bed that would travel the length of the machine on V-slot wheels and also designed a rudimentary tail and headstock idea to create a spindle.

The principle of the machine is that carbon tow (a small ribbon made up of thousands of carbon fibres) will be wrapped off a reel onto a mandrel (a small tube) with epoxy applied. The tow will be applied to the mandrel in patterns of movement where the mandrel turns and the sliding bed moves back and forth, allowing the tow to wrap around the machine. Research indicates it's a good idea for the carbon tow to be applied at variable angles to the mandrel and so some form of turning head to change the angle is needed. Ultimately the carbon tow could flow through a reservoir of epoxy resin en route to the mandrel, but it's common to start off applying the tow dry to practise, and making first tubes by just painting epoxy onto the tow and mandrel whilst it's turning. As such, we aren't going to create the reservoir system until we have had a lot of practice runs.

In the last part, I began to devise head and tailstock parts to mount and drive the mandrel assembly. Opting to have, for

It's a good idea for the carbon tow to be applied at variable angles to the mandrel
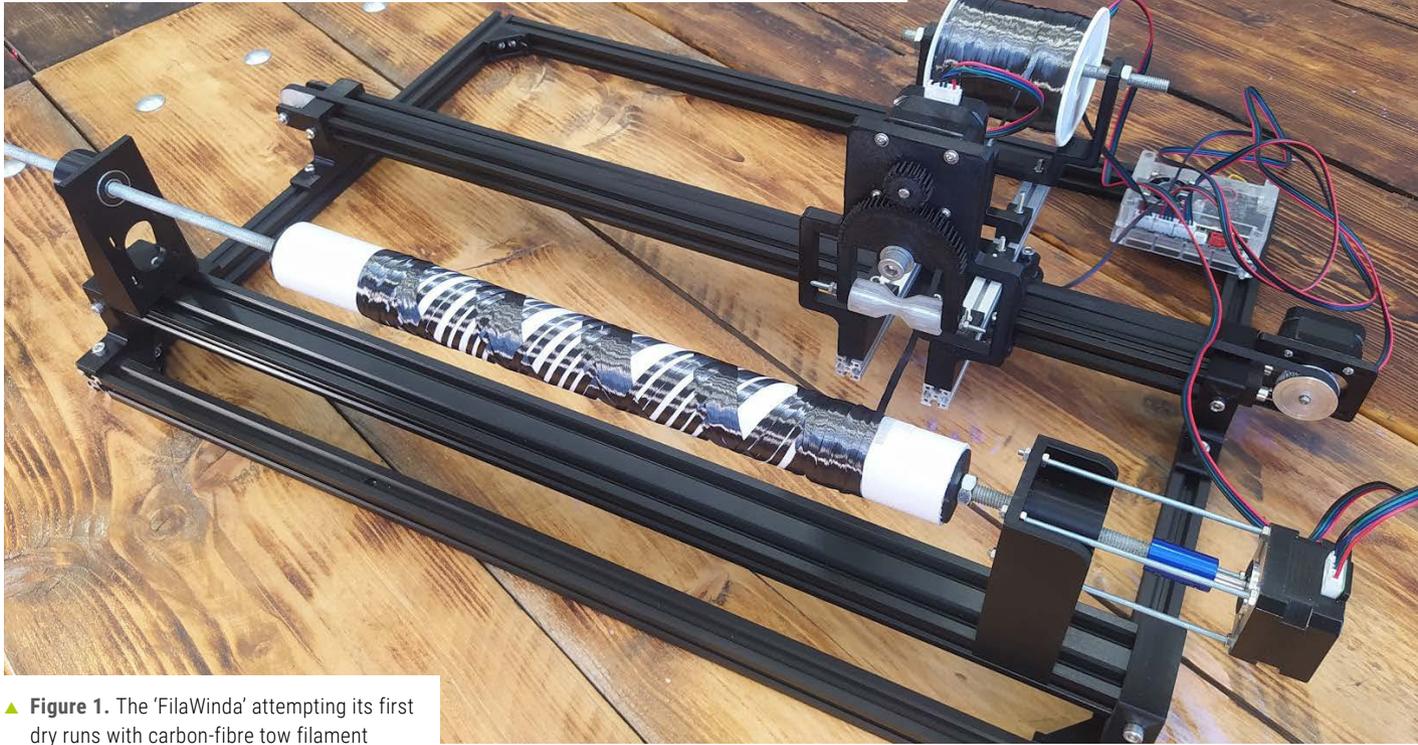
▲ **Figure 1.** The 'FilaWinda' attempting its first dry runs with carbon-fibre tow filament
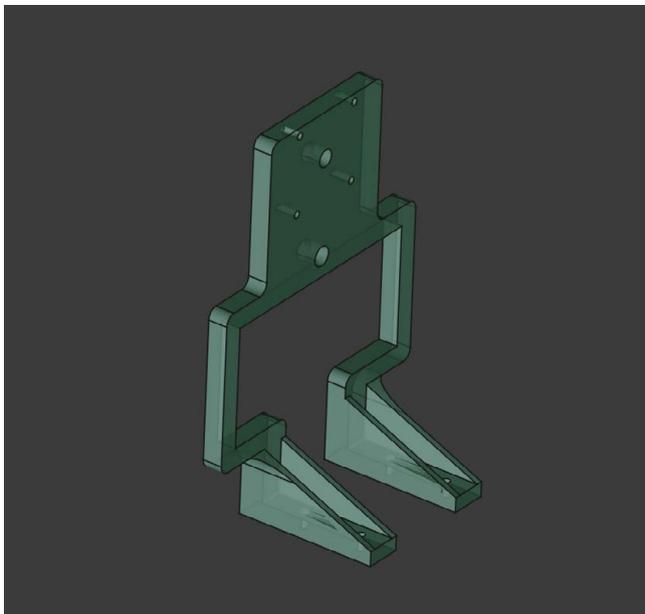
the headstock, a stepper motor mounted underneath the shaft and then use some GT2 gear pulleys and a belt to turn the spindle. After some consideration it was realised that this perhaps added some unneeded complexity and it was possible to direct drive a threaded rod with an inline stepper motor, **Figure 2**. Being quite happy with other aspects of the head and tailstock design, I made the new headstock to match the centre spindle height of the older design which could still be used as the tailstock. The head and tailstock are both fitted with two skateboard-style bearings which are a press-fit into the design and have an 8mm centre hole. Adding a length of 8mm threaded rod through the head and tailstock means we can then mount

◄ **Figure 2.**
The second headstock design with a direct-drive inline NEMA 17 mount

⚠

Warning!
Moving parts
Be careful when handling this project because it has moving parts. Children should be supervised.
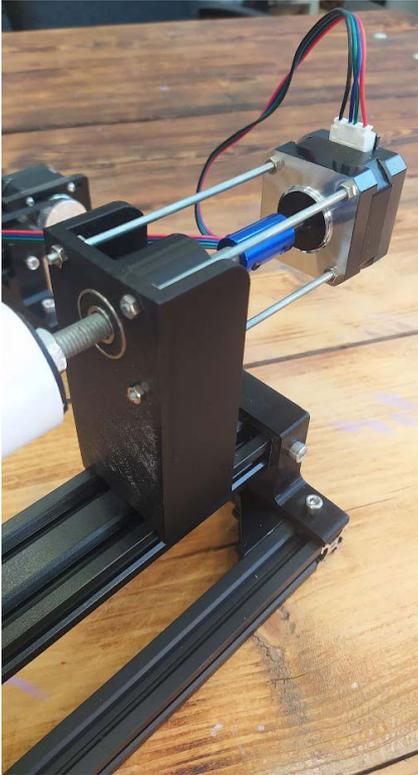
mandrels of different sizes onto the system. In the headstock, I designed mount points for a NEMA 17 stepper motor which is mounted on some short lengths of M3 threaded rod. Finally, a small commercial 5mm to 8mm coupler is used to connect the stepper motor to the shaft, **Figure 3**. To remove the shaft to place a different mandrel system on it, I can just undo this connector and pull the shaft out from the tailstock end. At some point I could replace the connector with a flexible type which will even out any small amounts of non-concentric movement between the motor and the threaded rod.

Come on you gears!

There were a few iterations and thought processes undertaken to create the main angle head assembly. Wanting to have a replaceable roller that could be positioned at variable angles, I needed some kind of geared roller holder to be

◀ **Figure 3**. The 3D-printed headstock with skateboard bearings, a threaded spindle, and inline NEMA 17

driven by a stepper motor. FreeCAD has some excellent tools for working with gears, and the design of the roller holder and drive gear was greatly assisted by the FC Gears add-on workbench. This workbench, once installed, allows you to quickly generate standard gears of varying types and, of course, then use additional FreeCAD tools in other workbenches to add geometry.

For the main roller holder part, I first created a 60-tooth pinion gear that was 8mm thick. Moving to the Part Design workbench, I created an active body and dragged the gear part into it. It's then possible to map sketches to faces of the gear and do the usual padding, extruding and pocketing operations to create the needed geometry. I first created a sketch with which to perform a pocket operation, creating both the centre hole in the gear and removing of the bottom half of the gear, **Figure 4**. Mapping a sketch onto the base of the half gear allowed the creation of the straight legs that in turn had holes added to receive a small length of M3 threaded rod to hold the roller. A simple fillet finished off the part with a stand-off around the hole. It's interesting that whilst this might look like a pretty complex part to design, it's actually a very simple job in FreeCAD.

Jumping back into the FC Gears workbench to create another smaller pinion gear which would be push-fit onto the 5mm shaft of a NEMA 17 stepper motor, I began to think about how these parts would be assembled into position. I needed to know what distance to set apart the centres of the mount holes for both the pinion gear and the roller holder
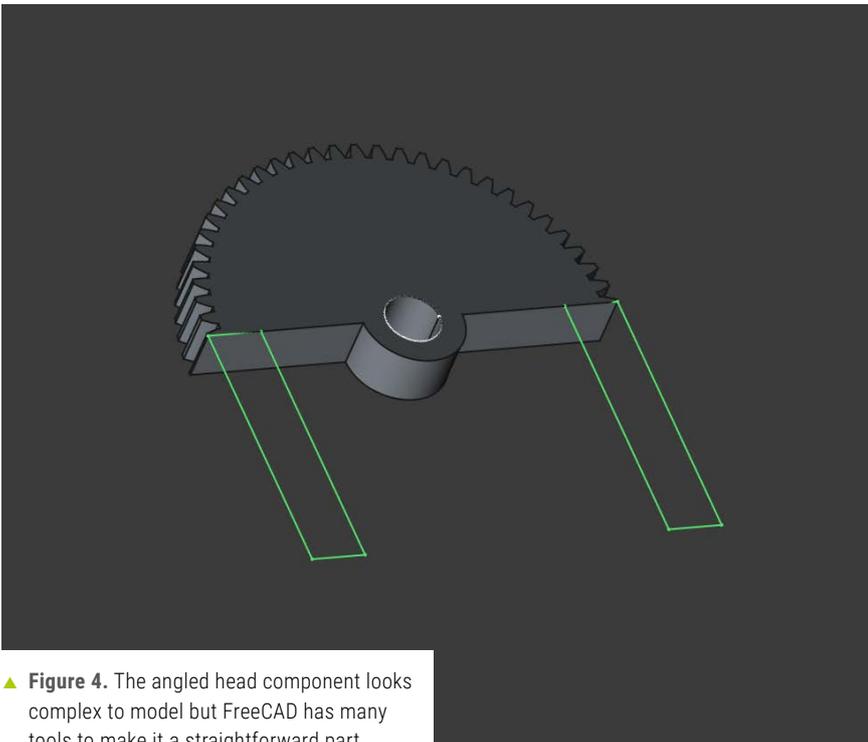
▲ **Figure 4**. The angled head component looks complex to model but FreeCAD has many tools to make it a straightforward part

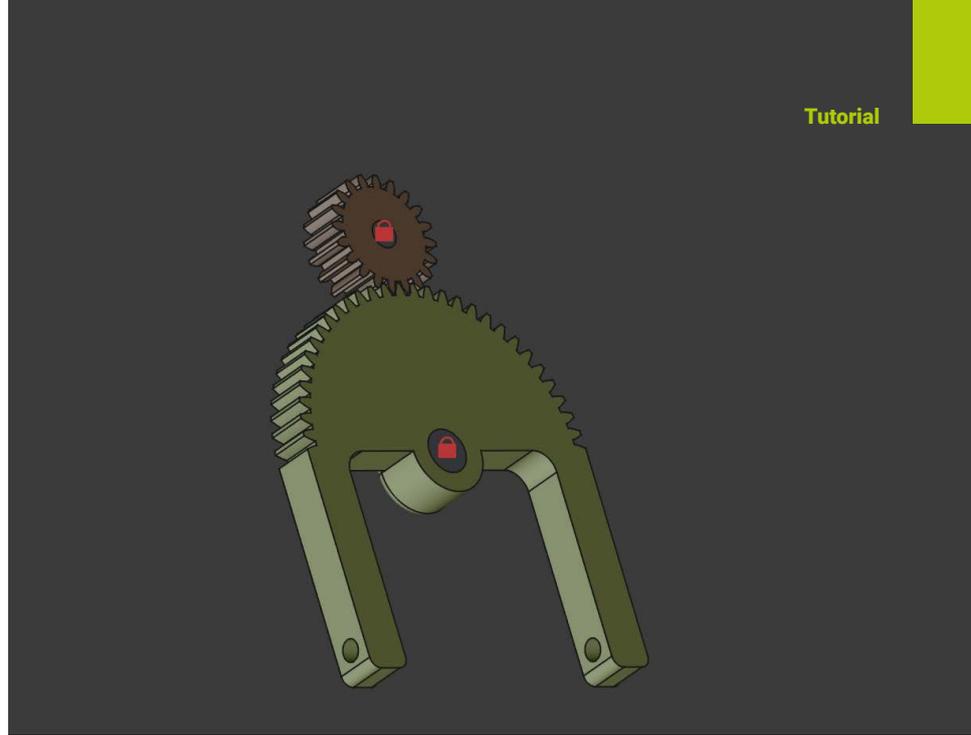parts. Whilst I could make educated guesses, a simple way to do this a little more accurately was to create a small assembly of the two geared parts in FreeCAD and then measure the distance between the centres once happy with the meshing of the gears. With the latest 1.0 version of FreeCAD, there is a new Assembly workbench which makes this pretty straightforward to achieve. I created and locked in position two cylinders to act as shafts for the geared parts and then constrained the gears onto the shafts, **Figure 5**. I could then adjust the shaft distance until satisfied and then use the new universal measuring tool in FreeCAD to check the distance and note that dimension for further CAD.

Roll with it

Making the frame to complete the main angle head was largely straightforward. As the roller holder articulates from side to side, it needed a large window in the frame to create space for the roller and threaded tow to be able to move through the frame unimpeded. The top section of the frame utilised the discovered dimensions from earlier to set the position of the NEMA 17 mount and the gear and the geared roller holder. In the first part of this series, I added some short lengths of 15 mm extrusion to our sliding bed and this served as the mount point for the main angle head frame assembly via some M3 fasteners. To mount the angle head assembly we simply used a M8 bolt, a couple of washers, and a nut. Whilst it should, after years of 3D printing, seem mundane to be able to print parts that fit well first time, it's still pretty cool to be able to print all this and put it together with gears meshing correctly first time, **Figure 6**.

The actual roller that the carbon tow will pass over will eventually be a disposable item as they will come into contact with epoxy resin; however, they are a pretty small part that is
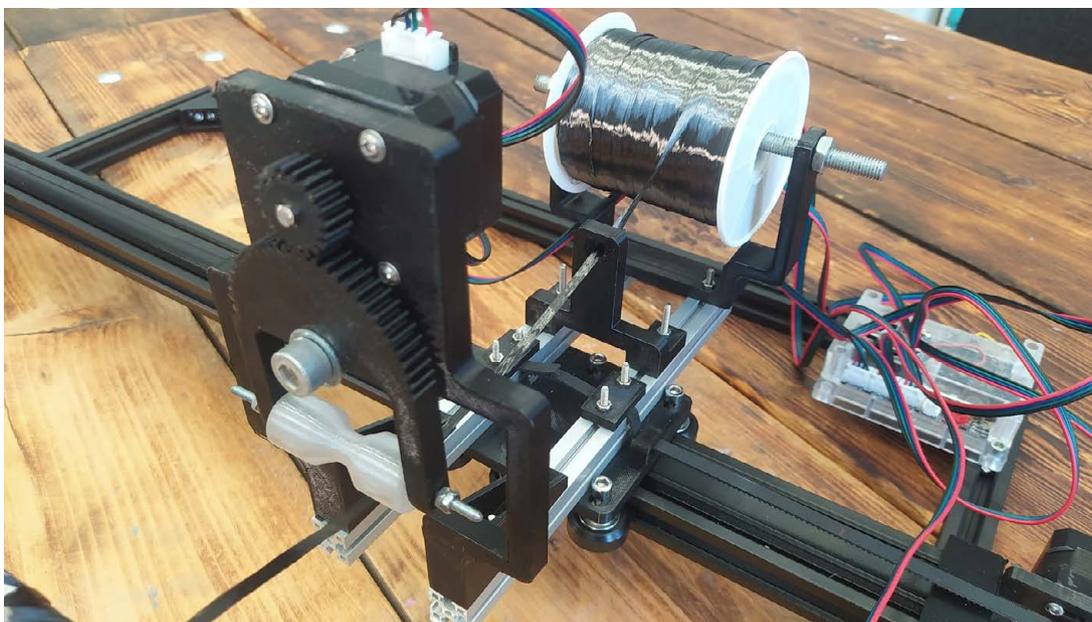
◄ **Figure 6.** The final assembly of the angle head and prototype filament delivery components

Figure 7: Creating a centring roller for the carbon-fibre tow to run over

easy to design and 3D-print, **Figure 7**. We sketched half of a profile of a prototype roller in FreeCAD and then used the mirror tool in the Sketcher workbench to complete the profile. A simple use of the revolve tool completed a first design attempt. The idea of the roller is that the angled edges try to keep the carbon tow in the centre of the roller mechanism. Finishing off this first iteration of the carbon tow delivery system, we created a simple bracket that could mount to the other end of the 15 mm rails to hold the reel of carbon tow.

Belt drive

One final job was to add the belt drive system to the long cross slide. The driven end of the system has a NEMA 17 mounted with a 40-tooth GT2 pulley in place. At the far end of the cross slide we have a 3D-printed matching idler pulley. I designed the idler pulley again using the FC Gears workbench that has a built-in tool for creating GT2 and other pulley/timing gear wheels. GT2 belting can be bought pretty readily online and

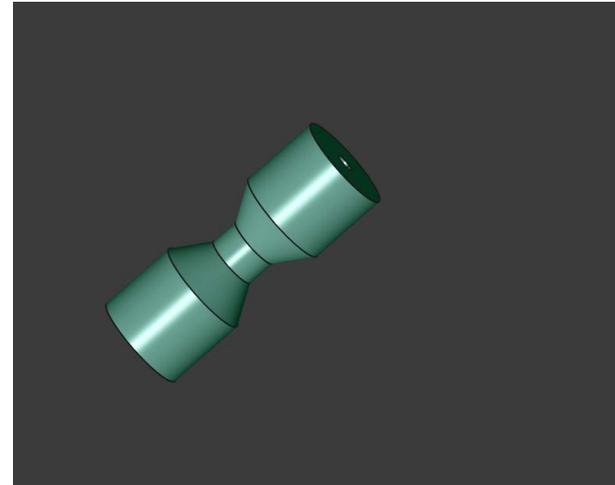we bought a few metres of 6 mm wide belting. We designed some small loops on the edges of the sliding bed plate and had originally planned to double the belt through the loop and clamp it back to itself for tension. A happy realisation was that it would be pretty easy to create a couple of clamp blocks and simply pass the GT2 belt over the top of the 15 mm rails each side and clamp it under tension. This worked pretty flawlessly, **Figure 8**. After some testing, I realised it was unnecessary to have the idler pulley with teeth as this made it more likely for movement along the long X axis slide to cause skipping. A quick redesign and the idler is now a blank smooth pulley for the GT2 belt to roll over.

This marked the point where I could mount all the NEMA 17 stepper motors and wire them back to a controller. A while ago, in issue 147, you may recall we converted a small lathe to CNC and used a cheap GRBL Woodpecker control board for control and explored creating custom settings and custom G-code to control the machine. For this carbon winder project, it's a similar process. Remembering this is a prototype GRBL

Figure 8. Simple blocks with a small groove on the underside snugly clamp the tensioned GT2 belts

can certainly get the machine moving to begin to work out how to create wound patterns. One slight hack is that it is using the Z axis as the rotation of the mandrel; this would probably be better served with the mandrel being driven by a non-stepper motor and using an encoder to then synchronise the rotations with the rest of the machine motion. However, for now, we simply set the number of steps per millimetre for this axis as the number of steps for one complete rotation; this means that we can issue simple G01 20 type commands and the Z axis will rotate 20 times. To the angle head and roller, simple experiments are undertaken with GRBL and the Universal GRBL sender to work out travel and desirable angles.

With any CNC machine I always suggest performing some 'air cuts'. On our CNC lathe this looked like running the machine with no stock and no cutting tools attached so the machine runs the code and you can observe to see if it's behaving as expected. It's no different with this machine; I performed a lot of 'air winds' to check movements. In the current stage of development, at time of writing, I've moved on to 'dry winding' where I am winding carbon tow around a mandrel, but without any epoxy, **Figure 1**. This means I can get a real sense of the winding operations as I experiment, but it's all non-permanent, I can then (slightly laboriously) rewind all the carbon back onto the reel by hand to save waste. Immediately after adding the carbon tow, it was obvious that the tow needs to be under some tension to stop it moving around on the mandrel, causing slight irregularity in the winding patterns. I've made an additional loop/ guide for the tow to travel through en route to the mandrel which also helps

to regulate the angle of the two arriving at the roller. I'm not sure the roller is actually needed; it may be better to have some form of slotted part the tow travels through on the angled head, and indeed, this might also be used as a 'squeegee' to remove excess epoxy.

It's been a fun project so far and all through the process I am reminded of how awesome it is that we can undertake these types of builds using relatively affordable 3D printing and using free and open-source CAD, CAM, and G-code tools. Speaking of open source, there are a lot of parts in this project and some still need revision; keep your eye out as at some point in the future I'll release the 'FilaWinda' source online. I can definitely recommend trying to create your own CNC machine, though: it's excellent fun! ⬡

Improvisation as design!

You may have realised at this point that indeed this is all being made up as I go along. It's certainly true that I am approaching the pattern-winding aspects of the project 'empirically'. This is a posh way of saying I am writing some G-codes, sending them to the machine, and seeing what happens. It's certainly possible to approach the pattern creation from a more mathematical standpoint, but getting a feel for what works at different scales is a valid approach. I can imagine with some extended tinkering I can find acceptable approaches and then perhaps create a spreadsheet or script that creates G-codes for given dimensions and given patterns of tube, but for now, playful tinkering it is.
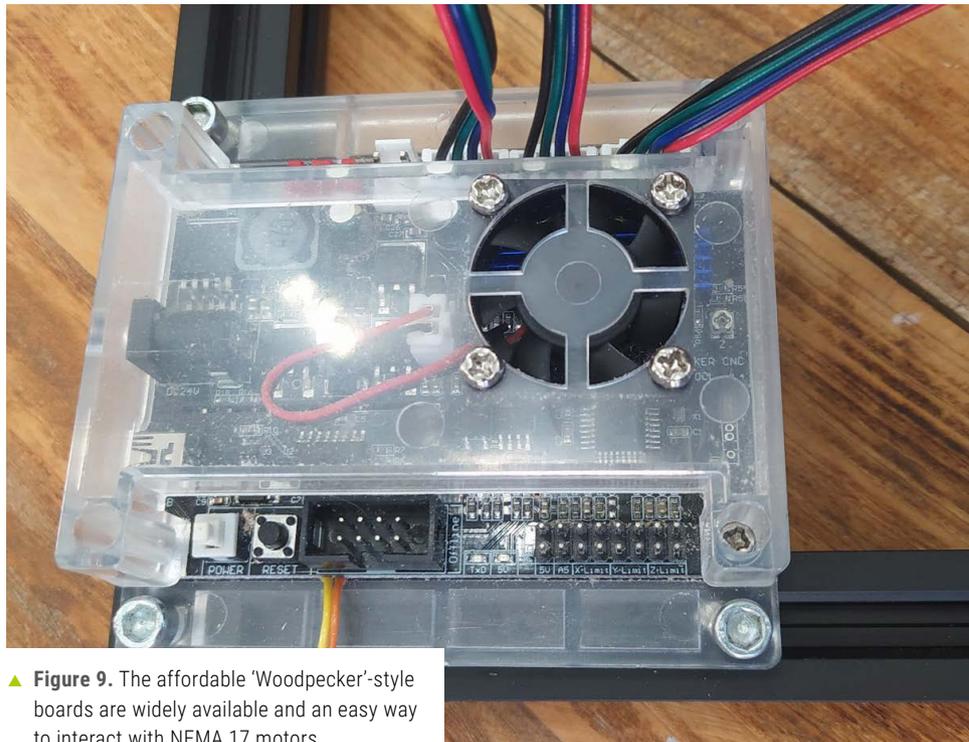
▲ **Figure 9.** The affordable 'Woodpecker'-style boards are widely available and an easy way to interact with NEMA 17 motors

Dehydrating fruit, vegetables, and herbs

With an electric food dehydrator, capture optimum seasonal flavours and enjoy them throughout the year

Maker

Nicola King

Nicola is a freelance writer and sub-editor. She's been slicing, chopping, and powdering this month – if only she had a pantry…

@holtonhandmade

Dehydration as a food preservation technique is as old as the hills, a way of extending the life of foods because, if the moisture is removed, this obviously inhibits the growth of bacteria, mould, fungi, and all those microorganisms that can cause decay when a food is left uneaten for too long.

Dehydrating foods is very easy to do, and you can create some lightweight and portable snacks – great for when you are out walking or camping, for example. The dehydrated form of the foods we will consider still holds a high percentage of its nutritional value. It's also a way of reducing food waste when you have bought (or grown) too much of a particular food, with the added benefit that the taste of many dehydrated foods can be much more intense and concentrated. Dehydrating food yourself can also help you avoid preservatives and save money against the high cost of the dehydrated foods you can buy in shops, some of which may contain added sodium and sugar.

An appliance of science

A food dehydrator is a piece of equipment that pulls the moisture out of foods, drying them at a low heat level so that the nutrients are preserved as far as possible. The key thing to remember is that dehydrators do not cook the food. Instead, they draw air in through the bottom or side of the machine and circulate that air with a fan, and at the same time a heating element is working at very low temperatures, so it's all about heat and airflow. They also, depending on their wattage and size, use very little power – the machine used for this tutorial only used three-quarters of a kilowatt-hour over a six-hour period (costing about 18p in the UK).

Bear in mind that we get a lot of water from some foods and by dehydrating them, we are actually reducing our water
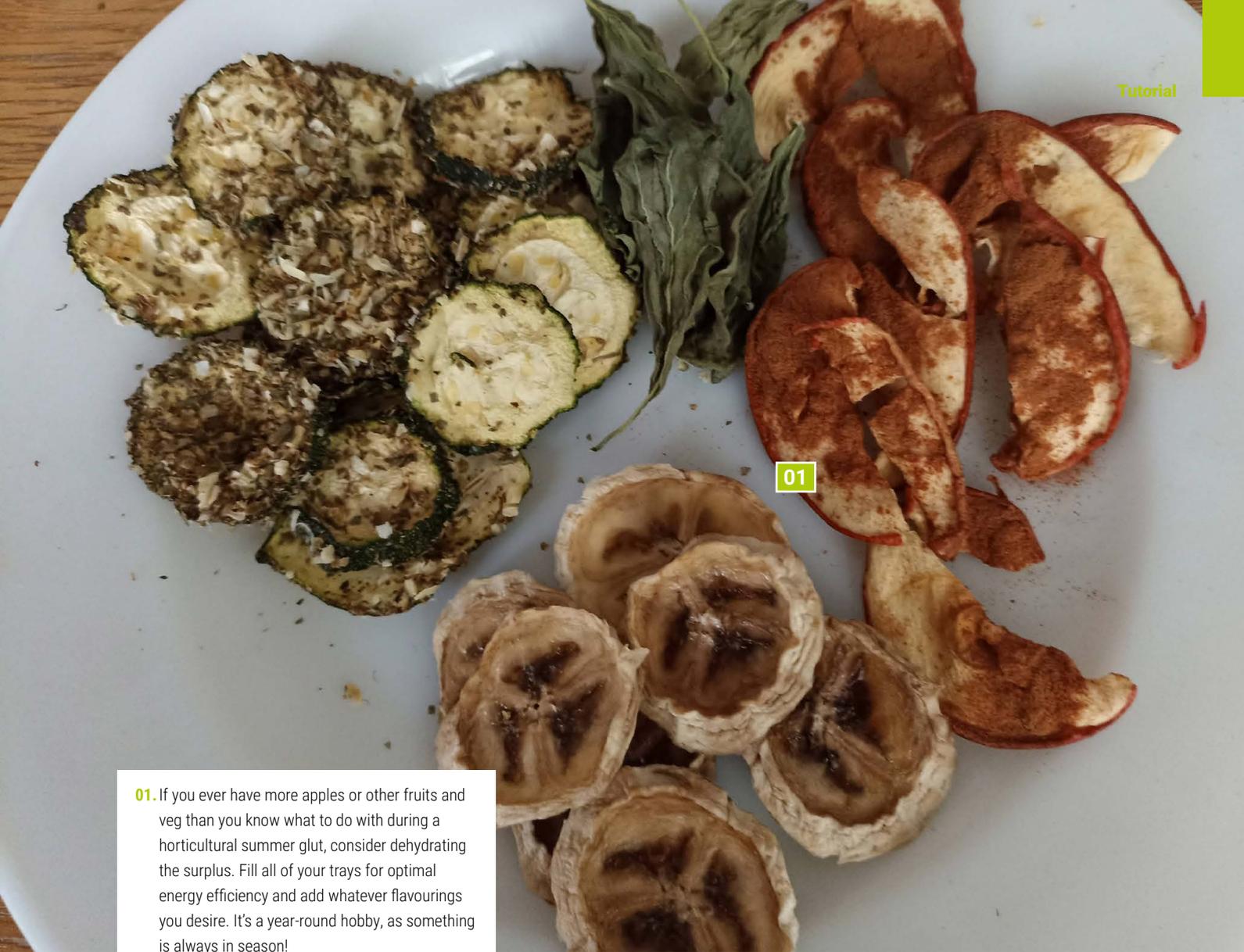
01. If you ever have more apples or other fruits and veg than you know what to do with during a horticultural summer glut, consider dehydrating the surplus. Fill all of your trays for optimal energy efficiency and add whatever flavourings you desire. It's a year-round hobby, as something is always in season!

intake, so do make sure that you drink enough water outside of snacking on your dehydrated fruits and vegetables. Also, when using an appliance like this, make sure that you either dehydrate savoury or sweet foods at any one time, not both – the flavours can transfer in the circulating air, so avoid mixing your foodstuffs if you don't want your apple snacks to taste of onion..

Don't skimp on the prep

Before you begin, do clean and dry all surfaces and equipment, also washing your hands as often as you need to when preparing your foods. The very first fruit that we tackled was the humble apple, and this is a great beginner project. We first created a lemon juice bath to soak the apple slices in, and basically used one part lemon juice to four parts water. When that was ready on standby, we washed our apples thoroughly and used a slicer/corer to split them into manageable pieces and to remove the core and seeds. The key to dehydrating foods successfully is to ensure that all of your pieces are as uniform as possible in terms of shape and not too thick, or

YOU'LL NEED

- A fresh fruit, vegetable, or herb to dehydrate
- Lemon juice (for fruit citrus baths – optional)
- An electric food dehydrator (trays washed before first use)
- A clean, airtight container to store the dehydrated product in (glass advised)
- Basic kitchen utensils (e.g. sharp knife, apple corer, tongs etc.)
- Fruit/vegetable cleaning brush (optional)
- Baking/parchment paper (optional)
- Spices/sugar/flavourings (optional)

◄ We purchased an inexpensive machine online, and here it is fresh out of the box, with the plastic trays already rinsed in some warm, soapy water, and ready for action. There are five layers, or trays, to this model and its dimensions are 31 cm in height and 28 cm wide – not exactly a small footprint in the kitchen. It uses around 345 watts of power

▲ A close-up of the temperature options. We read one review on this appliance where the user had found it ideal as a tool for drying out his 3D printer filament, in a well-ventilated room of course! Obviously, you would not then use it for food dehydration afterwards

they'll take longer to dry out. We sliced our chunks a little thinner, maintaining a constant thickness, and then plunged them into the lemon juice mix for around five to ten minutes. It's important to do this if you are keen to avoid the enzymatic browning that usually occurs when an apple is cut and oxygen is introduced into the tissue of the fruit, causing oxidation.

Next, we'd read that using a liner sheet of baking or parchment paper in the plastic trays makes the latter a little easier to clean. It also makes it much easier to grab your finished fruits and veg out the trays, so we hand-cut some very rough circles that fitted inside them, and were then ready to place the fruit slices on top in a single layer with space between each piece of apple. It's not necessary to add any flavourings, but a match made in heaven is apple paired with cinnamon, so we added a sprinkling over the top of the slices once they were in the tray. (If nothing else, the heavenly cinnamon scent that pervaded the kitchen was worth the effort.) You could add anything you like to dehydrating fruits and vegetables,

including other spices such as nutmeg, or even sugar if you have a sweet tooth. We then set the dehydrator to around 50°C and left the machine to do its work, checking back every hour for the first few hours just to ensure all was well.

Not too hot, not too cold

It's worth talking a little here about the temperature to set when dehydrating your foodstuffs, as it's crucial to dehydrate at the correct low temperature and hitting that happy medium can be down to some trial and error. Certainly one thing that you do want to avoid is 'case hardening', which happens when the exterior of a food dries out too quickly due to too high a temperature being set, causing the formation of a tough case on the outside. This then consequently prevents the inside of the food from dehydrating properly.

We left our machine on for around six hours and the apples were perfect at that point. Bear in mind that the length of time that it takes to dehydrate will depend on the wattage of the

machine, as well as the thickness of the slices you've cut. Clearly, if you can see or feel moisture, then the food is not dehydrated and you'll need to do it for longer, but there are some ways to check if it's ready and it's basically down to texture. The first tip is to leave it for five or ten minutes after turning off the dehydrator, to give it time to cool. Then, if you can snap any fruit or veg in half, it's definitely ready. Apple slices should be crisp and crunchy to bite on and if you squeeze them in your hand, there should be no bacteria-forming moisture or stickiness.

Gathered up into an airtight glass jar, we then put our cooled slices in a dark cupboard and they'll now be good for around six months or so. A tip we've picked up is to toss the

> *It's crucial to dehydrate at the correct low temperature*

jar around a bit and, if any pieces stick to the side, it's not properly dehydrated. It's important to note that if you see any mould developing in the jar a week or two after you've stored your bounty, you will need to throw the contents away.

We tried the same process with some courgette slices, but this time we 'blanched' the courgette first as a pre-treatment. This basically involves dipping it in boiling water for around a minute, then putting it into cold water – for some vegetables, this helps to preserve the colour and texture, slow down enzyme action, and shorten the drying and rehydration times. Some say it also improves the taste, but it's up to you. We then seasoned the slices with some herbs/onion powder, but you could use a stock cube, paprika… whatever you prefer.

Alternative ways of dehydrating

So, if you simply don't want to use an electric food dehydrator, or don't have the kitchen space to store one, there are other numerous ways of removing the moisture from fruits and vegetables. Let's take a look at some options:

- **Sun/air drying**. Given that these forms of food preservation have existed for thousands of years, they are clearly proven and are easily the cheapest options, if not a little slow, but we think some delicious sun-dried tomatoes might be worth the effort! If you have the appropriate consistent and predictable hot weather and extremely low humidity/dry air (sadly, not something we can rely on here in the UK!), sun drying involves laying foods such as fruits outside during the day on some kind of tray, covered usually with a mesh, cheesecloth, or something to protect them from animals/insects. You can also buy or make your own 'solar dehydrator', just like this one made entirely from recovered materials:

rpimag.co/SolarDehydrator. Air drying in the shade is a better option for drying some foods such as leafy greens, as it protects these foodstuffs from very harsh sun rays.

- **Air fryer**. Try using the gadget that adorns so many kitchens these days. From our research, it seems that air fryers can work reasonably well as food dehydrators, and some now even have a 'dehydrate' function setting. If you have the ability to set your air fryer to a low temperature/fan speed, then you are more likely to have success dehydrating foods. How long it will actually take to dehydrate any food depends on your particular air fryer, the temperature that you set it at, the specific food you are dehydrating, etc.

- **Oven**. The good old oven can also be used for dehydration, but remember that the temperature should be around or below 60°C, otherwise you'll just end up cooking

the food. Not all ovens can operate at the low temperatures required for dehydrating. You'll also need to use a rack so that the air can circulate better, and our research suggests a need to prop open the oven door too. Given that using an oven to dehydrate can take several hours, it doesn't seem a particularly cost-effective way of removing moisture, plus you'd need to constantly monitor progress and rotate the food as required.

- **DIY dehydrator**. It would be remiss of us not to mention that you can hack your very own DIY food dehydrator, just as these makers have done: **rpimag.co/DIYDehydrators**. You're probably one step ahead of us, but it goes without saying that you can also use a Raspberry Pi to control the whole dehydrating process, and it's something we may try ourselves very soon: **rpimag.co/IoTDehydrator**.

With all of that digested…

Our apple slices are delicious and contain the same calories/protein/fat/sugar/fibre as their former fresh selves. Obviously, as with anything, 'you pays your money and you takes your choice'. Our appliance was a very cheap online purchase with plastic trays, but you can spend much more and get something far more substantial made of stainless steel with a glass door, which will likely perform much more effectively. Either way, we'd recommend food dehydration as a great way of saving money, eating healthily, and reducing food waste. ◖

▲ Some thinly sliced apple pieces prior to dehydration. We dug out our apple corer/slicer and then thinly sliced those pieces before giving them a refreshing dunk in our acidic lemon/water bath. This could be done with bananas too in order to reduce the chance of browning of the fruit

Easy foods to dehydrate

We've chosen some pretty easy fruit and vegetable projects for our tutorial, and here are some more of the almost foolproof ways to succeed. Dehydrating fruits and vegetables is not quick, but it's worth the time investment and, with all of these projects, make sure you dehydrate the product well *before* it starts showing signs of turning bad, so use fresh ingredients:

Mushrooms – give them a thorough clean and get rid of any dirt particles with a vegetable brush. Slice them up (around 5 mm in thickness) and lay out on your dehydrator tray. Mushrooms rehydrate beautifully when you add them to hot water/soups/casseroles etc.

Strawberries and raspberries – a personal favourite that we use in overnight oats. This author was actually prompted to start dehydrating fruit after seeing some extremely overpriced dehydrated raspberries in a health food shop. Home dehydration results in a cheaper, sweet, and slightly tart treat that is highly recommended.

Frozen vegetables – this idea was a surprise, but dehydrating them is actually very easy, as they are pre-cut, pre-blanched, and just ready to throw into your dehydrator. When you want to use them in a soup or stew, they are then ready to go. An additional idea is that, once dehydrated, you can also powder them by throwing them in a blender and pulsing on a low speed, and you can then enhance dishes' flavour by adding the punchy nutritious vegetable powder to pretty much any savoury meal. In fact, dehydrating any greens, then powdering them, and adding them to savoury dishes is a great way of ramping up everyone's veg intake without them even knowing it! The same applies to fruits too.

Spring onions/scallions – wash them thoroughly, chop them up, and you're ready to dehydrate. Could it be any easier?

Courgettes/zucchini – wash them, slice them thinly, and add to your dehydrator. Season them with something delicious and you have some tasty vegetable chips that may be a little healthier than other chip-like alternatives.

Whilst many foods like fruits and vegetables can be dehydrated, there are also a number of other foods that should not be considered as suitable at all for dehydrating. The best way of preserving some foods is just by freezing them. Here are a few to keep clear of your dehydrator:

Fats/oils – foods containing high amounts of both or either of these should not be dehydrated as they will likely go rancid very quickly. Examples would include avocados, olives, nut butters, etc.

Dairy products, eggs, and meats – it is very important to underline that the dehydration of these is not something that should be tackled by a home dehydrator, to avoid things like salmonella and other bacteria developing.

▶ Dehydrating some fruit slices or veggies for a healthy on-the-go snack is easy and straightforward. The instruction booklet suggested it was also possible to dehydrate meat and fish with this machine, but that's a whole different ball game, for many health-related reasons, and we'd advise to avoid those dehydrating such foodstuffs unless you really know what you are doing

Hardly a new idea

We've touched on the fact that dehydrating food is something that our ancestors were doing some time ago, and it's thought that the first dalliances into dehydration occurred around 12,000 BCE in the Middle and Far East. The lack of humidity and abundant hot sun and wind would have naturally dried out certain foods. The ancient Egyptians also dried out fish, poultry, and some fruits so that they could use them long-term throughout the year, important in times of drought or famine. In Europe, clearly the weather was not as hospitable to dehydrating, so in the Middle Ages, 'still-houses' were built so that foodstuffs could be dried inside them, usually strung across the space over a fire.

Two French inventors and food preservation pioneers, Masson and Chollet are thought to have invented the first automated dehydration process around 1800 – they heated food at a high temperature and extracted the air at the same time to create a vacuum, evaporating water and preventing growth of bacteria and microorganisms. It is thought that they compressed the foods into 'cakes'.

With the groundwork laid, arguably the next major progression in terms of dehydrating came late in the 19th century, when the 'spray-drying' technique was first described. In a nutshell, this was a way of forming a dry powder from a liquid by quickly drying it with a hot gas. Spray-drying grew in popularity, with World War II seeing an increase in the use of this process as troops needed lightweight and nutritious meals, and dehydrating food obviously took the bulkiness factor out of the equation. Powdered eggs and milk were rationed for the general UK population during that war too, and were largely used because powdered food forms prolonged shelf life and bypassed issues such as lack of refrigeration options.

Since then, major leaps have been made in improving food dehydration techniques and many of us buy dehydrated and freeze-dried foods (a form of dehydration where food is frozen and then dried under pressure) on a regular basis without even considering it, e.g. spices and herbs, stock cubes, instant coffee, powdered milks, raisins, sun-dried tomatoes, and so on. And, ever since the onset of space travel, astronauts have had dehydrated food as a diet staple.

the maker toolset

Everything you need to set up your own makespace

By Rob Zwetsloot

Making is one of the most fun hobbies in the world, even if we do say so ourselves. It also encompasses so many things – from simple circuits and humble sewing to futuristic 3D printing and post-apocalyptic metalwork, you can express yourself in so many physical ways.

If you're new to the hobby, it can be tricky to know where to start – so we've put together a guide to help you get started on your maker path with some universal (and some less universal) tools and resources. What will you make?

Tools for every maker

Don't get caught without one of these essentials

Hammer

Screwdriver and socket set

▼ While traditionally used for soldering, helping hands can really help with some other fiddly tasks
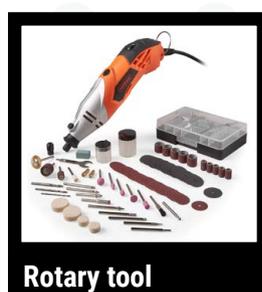
Helping hands

Glue

▲ Wood glue and superglue are indispensable for making, and sometimes plastic cement is useful too

Vice

Metal ruler

Cutting mat

Pliers

Utility knife

Rotary tool

◀ Often called a Dremel (named after the brand that also makes rotary tools), these are useful for cutting and sanding plastic, along with some drilling

Electronics tools for every maker
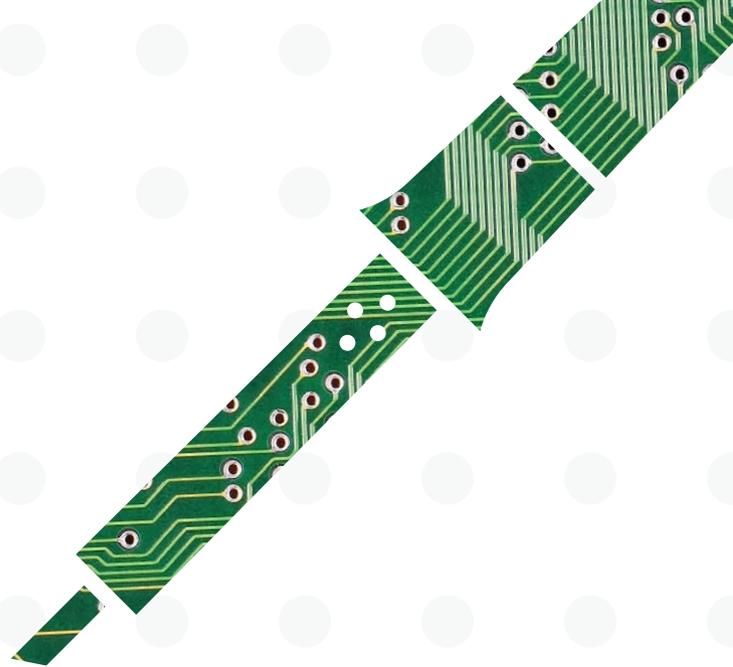
Want to make some circuits?
Here's what you'll need

Prototyping wire in various colours
rpimag.co/wires
Multicoloured wire can be very useful for following the logic of your own circuit, otherwise fixing faults can be a headache.

Breadboard
rpimag.co/breadboard
Setting up and testing circuits is easy when you don't have to solder them. We like these annotated half-size boards, with negative and positive rails along each side, and 30 rows of connected pins between them.

Soldering iron (and solder)
rpimag.co/solderiron
For when prototyping is complete and you need to create something more permanent. You can usually get kits with solder suckers, little bases to keep your (very hot) soldering iron in, and other tips. Check out this guide for how to get started before diving in: **rpimag.co/soldering**.

Wire strippers
rpimag.co/wirestrippers
With the wires, you'll need to make sure they can connect to the bread-board – or to other components when you start soldering. Wire strippers are a necessity to strip the plastic off.
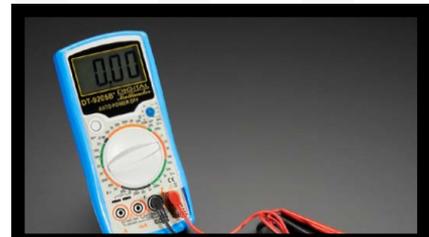
Multimeter
rpimag.co/multimeter
To diagnose issues with your circuits, a multimeter is great, being able to show you current flow, resistance, and more between two spots. Also, it can be used around the house.

Electronics starter kits

Circuits need components. You can always buy whatever a project will need; however, getting a small electronics starter kit is a good way to get some basic components that will help you with your first circuit.
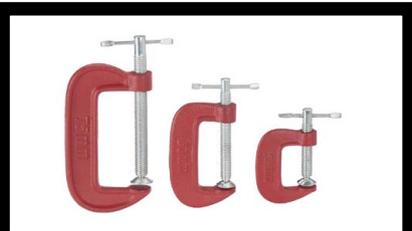
Tools for advanced makers

Take your making a step further with these accessories

Glue gun

Hot glue is your friend whether you're in a hotel room finishing up a costume at 3am, or even if you just need to quickly put some (non-metallic) pieces together. A glue gun can make your life much easier. Our top tip is to get one with at least two heat settings.

Workmate

An indispensable alternative / addition to a workbench with holes and a split so you can drill through things without drilling into a desk, or saw through things without cutting into your workbench.

Hacksaw

Need to cut some metal? A hacksaw is suited for the task over a regular saw, especially when you don't have access to a big mitre saw.

Power drill

Handy for making and for putting up shelves – make sure to get a selection of drill bits for different materials too.

G clamps

When you need to hold two pieces of anything together firmly, and it would be two awkward in your vice. Great for woodwork and for allowing glues to set and cure overnight.

Saw

When you need to cut some wood, a classic wood saw will see you through. Mitre boxes that help with cutting at specific angles are a great addition to a saw as well – and if you need to do a lot of precision cutting, a jigsaw is a worthy upgrade.

Metal model files

These are great for fine detailing on 3D prints, plastics, and wood. They come in sets of different styles – mainly round and square.

3D printer guide

Make your dreams a reality with these additive manufacturers

3D printer accessories

Spudgers, nippers, scrapers, brushes, tweezers, files, and more are very helpful for getting your 3D print off the bed, and then cleaning it up ready for use. You can get sets anywhere you can buy a 3D printer, and also on Amazon.

Software

Designing prints yourself can be fairly simply depending on what you're trying to make. Free web-based software such as Tinkercad (**tinkercad.com**) is quite powerful. If you need to make something more elaborate, Fusion 360 (**rpimag.co/fusion360**) is a popular option. Models need to be sliced as well – a process of telling the printer how to print the model – and 3D printers usually have slicing software recommended for the model.

PLA printer
Price range: £300-£2000+ / $400-$2500+

This traditional type of 3D printer heats up and layers plastic upon plastic as dictated by a 3D model. These are great for prototyping cases and containers for your project, but can be used for the final product as well! Along with a ton of little life-improving knick knacks and boats you'll find around the house like some kind of plastic *Bladerunner* origami.

In issue 80, *HackSpace* (**hsmag.cc/80**) did a great run-down of the current breed of printers and how they perform. They recommended the Prusa XL; however, some of the cheaper options like the Prusa MK4S are also fantastic printers.


Resin printer
**Price range: £250-£3500+ / $300-$4000+**

A serious printer for advanced makers, resin printers harden layers of (toxic) resin with UV light. It takes a lot longer and has its own set of quirks, but the result is usually a smoother model. Printers like this are much more expensive and require more work to finish them, involving washing the (toxic) residue off the print and letting it cure in sunlight. Rubber gloves, goggles, and sometimes a face mask are required.

The Elegoo Saturn 4 Ultra is quite well regarded and not too expensive – great for hobbyists printing small models – while the big Formlabs machines will run to thousands and are probably not great for beginners.
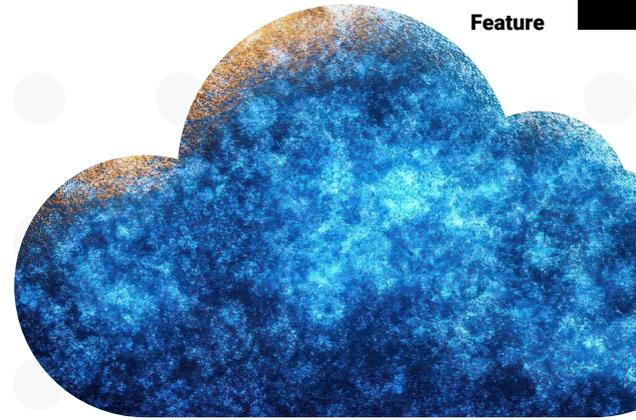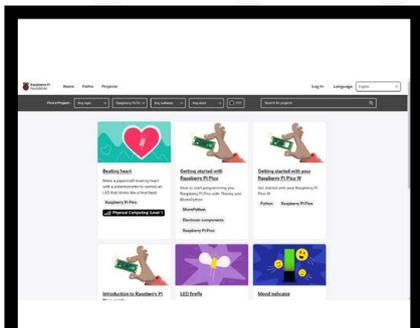
Maker resources

Places to learn and get tips, aside from *Raspberry Pi Official Magazine* of course
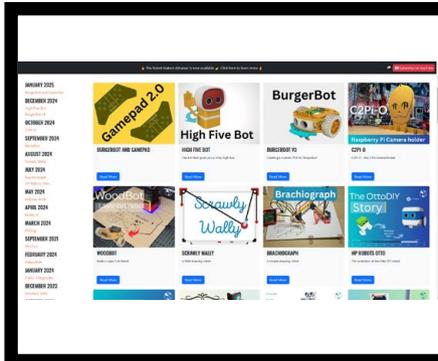
Kevs Robots
kevsrobots.com

With regular appearances in *Raspberry Pi Official Magazine*, Kev is well known in the community for tons of great robotics projects using a Raspberry Pi computer or Raspberry Pi Pico. He includes videos and write-ups for his various builds – including tiny turtle robots, moving robot faces, and a robot that will give you a high-five when you need one.

Penguin Tutor
penguintutor.com

Alias Stewart Watkiss, a regular in this magazine, builds a huge variety of simple and advanced electronics projects using Raspberry Pi and Pico. He also does great breakdowns of the builds on his YouTube channel, including where he went wrong if a project has sadly failed. Recognising and learning from our failures is something we should all do.

Raspberry Pi Projects site
rpimag.co/projects

The Raspberry Pi Foundation's project site is full of great tutorials for people starting out, covering a broad range of programming, building, robotics, and even 3D modelling in Blender. Several of the projects work as a series, allowing you to build up your skills as you go.
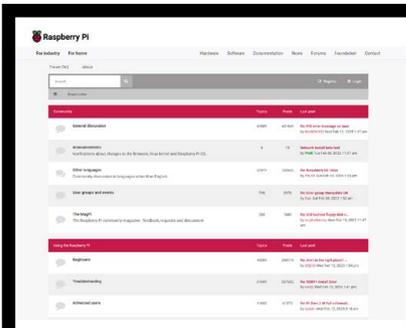
Raspberry Pi forums
rpimag.co/forums

Got a burning question about an error and not sure how to fix it? The forums for Raspberry Pi are full of active and very smart members – and they've probably answered questions like yours before! Just search the forums to check.

#MonthOfMaking

March is the #MonthOfMaking for *Raspberry Pi Official Magazine*! Send us what you're making over on our social medias or even via email if you wish. The only rules for the event are: have fun.

PROJECTS FOR MAKERS & HACKERS

Raspberry Pi 5

BUILD A
FLAT-PACK
ROCKET

MAKE ELECTRONIC
MUSIC WITH A
RASPBERRY PI PICO

BOOK OF
MAKING

2025

Pico 2

MAKE A
CONNECTED
PLANT MONITOR

BUILD SMART
HOME LIGHTING

& LOTS
MORE

FROM THE MAKERS OF HackSpace MAGAZINE

BOOK OF MAKING 2025

STEP INTO THE WORLD OF MAKING!

- CONTROL THE WORLD AROUND YOU WITH A RASPBERRY PI PICO

- BUILD YOUR OWN CREATIONS USING OUR STEP-BY-STEP GUIDES

- DESIGN FOR 2D AND 3D FABRICATION METHODS AND MAKE THEM A REALITY

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

rpimag.co/BookOfMaking2025

Mini displays

Perfect for portable projects, small screens come in many types and sizes. By **Phil King**

Some projects require an on-board display to show data, especially when it's not practicable or desirable to hook the device up to a full-size monitor or larger touchscreen. There are countless mini displays available, coming in various sizes, types, price ranges, and even different shapes. Some are HATs that mount directly onto a Raspberry Pi computer's GPIO pins; others are designed to be mounted on a Raspberry Pi Pico. Many displays are connected via individual pins, using protocols such as SPI or I2C, offering greater versatility as they can be used with a range of devices. You can even get mini displays with a standard HDMI connector.

As mentioned, there are several technology types for mini displays, including LCD, OLED, and e-ink. Adafruit even used to sell a couple of glowing VFDs (vacuum fluorescent displays), but these have since been discontinued. Each display type has its pros and cons, so selecting the most suitable one for your project is key. To help you out, we've selected a few of the best and most interesting mini displays, encompassing several types.

HyperPixel 4.0

◀ This HAT is one of the most vibrant displays around

We first covered the HyperPixel way back when, and it's still one of the best Raspberry Pi displays around. This is the rectangular 4-inch model, but there's also a square version. It also comes with optional capacitive multi-touch if you need that.

Whichever version you choose, this is a HAT that mounts onto any Raspberry Pi computer's GPIO header. Since it uses nearly all the pins to communicate, that does mean it can't be used with other HATs, but the I2C pins are broken out so you could connect a sensor.

The 800×480 display is stunning, running at 60 frames per second with great pixel density and 18-bit colour (enabling 262,144 shades). Unlike most similar screens that use the standard SPI protocol, it uses a high-speed DPI interface that enables it to shift five times more pixel data. Note that to use it with the latest version of Raspberry Pi OS, you'll need to add a line in the **config.txt** file to use the kernel drivers.

Verdict

If you want a display HAT, this is one of the best.

9/10

1.9″ 320×170 Colour IPS TFT Display – ST7789

▲ This impressive LCD works well with a variety of devices

As used in the Photon 2 Lander project showcased last issue, this lovely little LCD has vibrant colour. The only caveat is that since the LCD was designed to be used in smartwatches, you should add your own plastic or glass overlay to protect it.

While the EYESPI port on the rear is for an FPC ribbon cable, there's also a breakout header for connecting it to Raspberry Pi or Pico using seven individual pins and the SPI protocol. Since the display has a built-in frame buffer, it works well even with smaller microcontrollers with little memory of their own.

The LCD itself is of the TFT (thin-film transistor) kind and uses IPS (in-plane switching), which means the viewing angles are great: up to 80° off-axis in any direction. Its ST7789 TFT driver is supported by the Arduino library, but can also be driven by Python with a user-space Pillow-compatible library, and by CircuitPython using a displayio driver.

Verdict

A vibrant little LCD, but it'll need a cover.

9/10

1.3-inch OLED Display Module for Raspberry Pi Pico

▲ This OLED screen mounts directly onto Pico's pins

An alternative to an LCD screen is an OLED (organic light-emitting diode) one. Based around an organic compound film that emits light when an electric current is passed through it, this results in a bright display without the need for a backlight. That's why the tech is also used in many high-end TVs.

This 1.3-inch example is monochrome and limited to a 64×128 resolution, but offers great value for money and is fine for showing info like sensor and weather data. It's designed to be mounted onto a Raspberry Pi Pico (with pin headers attached), so is fairly easy to set up and program with MicroPython, C/C++, or Arduino IDE. It uses the SPI protocol by default, but can be switched to I2C by modifying a resistor on the rear. Other size versions are also available.

Verdict

A bargain option for your Pico project.

8/10

Inky pHAT

This is one of many electronic ink (e-ink, or e-paper) displays available, which vary greatly in size and come in monochrome and colour types. The big advantage of e-ink is that is uses so very little power – none at all to maintain the same image/text on the screen – making it ideal for portable projects that only need to update the display every so often, such as a calendar or weather display.

The downside is that refreshing an e-ink display isn't instant: a typical monochrome takes a second or two, while the tri-colour version (red/black/white or yellow/black/white) of the Inky pHAT takes around 15. Still, that splash of colour adds a bit of interest and you can show images so long as they're saved in a special Indexed colour mode and exactly match the size of the display: 212×104 pixels. Despite its smaller, Raspberry Pi Zero-style form factor, the Inky pHAT will work with any 40-pin model, communicating via SPI.

▲ This tri-colour e-ink display uses very little power

Verdict

A small and effective e-ink display.

8/10

HyperPixel 2.1 Round

Mini displays don't have to be rectangular or square. This 2.1-inch screen is perfectly round – essentially a 480×480 square display minus the corners – and has a real wow factor. A female header enables you to mount it straight onto the GPIO pins of a Raspberry Pi. You can even fit a Pi Zero onto the rear so it doesn't show from the front.

Like its 4-inch sibling, the HyperPixel 2.1 Round is a really high-quality LCD screen with a high-speed DPI interface that enables it to shift five times more pixel data, with a 60fps frame rate. As well as 18-bit colour, it has an impressive 229ppi pixel density and IPS for excellent viewing angles (up to 175°). It's also a touchscreen (so long as you use a legacy version of Raspberry Pi OS), so you could potentially use it for a smartwatch project.
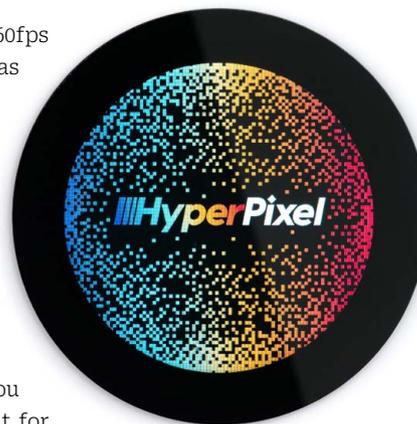
◄ It's an all-round impressive display!

Verdict

Pricey for its size, but has the wow factor.

8/10

3.2″ IPS HDMI LCD Display

Waveshare > £32 / $30 | waveshare.com

You can mount this HDMI screen on the rear of a Raspberry Pi

While most mini displays must be connected to Raspberry Pi via its GPIO pins, some have an HDMI port so you can use them just like any other standard monitor. As well as ensuring a high frame rate, this has the major advantage of freeing up all the GPIO pins to use in a project. It means the screen can also be used with other devices with an HDMI output.

This Waveshare example has a full-size HDMI port on the rear and a 3.2-inch LCD with a decent 800×480 resolution, although it's not a touchscreen. With IPS, the viewing angle range is good at around 160°. There's also an adjustable backlight enabling you to alter the brightness using a couple of side buttons.

Using the supplied standoffs, the screen can be mounted on the rear of a Raspberry Pi, with the latter supplying its power via a couple of pogo pins – or you can use its USB-C port for a separate supply.

FOUR-DIGIT SEVEN-SEGMENT DISPLAY

The Pi Hut > £3 / $3 | thepihut.com

If you just need a basic digital display for showing sensor readings, you could always go old-school with a seven-segment one. Just like an old digital clock, this one has four digits – each with a decimal point – that light up in red. As it's a multiplexed, common-cathode one, you can control all four digits with eight GPIO pins – or fewer if you use one or more 74HC595 8-bit shift registers.

For when you only need a simple digital display

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ED-IPC3100

An industrial computer based on Raspberry Pi CM5. By **Phil King**

✎ EDATEC   ⊕ **rpimag.co/ipc3100**   ¤ £232/$288 (3120 model)

▶ This industrial computer is housed in a metal case with built-in ribbed heatsinks and screw-in antennas for Wi-Fi and 4G LTE

Quick off the mark, EDATEC has already integrated the recently launched Raspberry Pi Compute Module 5 (CM5) into a new range of industrial computers. The ED-IPC3100 comes in four main flavours along with numerous possible configurations for RAM, eMMC flash, and connectivity.

The unit we're reviewing here is the IPC3120 model with 2 × RS485 and 2 × RS232 serial COM ports (as on the 3110), plus a 3.5mm audio jack and internal connectors for MIPI DSI, MIPI CSI (camera), stereo speakers, and FPC HDMI video – although all of the models feature an external HDMI port. It also boasts Wi-Fi and Bluetooth connectivity, along with 8GB of DDR RAM, a 16GB eMMC flash drive (you can have up to 64GB), and 4G LTE cellular connectivity.

The other main models in the range offer a variation on the serial ports: the 3130 has 3 × RS485 and 1 × RS232, while the 3140 has 4 × RS485. The arrangement that you choose depends on what kind of industrial-standard add-ons, such as sensors and relays, you wish to connect.

The ED-IPC3100 comes in four main flavours along with numerous possible configurations

▲ The rear of the unit has a standard DIN rail mount, along with slots for a nano SIM and microSD card

Custom board

Designed for use in challenging industrial settings, the ED-IPC3120 houses a CM5 on a custom motherboard inside a robust metal case with built-in heatsinks. The rear has a standard DIN rail mount, nano SIM and microSD slots, and a micro-USB port for flashing the eMMC. On top of the unit are connectors to screw in the supplied antennas for Wi-Fi and 4G. On the bottom, you'll find a full-size HDMI video port, two USB 2.0 ports (sadly not USB 3.0), and a handy reset button.

On the front are two Ethernet ports (one Gigabit, the other only 10/100M), the RS282 / RS485 serial connectors, 3.5 mm audio (3120 model only), and an array of status LEDs. You'll also find the only power input: two pins with a removable terminal block to connect VIN+ and GND wires from a suitable source. The good news is that it supports a wide range: 9V–36V DC.

To access the internal connectors, you'll need to open the case with a screwdriver. As well as the aforementioned connectors for the 3120 model, you will find an M.2 interface to connect an SSD, a ten-pin breakout, full 40-pin GPIO header, 5V and 12V 1A outputs, and holder for a CR1220 battery to power the real-time clock.

Booting up

Connected to an HDMI monitor, it booted up quickly into the desktop version of Raspberry Pi OS Bookworm. We found we needed to configure the Wi-Fi connection via the raspi-config menu, because the desktop tool wasn't responsive, but we soon got it working. Connecting it up to 4G (with a nano SIM card inserted) takes a little configuration via the Terminal, but is explained in the online manual.

To test out the unit's passive cooling capabilities, we ran a 30-minute stress test on all four CPU cores. It reached a maximum temperature of just 48.8°C – nowhere near the level requiring throttling, and an improvement on the IPC3020 (CM4) model we tested in issue 142. ◘

▶ The front panel has status LEDs, a two-pin DC power input, 3.5 mm audio jack (3120 model only), RS232/RS485 connectors, and two Ethernet ports

Verdict

A very capable CM5-based industrial computer range with plenty of configuration options to suit various use cases, it also offers good connectivity options and excellent passive cooling.

9/10

10 amazing:
Raspberry Pi 5 accessories

Power up your Raspberry Pi 5 with these incredible add-ons that enable extra functionality

Raspberry Pi 5 is a powerful machine, capable of incredible feats for such a tiny device; however, it's not omnipotent. While there's no God HAT to grant it this special power, there are various add-ons that will help improve it and widen the scope of what it can do.

01. FlightAware Pro Stick
Aircraft tracking
rpimag.co/flightaware
£45 / $47

It's a fun little project to create a live flight radar – it's also a decent primer on how radio signals work, and what kinds are freely available to use.

06. ICE Tower Plus Cooler
Serious heat dissipation
rpimag.co/icetower
£19 / $20

This is a little overkill for cooling your Raspberry Pi 5, but it does look pretty… rad. You thought we were going to say cool, right? Shame on you.

02. USB sound card
Stereo sound
rpimag.co/usbstereo
£9 / $9

Raspberry Pi 5 lacks a headphone jack. With this USB sound card, you can add proper speaker ports and even microphones.

07. Home Assistant Connect
Easy home automation
rpimag.co/haconnect
£30 / $31

Adding a wireless home automation standard can sometimes involve special add-on board upon special add-board, but with this USB stick you immediately get Zigbee support.

03. Flirc
Remote control
rpimag.co/flirc
£19 / $20

An easy way to add remote control support to Raspberry Pi 5, great for media centre setups using Kodi. You simply need to program the inputs on another computer.

08. TEMPerHUM
Environmental sensor
rpimag.co/temperhum
£29 / $36

There are various ways to add temperature and humidity sensors to Raspberry Pi – basic sensor components via GPIO, the Sense HAT, and also this USB stick.

04. 4˝ HDMI Round Touch Display
Circle vision
rpimag.co/rounddisplay
£89 / $93

A very different kind of display for your Raspberry Pi 5 – it's actually quite large too! Maybe it could be an interesting alarm clock or small wall clock?

09. RetroFlag 64Pi Case
Ultra protection
rpimag.co/64pi
£28 / $35

Raspberry Pi 5 has a 64-bit processor, so why not secure it in a see-through plastic case of the most famous 64-bit games console ever? Nostalgia sure is a powerful drug.

05. PiFi
Personalised router
pifi.org
£35 / $35

Turn Raspberry Pi 5 into a Wi-Fi router with PiFi – it also includes VPN and ad-blocking for a better browsing experience when you're out of the house too.

10. IR Thermal Imaging Camera
Hot photos
rpimag.co/thermalimgcam
£110 / $114

While there are many official and unofficial IR cameras for Raspberry Pi 5, this one hooks up via USB-C instead of the CSI port, keeping the latter free for… a different camera perhaps.
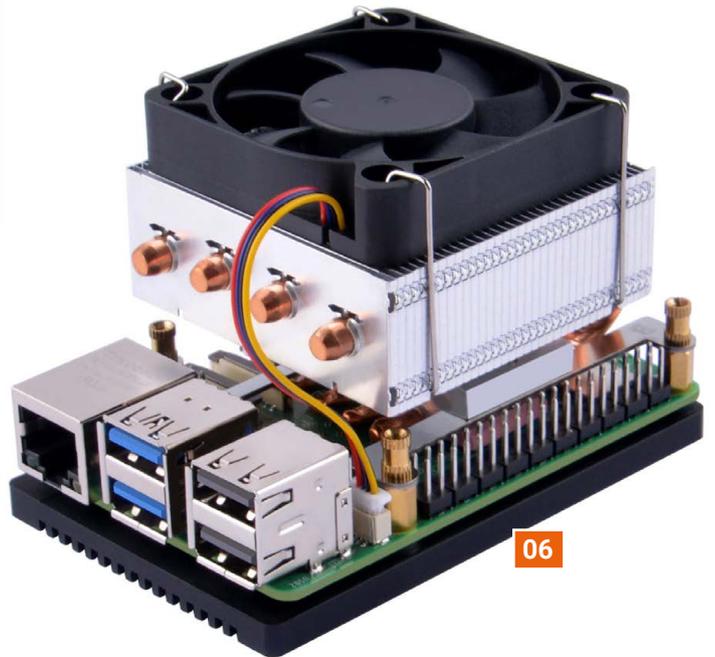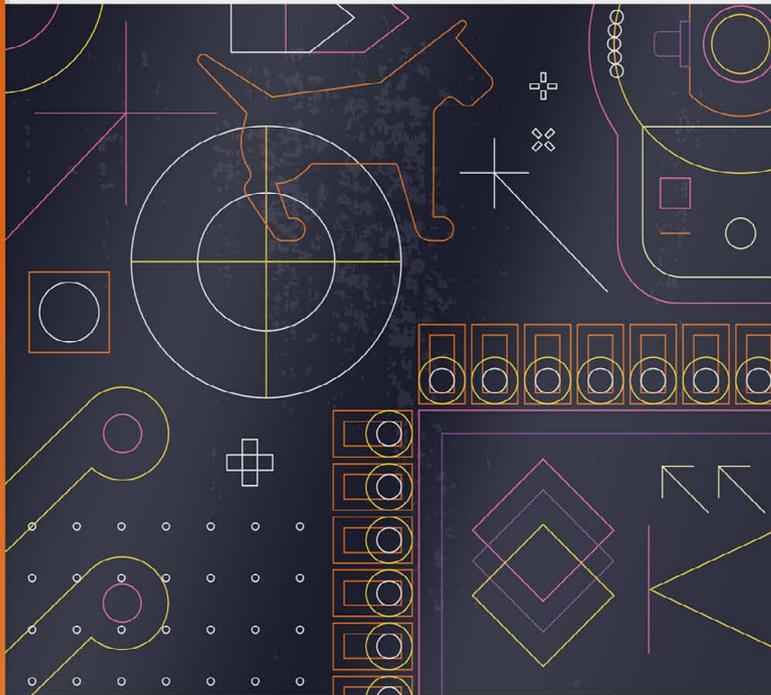
Design an
RP2040 board with KiCad

Creating Raspberry Pi Pico-compatible PCBs

Raspberry Pi PRESS

Jo Hinchliffe,
Ben Everard

Design an
RP2040 board with KiCad

Creating Raspberry Pi Pico-compatible PCBs

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*

NetworkChuck

Chuck teaches folks how to be an IT professional and part-time tinkerer, one video at a time

Name Chuck Keith
Occupation UC engineer
Community role YouTuber
URL rpimag.co/networkchuck

YouTubers can come from anywhere. In Chuck of NetworkChuck's case, he sold toilets. However, growing up he'd been a bit of a tech kid. His dad was in IT and would being back old hardware that both would tinker with.

"I got back into tech – partly out of necessity and maybe a little bit of survival," Chuck says. "My wife and I had just had our first daughter, and the pressure to provide was getting real. In between sales calls, I would crack open my CompTIA A+ study guide, hoping to earn my first IT certification and land my first job in IT. And that's exactly what happened. I started as a junior helpdesk support specialist (I didn't know you could be lower than tier 1 helpdesk) and knew almost nothing. But for the first time ever, I didn't hate going to work. I became obsessed! I'd stay late to study and help the system and network admins with their projects. It was a whole new world for me. I had always loved technology, but I had never experienced this level of nerdiness."

"The reason I love tech – especially things like Raspberry Pi – is that they're not only fun, but they translate to real-world skills," Chuck continues. "The projects you build with something like a Raspberry Pi can lead to incredibly fulfilling and lucrative careers."

How did you get into Linux?

Networking led me to Linux. While most of my time as a network engineer was spent with Cisco IOS, some of the newer switches had a Linux back end, and Cisco phone systems used Red Hat. I was tasked with spinning up a few Linux virtual machines for the development team, and Linux kept popping up everywhere. I was terrified.

I knew I had to learn Linux, but I wasn't quite ready to take the leap yet. Then I heard about Raspberry Pi – these small, lightweight computers people were using for fun projects – and I just couldn't resist. One afternoon, I took my lunch break, drove to MicroCenter, and bought my first Raspberry Pi, a 2 [Model B].

▲ Chuck got hands-on with Raspberry Pi 5 for its release
◄ A classic Raspberry Pi project – retro gaming via RetroPie
▼ Using home automation to make your home very spooky

I had no idea what I was doing, but as I fumbled my way through setting it up and tried a few projects, I got addicted. The Raspberry Pi was my gateway drug to Linux.

What do you usually use Raspberry Pi for?

Everything. I use it for home automation with Home Assistant, running a DNS server with AdGuard, hosting a Time Server with TimeBeat, turning it into a travel router and a travel NAS, and even as a wireless hacking tool with Kali Linux.

What's your favourite thing you've made with Raspberry Pi?

Even though it didn't get many views, my favourite Raspberry Pi project was building a haunted house. I used multiple Raspberry Pi, sensors, cameras, and legit haunted house props to make a walk-through experience for kids in my neighbourhood on Halloween.

How did you start out YouTubing?

I've always loved YouTube and have

been on the platform since the very beginning. My personal channel was classic early YouTube stuff: stunt videos with my siblings and friends.

I tried daily vlogging with my family when that was hot, but it just wasn't our thing. I loved YouTube, but I needed to focus on my career, so I put down the camera.

Then I started watching a YouTuber named Jorge Almazan. He made content about his IT journey, documenting how he got Cisco certifications and how they helped his career. It was so encouraging, and it gave me a massive boost of motivation in my own journey.

It's where the idea of NetworkChuck was born. I was encouraged by Jorge's channel, but there wasn't much else like it out there. In fact, he was the only one I could find talking about tech this way. I knew it was time to pick up the camera again and make content that would help others find a fulfilling job in IT.

My first video was filmed in an IT closet at work, documenting me setting up a fleet of Cisco Firewalls.

What is one security tip you'd give everyone?

Know your attack surface and routinely audit yourself (and your family). ⬠
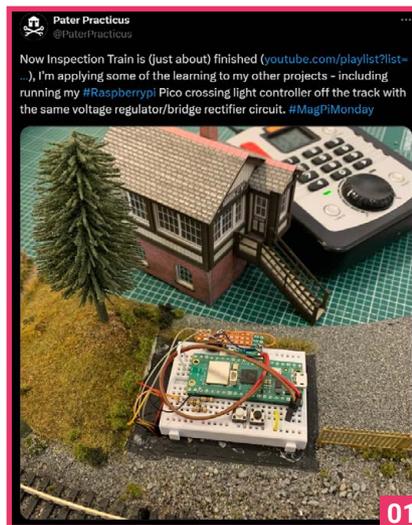
#MakerMonday

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.

This issue we're saying goodbye to #MagPiMonday, and welcoming in the new #MakerMonday, so remember to follow along at the hashtag #MakerMonday!

01. The train set gets yet more upgrades, thanks to a bit of experience

02. The electronics in a game like Operation may be simple, but that doesn't make the buzzer any less scary

03. It's so powerful it's emitting lightning! Wow!

04. An interesting new take on a voice assistant

05. A nice, more robust, and probably cheaper alternative to the Sony frame, we say

06. We love truly autonomous robots, and they're only getting more powerful.

07. As usual, be careful with CRT units, but this is *very* nice.

08. Hmm, has technology gone too far this ti-… oh wait, it's time for tubby custard

09. We love the simple representation of the ISS flying across the globe.

10. Water deterrent just sounds like you've made a squirrel super soaker. We want one.

Pater Practicus @PaterPracticus

Now Inspection Train is (just about) finished (youtube.com/playlist?list= …), I'm applying some of the learning to my other projects – including running my #RaspberryPi Pico crossing light controller off the track with the same voltage regulator/bridge rectifier circuit. #MagPiMonday

Kevin McAleer 🤖 **Robot Maker** ✓ @kevsmac

Happy #MagPiMonday This weekend I recreated the game of Operation but used a Raspberry Pi Pico to control the buzzer and nose LED! I used the ENORMOUS @pimoroni Pico Jumbo and some crocodile clips and a @monkmakes Speaker for audio.

Read up more here:

Operation Pico

From kevsrobots.com

Stratos
@polydefkis12

Follow back **08**

Happy #MagPiMonday. This weekend I completed the project I had started during Christmas. I managed to transform a teletubbies toy into a real teletubbies which has an LCD screen on its tummy that plays youtube videos with sound.

youtube.com
Teletubbies toy with real LCD screen on its tummy playing ...
My new instructables guide on getting a teletubbies toy
with a real LCD screen on its tummy to play real videos wit...

Λnɪndɪta: ✔
@anindita_basu

Weekend was spent making a digital photo frame project for my brother (to replace the Sony frame I'd gifted him a decade and a half ago, and which has taken its last breaths). Am now waiting for the frame enclosure to be delivered (so that the machinery at the back is protected), but the basics are done. Also, this is the very first time I am using Pi (and Linux) and am hooked 😀

Pierre-yves Baloche
@FunkyPiwy

So glad to share with you all on this #MagPiMonday / #MakerMonday post, the first pictures of my #GerByBot, inspired from @kevsmac, to have both desk and mobile 🤖, powered by @pimoroni 's #InventorMiniHat. And the project is far from over as software goodies are cooking too 😉 !

03

Simon Prickett 📷 | simonprickett.dev
@simon_prickett

09

I got my ISS Tracker up and running again!

05
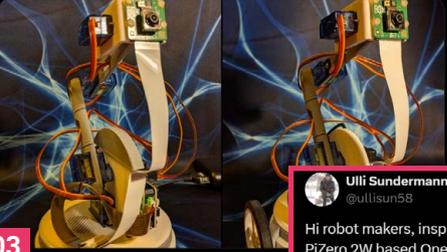
Ulli Sundermann
@ullisun58

06

Hi robot makers, inspired from @kevsmac #SMARS Mini I am built my PiZero 2W based OneEye robot. Not finished yet, but the first movements working fine. Videostreaming should be analized from a Pi4 in the network, motorsignals shoud transfered via socket to the OneEye back

David
@Davided19279031

10

This weekend my updated Raspberry PI AI camera project with AI tracking of squirrels and large birds with water deterrent. Details at github.com/dave-ct/ai_obj...

Fernando Gonzalez Sidders
@fsidders

I have made a TV Assistant with a Raspberry 4 When you are watching TV, and according the actual show (Movie or series, News,Landscape or Sports) you press a button and using OpenAI or Gemini, you get additional information through speech. I didn't finish yet. adding more options

News | Tv Series/Movies
Landscapes | Sports

04

Gam3t3chElectronics
@Gam3t3ch

Made a test suite for my crt units my old gear takes up too much space. Raspberry Pi B v2.0 I've had for 10 years finally getting much needed love.

07

Events in pictures: Raspberry Pi Meetup & Workshop #5 Puchong, Malaysia

Machine learning with Scratch at community Raspberry Pi events

December of last year saw makers and students get hands-on with creating machine learning models in Scratch to recognise patterns, exploring how machine learning works in real time with real world applications. They sent over pictures to prove it too!

Find out about more community events on page 124, and submit yours at **rpimag.co/events** for special Raspberry Pi support packages.

01. Creating ML models in Scratch is a very real thing!

02. Registering your event will allow you to get support packages for the event itself, complete with Raspberry Pi merch

03. The Raspberry Pi Meetups in Puchong are held every few months

04. A variety of folks attended the workshop

Find out about next month's events and pop-ups on

PAGE **124**

Crowdfund this

Great crowdfunding projects this month

Eight 24-Bit ADC 8-Layer Stackable HAT

If you need a serious number of various data inputs into Raspberry Pi, this stackable HAT has you covered. Sequent Microsystems reckons it will be great for environmental monitoring, robotics, industrial/home automation, and scientific research.

▶ **kck.st/4jUXrN4**

BerryBot

Another take on an educational programmable robot for Raspberry Pi, BerryBot is programmable in Python and Arduino IDE, and is controllable via a smartphone app. This one hasn't launched at the time of writing, but we eagerly await to see when it is.

▶ **rpimag.co/berrybot**

Together we can make a difference

Give young people the opportunity to learn about technology

The Raspberry Pi Foundation enables young people to realise their full potential through the power of digital technologies, but we can't do this work without your help. Your support helps us give young people the opportunities they need in today's world. Together we can offer thousands more young people across the globe the chance to learn to create with digital technologies.

Generous donations from organisations and individuals who share our mission make our work possible.

DONATE NOW

Raspberry Pi Foundation

Donate today to make a difference: **rpf.io/donate**

Your Letters

Raspberry Pi Official Magazine

As one can see on pages 128 and 129 of *The MagPi* magazine issue #150 (magpi.cc/150), starting with the next issue, 151, The MagPi will now simply be named *Raspberry Pi Official Magazine*. This raises some questions: What will happen to MagPiMonday? Will the magpi.cc domain still work in the future? Is it safe to rename a magazine in times where print magazines are on a decline?

Stl1988 via the forum

We really enjoyed the vibrant chat that you sparked on our forums (**rpimag.co/forums**) about our new name. And we hope you are enjoying the new magazine now that you have a copy. In answer to your questions, we are going to use #MakerMonday. And yes, the old **magpi.cc** link still works, and we are using a new **rpimag.co** link from now on. We think this is the right thing to do to ensure our new readers can find us. Making magazines is precarious, though, and we urge readers to subscribe to the new magazine (**rpimag.co/subscribe**).

What the stack?

You shared a nice stack online for learning AI. Is this part of a training program or education effort? I'm curious what is in the bottom box. I think I found the others.

Jon Morss via LinkedIn

Glad you liked it (see image). This was a high-end stack of Raspberry Pi kit we are putting together that combined a variety of top-flight components. From top to bottom, they are: Raspberry Pi 5 with 16GB RAM, Raspberry Pi AI HAT+,

Argon DATATERM M.2 NVMe SSD (128GB), Argon OLED Module, and Argon ONE V5. We're putting together a test bed for Raspberry Pi AI projects that we will be covering in-depth in the next issue, and we are also working on a Raspberry Pi AI book available later this year. The Argon ONE V5 has now become a home server and automation unit (awaiting ZigBee compatibility) and PJ Evans is writing up a review for our next issue. The Raspberry Pi 16GB and AI HAT have become a separate build with an AI Camera attached. We do love our jobs!

▲ A stack of high-end Raspberry Pi equipment

Sharing projects

Hey! I have been working on a project that is like a long-range communication station that works on Pico W. Here are some photos; let me know if you are interested in this. Would love to share this project with others.

Roberts Treize via Facebook

Hi Roberts. Thank you so much for sharing the photos with us of your project. We suggest that you put together some information describing the build so we can share it with our readers. And we hope to do a Project Showcase on this in a future edition. In the meantime we'd be delighted to share a photograph of it with our readers.

▲ Roberts Treize's long-range communication station

Contact us!

Community Events Calendar

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

01. Raspberry Pi JAM: Discovering Tiny Tech with Buttercup

📅 **Saturday 8 March**
📍 **Bessie Branham Recreation Center, Atlanta, GA, USA**
▶ **rpimag.co/dtt151**

Join Buttercup STEAM at the Bessie Branham Recreation Center in the Kirkwood neighbourhood for an exciting Raspberry Pi JAM! Dive into physical computing with Raspberry Pi, creating projects with lights, motors, and sensors. Learn to code, tinker with tiny computers, and discover the fun side of tech! Ideal for kids, teens, and families. Let's get creative with coding!
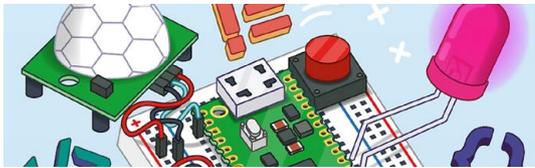
02. Introductory Workshop on IoT using Raspberry Pi

📅 **Saturday 15 March**
📍 **TSSCAR, Madurai, India**
▶ **rpimag.co/iot151**

Visit the event for an exciting hands-on workshop on the Internet of Things (IoT) using Raspberry Pi! Designed for beginners, this session will introduce the fundamentals of IoT, Raspberry Pi, and how to build simple IoT applications. Participants will gain practical experience in setting up and programming Raspberry Pi, interfacing sensors, and connecting devices to the cloud. No prior experience is required – just a passion for learning and innovation!

03. 7th Annual Raspberry Jam West Virginia

📅 **Saturday 15 March**
📍 **Geary Student Union, Charleston, WV, USA**
▶ **rpimag.co/rjwv151**

Raspberry Jam WV is an exciting event celebrating creativity, innovation, and hands-on learning! Open to ages 10 and up, it offers free programming workshops where participants can dive into coding and tech. Explore the exhibition area, where makers and software engineers showcase their projects, and connect with sponsors dedicated to advancing STEAM education in West Virginia. Whether you're a tech enthusiast, a curious learner, or a supporter of education, Raspberry Jam WV has something for everyone!

04. Raspberry Pint

📅 **Tuesday 25 March**
📍 **Online**
▶ **rpimag.co/pint151**

Most Raspberry Pint presentations are about building personal or professional projects with Raspberry Pi and other maker technology. They also welcome presentations about skills and techniques such as website design, PCB design, software development, 3D printing, soldering, etc. Occasionally, they have had presentations about deep learning, big data, IoT, etc., and would love to hear about what you do in your hobbies or professional life. All makers and all kinds of digital making welcome — the quirkier, the better.

FULL CALENDAR
Get a full list of upcoming community events here:

rpimag.co/events

05

02

05. Embedded World 2025

▫ **Messezentrum 1, Nürnberg, Germany**
⦿ **Tuesday 11 March to Thursday 13 March**
▶ **rpimag.co/ew2025**

The Raspberry Pi team is looking forward to returning to Embedded World in 2025. There you'll be able to meet us and experience demos from across the full spectrum of Raspberry Pi products, including Raspberry Pi Pico 2, our AI product range, RP2350-based solutions, and our latest industrial device: Compute Module 5.

You'll be able to see how companies around the world use Raspberry Pi to support their industrial applications and discover how Raspberry Pi can help you with your own solutions.

Official Raspberry Pi Event

Win 1 of 5
PiFi kits

Turn Raspberry Pi into a wireless router with VPN and ad-blocking capabilities with the PiFi kit, a dongle and software set that you can control via your smartphone. We have five of these excellent kits to give away.

Head here to enter:
rpimag.co/win
Learn more:
pifi.org

Terms & Conditions

Competition opens on **26 February 2025** and closes on **27 March 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.

2nd Edition
Updated for
Raspberry Pi Pico W

Get started with
MicroPython on
Raspberry Pi Pico

The Official Raspberry Pi Pico Guide

Raspberry Pi
PRESS

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Ben Everard
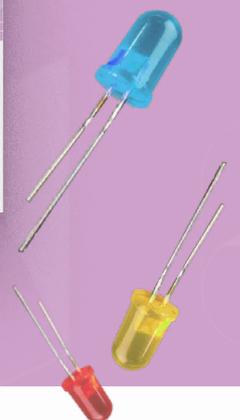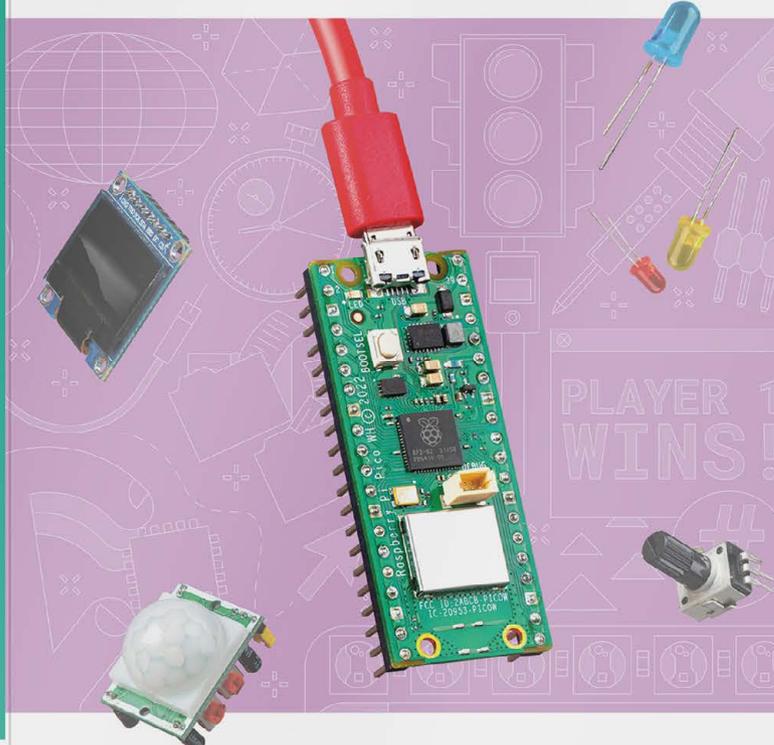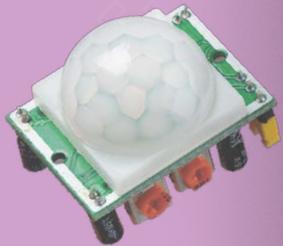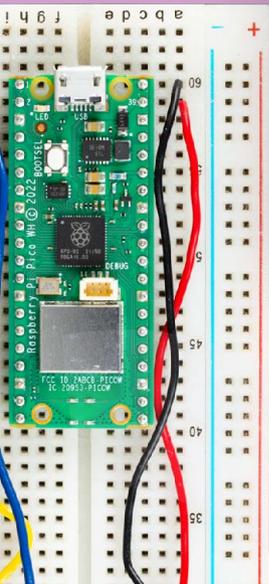
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Email Charlie Milligan at: **charlotte.milligan@raspberrypi.com**

Official Magazine
#152

Raspberry Pi AI

Running LLMs, image detection, speech-to-text, language translation, and more!

On sale 27 Mar
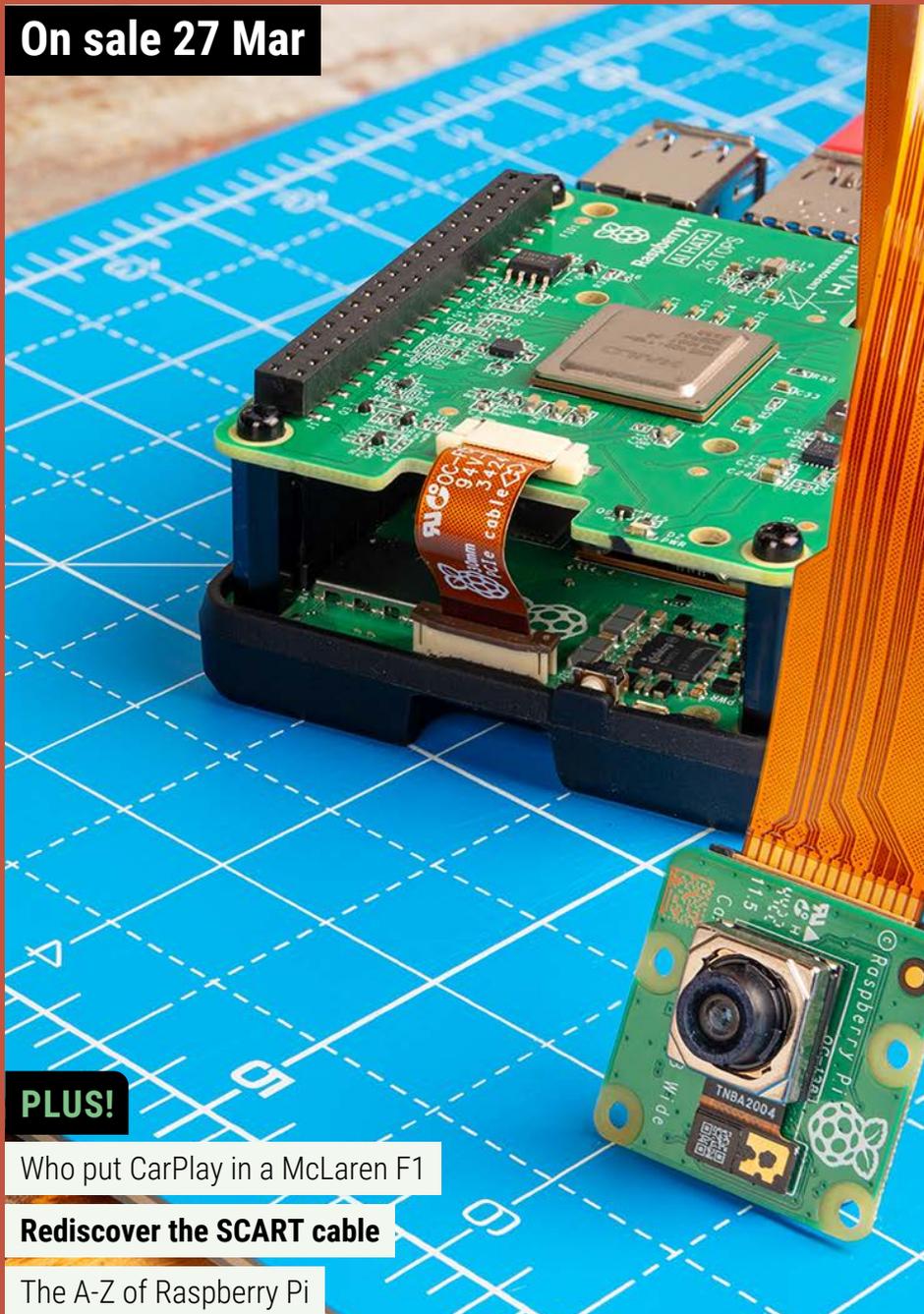
PLUS!

Who put CarPlay in a McLaren F1

Rediscover the SCART cable

The A-Z of Raspberry Pi

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Meet Tim Toady

Not invented here syndrome is not welcome round these parts

As well as being features editor of *Raspberry Pi Official Magazine*, I've recently taken on a new role: tech support. Unpaid tech support to my parents, that is. They recently had a computer fail on them, and were about to buy something grossly over-specced and over priced to replace it. I kid you not, they even asked me whether I'd recommend a Mac.

Of course, as they already had a mouse, and a screen, and a load of cables, there was no need to spend ridiculous sums of money on a machine destined to word processing, email, and web browsing. They've now got a perfectly functional Raspberry Pi 500 doing the job, which for them also comes with free tech support including home visits.

The Raspberry Pi 500 isn't a perfect replacement for what they had before, though. In many ways it's better – faster, no viruses – but it is lacking a 3.5mm audio jack. And it's this that's really got me thinking this month. While researching ways to get around this problem, I've come to the realisation that there are loads ways around it. You can get cheap USB-C to 3.5mm cables. You can buy HDMI to 3.5mm adapters. There's always Bluetooth connectivity, if you don't mind having your devices run out of power occasionally.

So. Much. Hardware

For audiophiles, there's a range of digital-to-analogue converter (DAC) modules. These are boards that plug into the GPIO pins of a Raspberry Pi and turn the digital signal of an audio file into something that an amplifier can work with. Some of these have amplifiers built-in, so all you need is a set of speakers and you've got a hi-fi; some of them have gold-plated connectors, though none that I've seen have had the electrons brushed in the same direction to reduce noise (I swear this comes from a press release I saw once extolling the virtue of a gold-plated cable).

All this goes to illustrate the truth of an old piece of programming wisdom: TIMTOWTDI, or There Is More Than One Way To Do It. Whenever you're stuck with something on a Raspberry Pi, or even if you just want to go beyond its normal capabilities, there is always more than one approach that will work. Thanks to open hardware, free PCB design software such as KiCad, and affordable PCB manufacturing services, you can even design your own add-ons. The future's bright – the future is Raspberry-coloured.

> *All this goes to illustrate the truth of an old piece of programming wisdom: TIMTOWTDI*

Andrew Gregory – Author

Andrew is working on a Raspberry Pi and artificial intelligence system that will identify and zap slugs on his allotment.

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