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Raspberry Pi

Official Magazine
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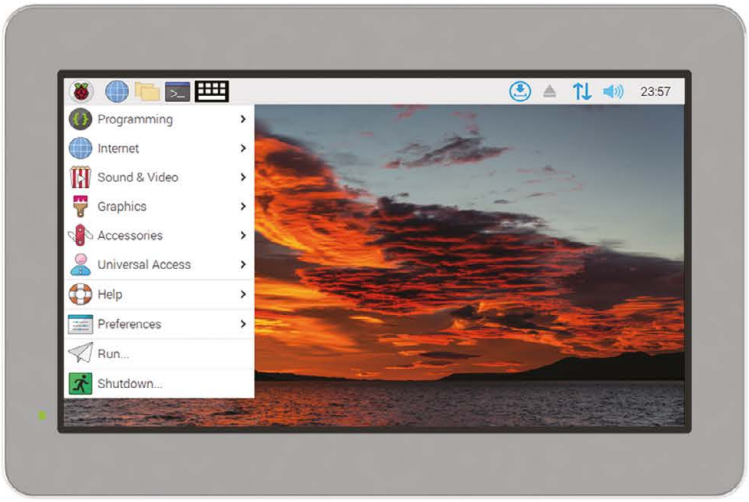

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COMFILE TECHNOLOGY

Welcome to Raspberry Pi Official Magazine

Editor
Lucy Hattersley
This month, editor Lucy's cat has trained her to 'object detect' the more expensive cat food in the supermarket.

rpimag.co

What if your next computer was powerful, incredibly efficient, and saved you a fortune? For years, I've had a Raspberry Pi computer on my desk and it's time you rediscovered why we live and breathe this machine.

Raspberry Pi's fast Arm architecture and Linux-based operating system runs liberating open-source software that matches, or exceeds, closed-source equivalents.

It runs cooler than traditional fan-powered desktops, its minimal footprint frees up space, and its dramatically lower purchase and operating costs are a game-changer.

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Lucy Hattersley – Editor

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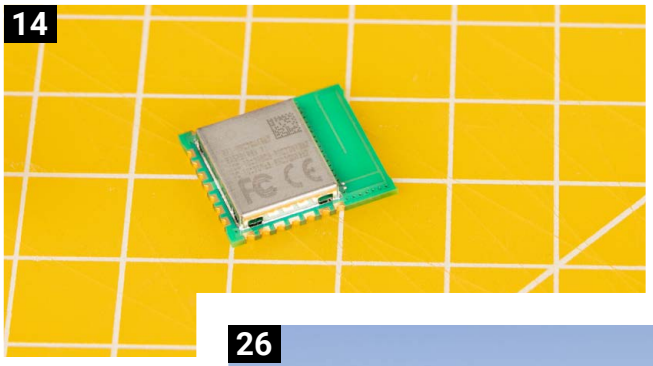

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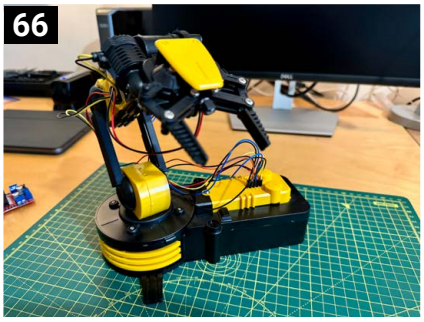

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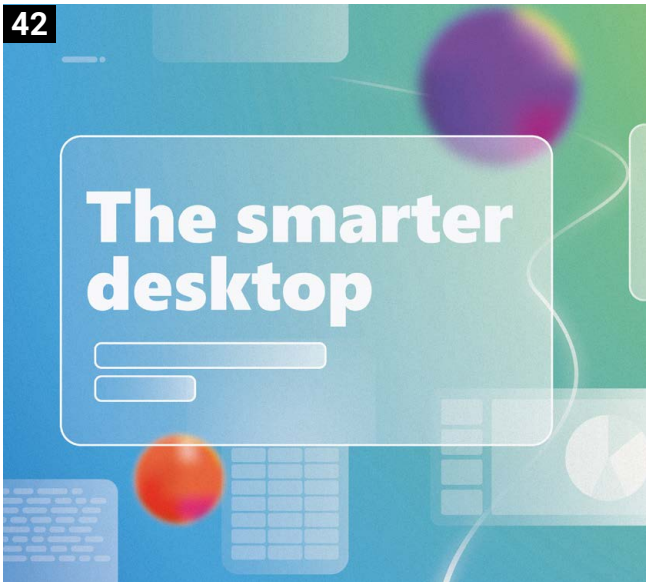

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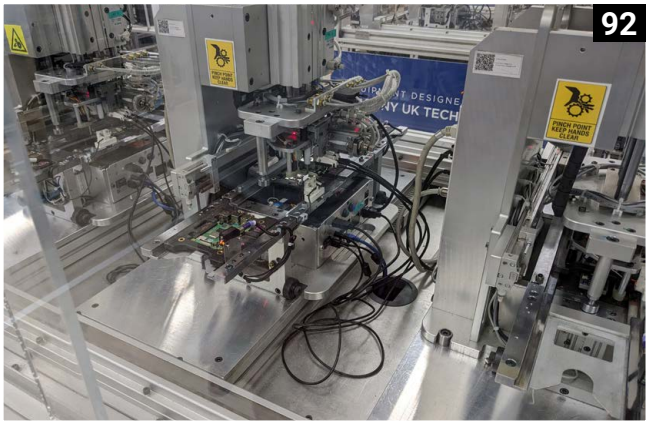

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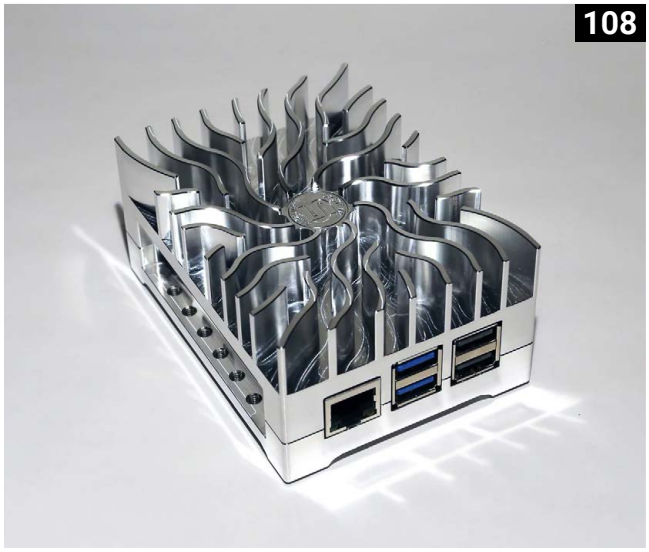

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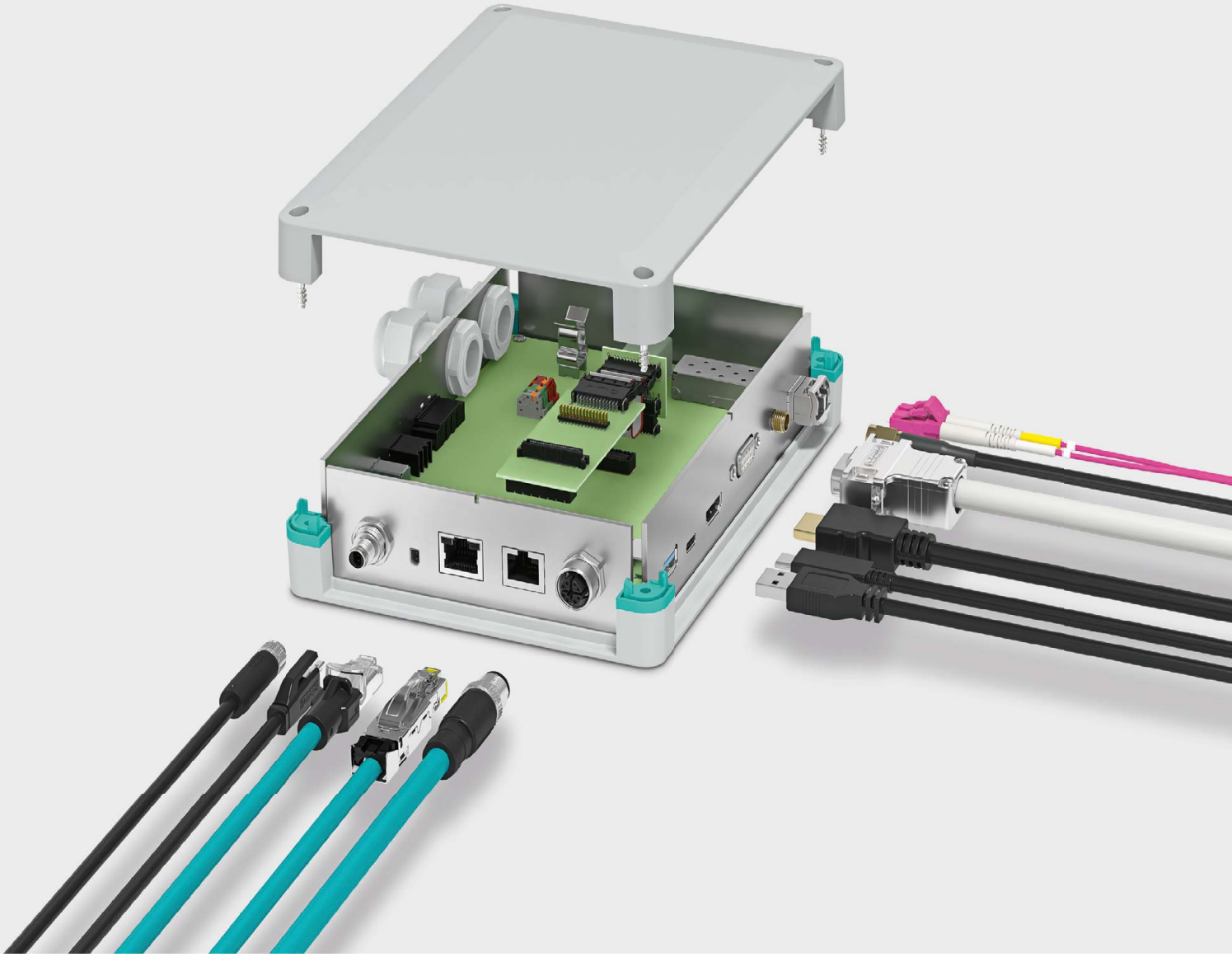
Win 1 of 5 PicoCalc kits



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ALPON X5 AI

Energy-efficient AI computing at the edge.

By **Lucy Hattersley**

Sixfab has announced a Kickstarter campaign for its new ALPON X5 AI.

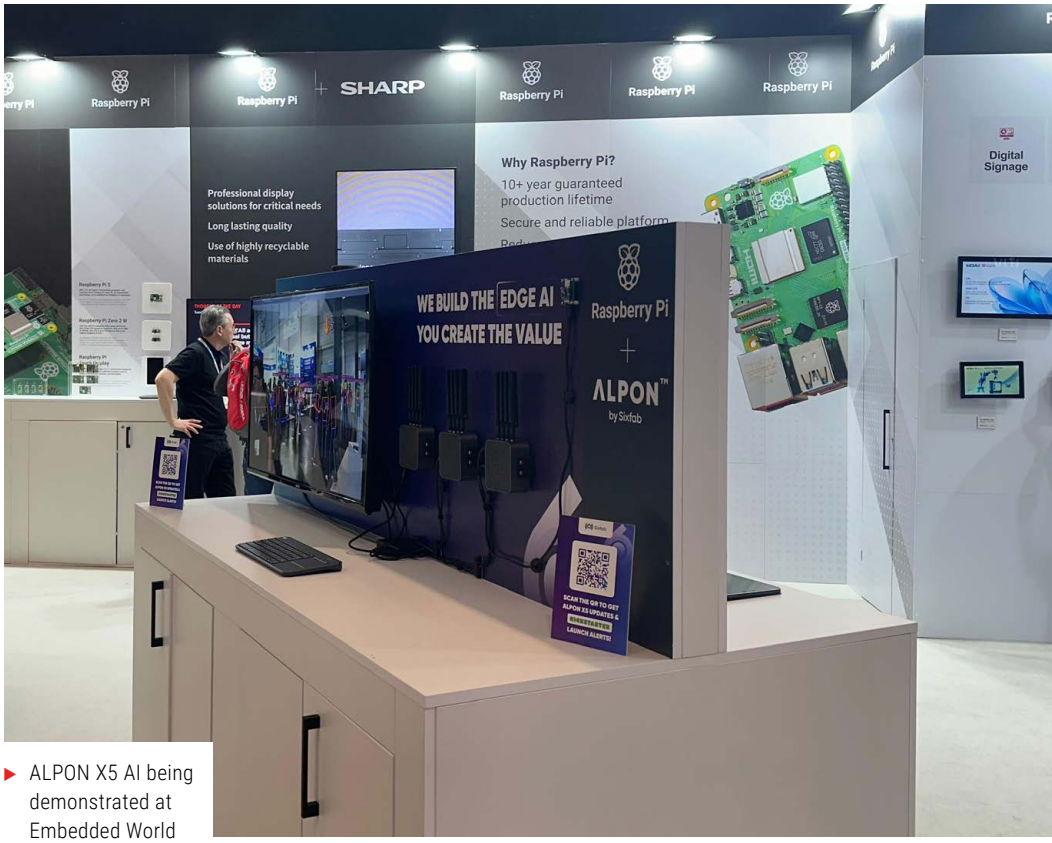
The product is a "high-performance edge computing solution designed for AI-driven applications," says Okan Saracoglu, VP, Growth at Sixfab.

Built around Compute Module 5, the ALPON X5 AI brings high-performance edge computing to the operational space. On-device AI is superior to cloud processing, which struggles with latency, bandwidth constraints, and transfer costs.

The ALPON X5 AI combines Raspberry Pi technology with DEEPX DX-M1 – a new AI acceleration chip from South Korea. The DX-M1 provides up to 26 TOPS (Tera Operations Per Second).

Like Raspberry Pi AI HAT+, this is a formidable capacity for an edge device that enables real-time AI inference tasks.

It supports the following SOTA (state-of-the-art) models: ResNet, MobileNet v1/v2/v3 SSD, EfficientNet, EfficientDet, YOLOv5, YOLOv7, YOLOv8, DeepLabv3, PIDNet, and the latest YOLO models.



▶ ALPON X5 AI being demonstrated at Embedded World

ALPON X5 AI with on-device NPU is geared for the edge AI hype everyone's talking about

Energy-efficient

A key aspect of DX-M1 is extremely aggressive low power consumption. According to Sixfab, it surpasses 40W GPGPU (general-purpose computing on graphics processing units) "delivering 20× greater efficiency, all while using just 5W of power."

DeepX states that DX-M1 "typically uses between 3–5W, making it ideal for local deployment. It can achieve 25 TOPS while staying under 5W."

It comes with an industrial case that is rugged and fanless, with network connectivity via Ethernet, Wi-Fi, Bluetooth, and eSIM LTE. It supports TPM 2.0 security for industrial use, and both DIN rail and wall mount connections are available. So it's ready to be deployed into the world.

Sixfab seeks target markets of smart camera modules, automotive, consumer electronics, security cameras, smart mobility, and edge computers. The device comes with integrated CSI camera ports, USB 3.0, and NVMe SSD expansion.

◀ Connectivity via Bluetooth, Wi-Fi, and 4G cellular

Innovators Program

The ALPON Edge Innovators Program unites forward-thinking developers, engineers, and businesses to explore on-device AI. Participants gain early access to ALPON AI edge computers, collaborate with Sixfab's experts, and help shape the next generation of AI-powered edge solutions.

This program offers engineering samples, early software builds, and real-world AI testing on the ALPON X5 AI platform, accelerating seamless AI integration into industrial, IoT, and enterprise applications.

rpimag.co/aloninnovators

"ALPON X5 AI with on-device NPU is geared for the edge. We've been working hard on it for more than a year to make edge AI as plug-and-play as possible for the Raspberry Pi community," says Saracoglu.

The new unit "combines industrial-grade performance with Raspberry Pi simplicity. Whether you're a developer, maker, or a team scaling up, this is the platform you've been waiting for."

We recently tested the ALPON X4. Our expert reviewer Phil King called it: "A powerful edge computer with excellent wireless connectivity, a robust enclosure, convenient cloud-based management, and ultra-easy initial setup."

Readers interested in the ALPON X5 AI, can find more information and sign up for early access via Sixfab's Kickstarter campaign: **rpimag.co/alponx5aisignup**.

▲ The device has an integrated CAM port, USB 3.0, external HDMI, and NVMe SSD expansion

Camera Module 3 Sensor Assemblies

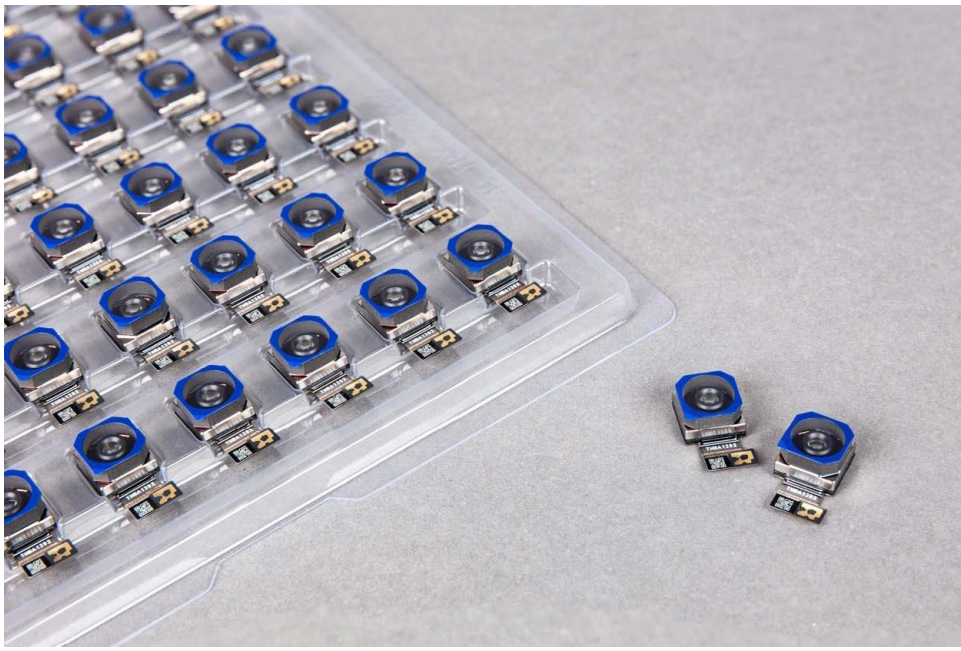
Put Raspberry Pi's camera sensor in your own product. By **Lucy Hattersley**

▶ Sensor Assembly features the same imaging technology as Camera Module 3

Raspberry Pi has announced a new product for industrial customers: Camera Module 3 Sensor Assembly.

Camera Module 3 Sensor Assembly (**rpimag.co/cam3sensorassembly**) enables customers to integrate Camera Module 3 into their own compact designs. It contains the same sensor and autofocus functionalities as the flagship Raspberry Pi Camera Module 3.

"Since its launch two-and-a-half years ago, our 12-megapixel autofocus Raspberry Pi Camera Module 3 has found a home in countless enthusiast projects, and in a wide range of industrial and embedded applications," says Mike Buffham, director of product management at Raspberry Pi. "But we've found that some of our embedded customers want to integrate our camera technology into smaller form factors than our 25 × 24mm module footprint can support."



▲ Camera Module 3 Sensor Assembly is available in Standard or Wide field of view, with regular and NoIR options

Cameras are the original Raspberry Pi accessory

It enables customers to "build the support circuitry that normally lives on the Camera Module 3 (mostly power supplies) onto [their] own circuit board," says Eben Upton, CEO and co-founder of Raspberry Pi.

As Upton notes, the product is "mostly relevant to OEMs (original equipment manufacturers) who want to build products on top of Raspberry Pi."

The Camera Module 3 Sensor Assembly features the same 11.9-megapixel IMX708 sensor and Phase Detection Autofocus (PDAF) capability as the full Camera Module 3. Raspberry Pi is also providing reference schematics (which you can view at **rpimag.co/cam3schematics**) and a bill of materials (**rpimag.co/cam3bom**) to aid customers in integrating necessary support components onto their own PCBs.

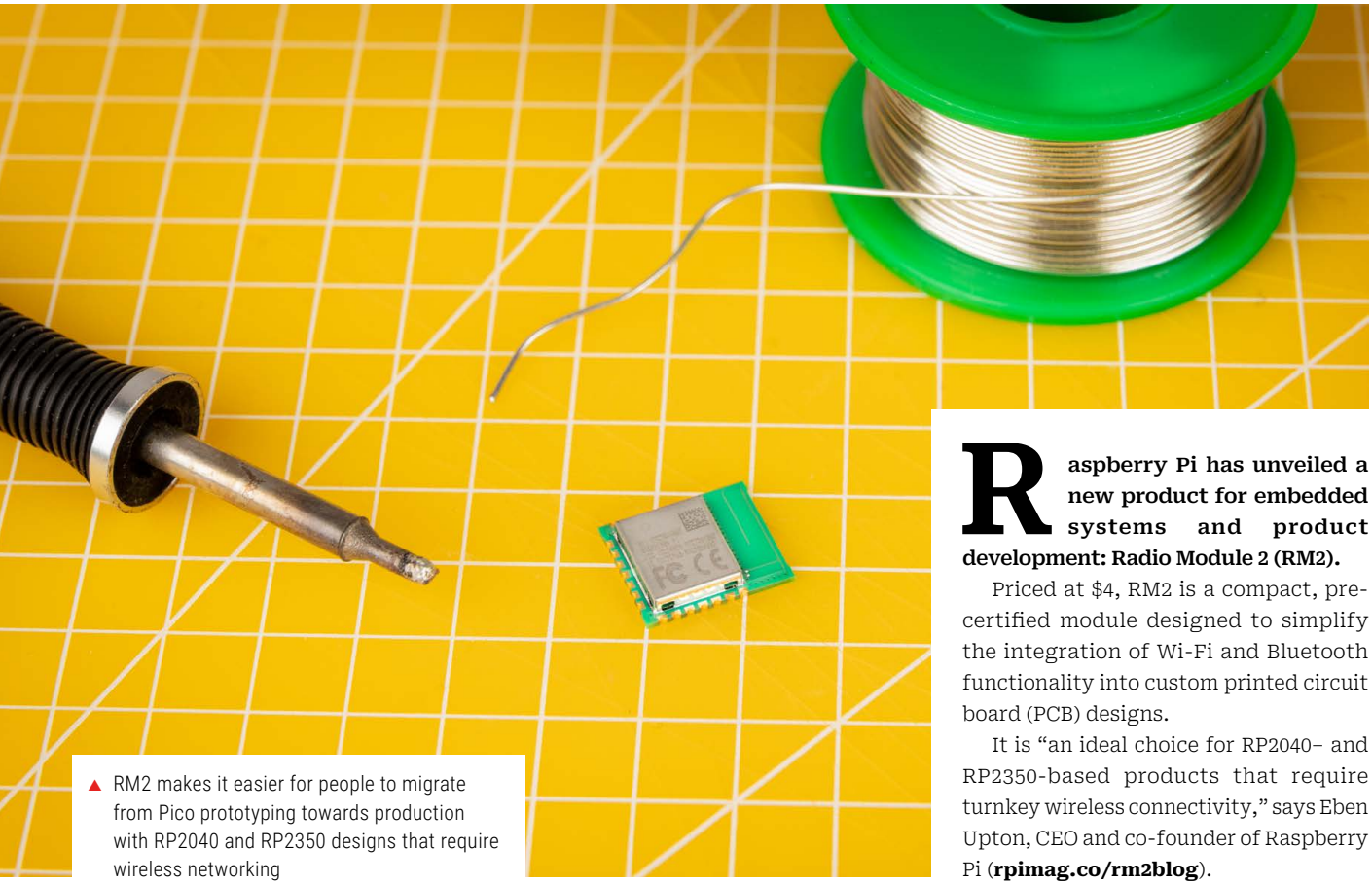
These new assemblies are available in visible-light and infrared-sensitive (NoIR) variants, with either a standard (75° diagonal) or wide (120° diagonal) field of view. "Cameras are the original Raspberry Pi accessory," Buffham adds, highlighting their diverse applications, from workplace safety to glacier stability monitoring. "We look forward to seeing Raspberry Pi Camera Module 3 Sensor Assemblies take our imaging technology to new and exciting places!"

Specifications

- Sony IMX708 sensor
- Resolution: 11.9 megapixels
- Sensor size: 7.4mm sensor diagonal
- Pixel size: 1.4µm × 1.4µm
- Horizontal/vertical: 4608 × 2592 pixels
- Integrated IR cut filter in standard variants; not present in NoIR variants
- Phase Detection Autofocus
- Operating temperature: 0°C to 50°C
- Onboard EEPROM for storing camera data

Radio Module 2 released

Add certified wireless to your industrial products. By **Lucy Hattersley**

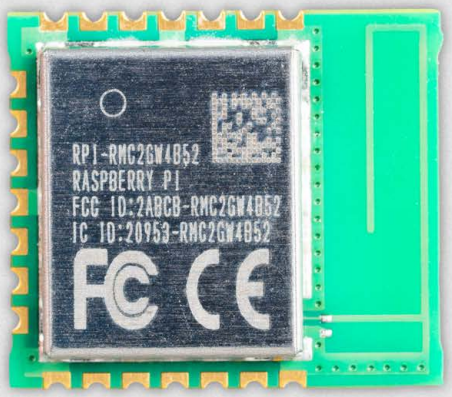


▲ RM2 makes it easier for people to migrate from Pico prototyping towards production with RP2040 and RP2350 designs that require wireless networking

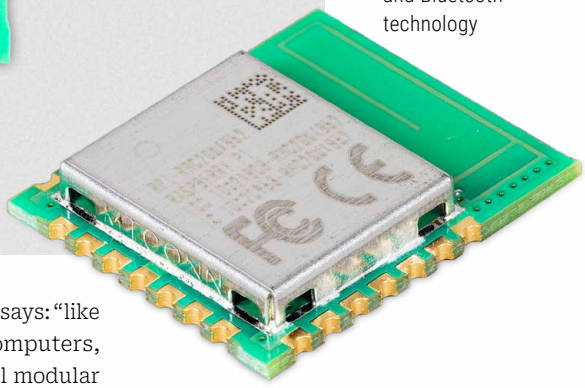
Raspberry Pi has unveiled a new product for embedded systems and product development: Radio Module 2 (RM2).

Priced at $4, RM2 is a compact, pre-certified module designed to simplify the integration of Wi-Fi and Bluetooth functionality into custom printed circuit board (PCB) designs.

It is “an ideal choice for RP2040– and RP2350-based products that require turnkey wireless connectivity,” says Eben Upton, CEO and co-founder of Raspberry Pi (**rpimag.co/rm2blog**).



▲ Castellated edges enable surface-mount technology (SMT) assembly, allowing RM2 to be easily mounted directly onto a PCB



▼ Radio Module 2 provides Wi-Fi and Bluetooth technology

Writing on the Raspberry Pi blog, he explains: "Every Raspberry Pi computer since Raspberry Pi 3B+ has been a 'module' from a conformance perspective: because we isolate the radio frequency components under a shield can, you can build your own wireless-enabled product around ours without having to re-certify the radio, saving tens of thousands of dollars."

> *Radio Module 2 comes with full modular certification*

Easy integration

Customers making RP2040 and RP2350-based PCBs have been asking Raspberry Pi for a wireless solution that provides the software and feature-set compatibility with Raspberry Pi Pico-series devices.

"We designed Radio Module 2 with these customers in mind," says Upton.

RM2 features castellated edge pads, an onboard 2.4GHz antenna, and a low-pin-count SPI host interface which makes efficient use of the host CPU's I/O budget. Its compact 16.5mm × 14.5mm form factor and minimal external component requirements (just a host CPU and power) drive down mass-production costs.

Explaining the appeal, Upton says: "like all our recent Raspberry Pi computers, Radio Module 2 comes with full modular certification, making it an ideal choice for designers who wish to avoid the tricky and expensive radio certification process."

Excellent performance

Radio Module 2 offers 1×1 single-band 2.4GHz Wi-Fi 4 (802.11n) and Bluetooth 5.2, supporting both Bluetooth Classic and Bluetooth LE. Its integrated internal PA, LNA, and T/R switch delivers excellent wireless performance even when sharing a single antenna between Wi-Fi and Bluetooth. Discover more on the Radio Module 2 product page (**rpimag.co/rm2**).

"It has already seen the light of day in a number of partner products, including SparkFun's Thing Plus – RP2350, and Pimoroni's Pico Plus 2 W, and we're looking forward to playing spot-the-RM2 in the next wave of connected devices," adds Upton.

Documentation

Raspberry Pi Pico SDK (**rpimag.co/picosdk**) and MicroPython (**rpimag.co/micropythonsdk**) provide a proven, supported software stack, and a straightforward development experience, from prototyping with Pico W or Pico 2 W to production with Radio Module 2.

You can find technical details of Radio Module 2 in its comprehensive datasheet (**rpimag.co/rm2datasheet**). Read all about it in the Product Brief (**rpimag.co/rm2productbrief**) and find its design files in the Product Information Portal (**rpimag.co/rm2design**).

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Embedded MIDI Synthesizer on Raspberry Pi

A synthesiser squeezed into an accordion sounds great. By **David Crookes**

Maker
Sergey Antonovich
Sergey is an embedded systems engineer specialising in real-time system software and sensor integration for self-driving cars and delivery robots.

rpimag.co/rpimidisynth

Although it's often considered to be a quaint, old-fashioned instrument in large parts of Europe and North America, the accordion is more popular than you may think. As well as playing a significant role in traditional, folk and ethnic music, it's used to produce jazz, pop and classical tunes. It's also of great cultural importance and a great symbol of musical expression.

Sergey Antonovich is certainly a fan and he loves to play the button accordion. He also spends a good chunk of his free time studying music theory and creating digital music instruments and accessories.

> *Without a reliable and flexible sound engine, the instrument cannot speak*

To that end, he's been working on bringing digital synthesiser capabilities to an acoustic accordion while preserving the instrument's authentic feel and sound.

To achieve this, Sergey has been using the Raspberry Pi Compute Module 3+, which he praises for its balance of performance and thermal efficiency. He's also produced a version that uses the Raspberry Pi Zero 2 W computer and created it with simplicity in mind so that anyone can try it out and see how it works.

The result is a system that is more flexible and less expensive than off-the-shelf MIDI synthesiser alternatives, that's still capable of playing beautiful, digital sounds. What's more, Sergey has fitted all of the electronics inside the accordion rather than have it trailing externally, which has allowed him to create a self-contained musical experience offering the very best sound quality.

Melodic move

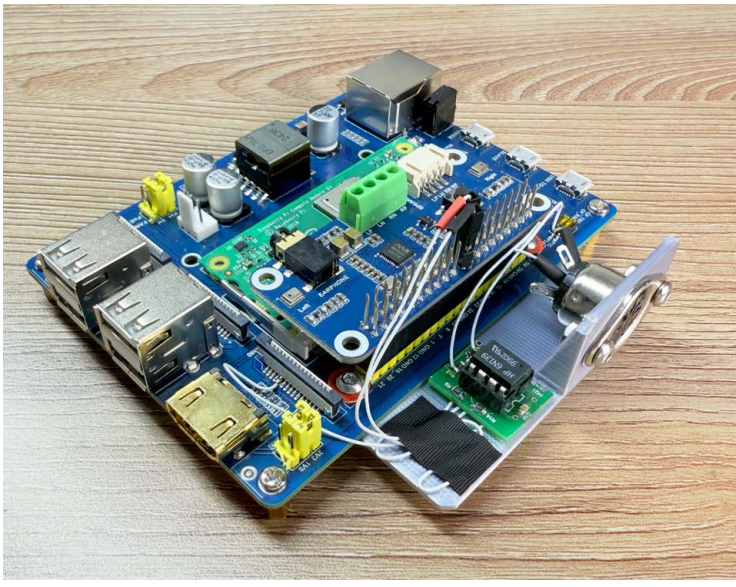
The project has been challenging. "When designing a digital musical instrument, the sound engine – the synthesiser – is not just a component. It is the instrument, in the ears of the audience," Sergey explains. "No matter how sophisticated the

01. It still looks like an ordinary chromatic accordion, albeit with new control knobs

02. This white box on top is a digital screen that displays information such as sounds and battery life

keyboard, pressure sensors, or expressive interface may be, without a reliable and flexible sound engine, the instrument cannot speak.

"In my work developing digital accordions, this challenge became central," he adds. "I had already developed a working logic board based on a microcontroller – responsible for scanning buttons, detecting bellows pressure, and generating MIDI messages. But I needed a standalone, embedded MIDI synthesiser: a system that receives MIDI input (via hardware DIN or USB), and outputs audio in real time. Crucially, it had to be small, reliable, low-latency, and flexible enough to support wavetable synthesis with user-replaceable sound banks."



▶ This is the first headless prototype on Raspberry Pi CM3+. It boots straight into performance mode. With 3ms latency, it is in the same class as hardware synths

All of the components fit inside the right-hand half of the accordion and it doesn't have the limitations of closed systems or hassle of external gear

Although Sergey did consider external MIDI synthesiser modules such as the MIDIPLUS miniEngine Pro, Ketron SD2 or Ketron SD1000, he didn't want separate cables, power, and clunky mounting. He also thought about using integrated hardware solutions offered by a small number of companies whose integrated circuits provide sample-based wavetable synthesis in compact form. But, again, he saw problems.

"They present several challenges for independent developers," he says. "There is no public access to development kits or documentation. They use proprietary sound bank formats, editable only with internal or vendor-provided tools. They have locked feature sets, meaning custom user banks are difficult to implement without proprietary tools, licences or vendor support. And cost-effective ICs like the SAM2695 or VS1053b rely on compact, generalised samples that may not fully capture the nuance of acoustic instruments."

Bellows power

As a result, Sergey began exploring a fully open approach. "I decided to use FluidSynth, a software synthesiser that supports SoundFont 2 wavetable banks that can be tuned for real-time operation on Linux-based single-board computers," he says.

FluidSynth is a software synthesiser that responds to real-time MIDI input by generating audio and it has a shared library that can be used in other programs. It also has a built-in command-line shell. Running it on Raspberry Pi Compute Module 3+ appeared the most logical solution to Sergey's problems and it means he could take advantage of the four ARM cores and 1GB of RAM, which is enough to load most SoundFont 2 banks.

"Using Raspberry Pi for audio synthesis offers several key advantages," he says. It has an open software stack with no vendor lock-in and full control over tuning, latency, and effects. When combined with FluidSynth, it also enables full support for the SoundFont 2 support, allowing users to replace or customise their sound banks, which is a highly requested feature among musicians.

"It also offers a good performance-to-power ratio which is critical for embedded use in sealed housings," adds Sergey. "And there's a strong developer ecosystem with up-to-date kernels, documentation, overlays, and toolchains."

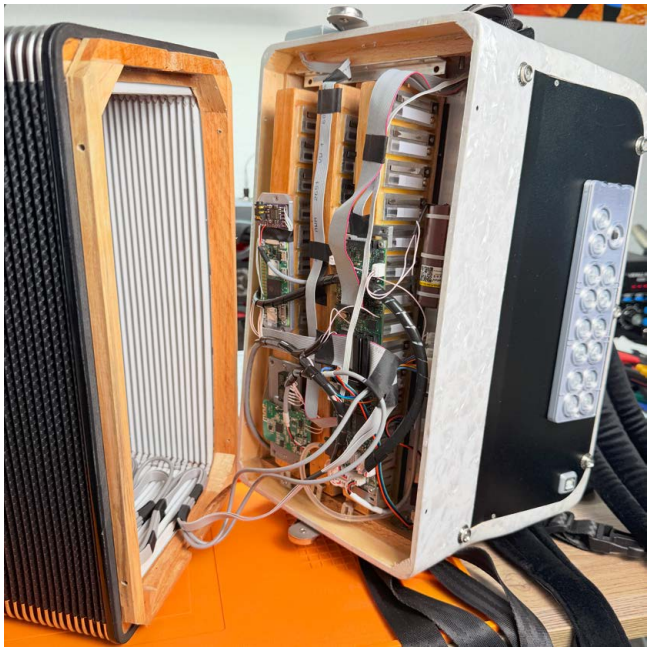
Raspberry Pi Compute Module 3+ can be integrated in a compact board design as well. "For benchtop prototyping, I used the Waveshare Compute Module PoE Board, Waveshare WM8960 Audio HAT, and a simple DIN MIDI input schematic on a 6N139 optocoupler," Sergey says.

Sound journey

For the instrument to work effectively, the time between pressing a key and the sound playing needed to be short. "The most critical metric for live performance is trigger-to-sound latency and, while hardware synthesisers typically achieve 1.5 to 3 milliseconds (ms), software solutions must carefully balance CPU load and audio buffering to stay within acceptable range – ideally below 10 ms to remain imperceptible to the performer," Sergey explains.

Quick FACTS

- Sergey creates interactive digital musical instruments
- They can mix acoustic and electronic sounds in real time
- This project creates the sound engine – the synthesizer
- It's based on Raspberry Pi hardware (CM3+ or Zero 2 W)
- It runs FluidSynth and supports SoundFont 2



▲ The system is also designed for safe power removal: thanks to a read-only root file system, the module can be switched off simply by cutting power

Using a minimal Buildroot-based Linux system and carefully tuned audio parameters, he achieved a consistent average latency of 3ms (from receiving a MIDI event to the sound being generated). Including MIDI transmission of around a millisecond, the total response time has come in at 4ms. 'That's fully competitive with dedicated hardware synths," Sergey notes.

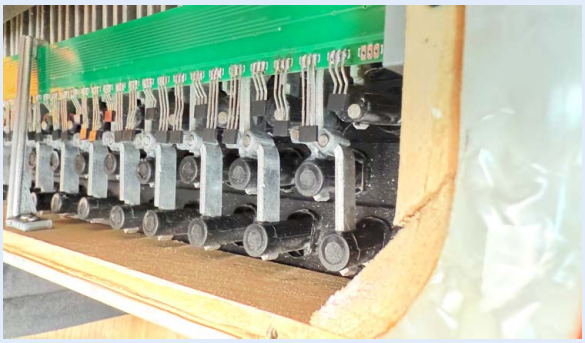
The system also handles playing 64 different notes simultaneously, which Sergey says is sufficient for a digital accordion with layered auto-accompaniment. "The audio output is clean, and no artifacts or dropouts occur under load."

The result is excellent latency, full musical responsiveness, and great sound quality in an instrument that is fully self-contained and can be played without relying on any external gear – enabling untethered movement on stage when paired with a basic wireless audio transmitter.

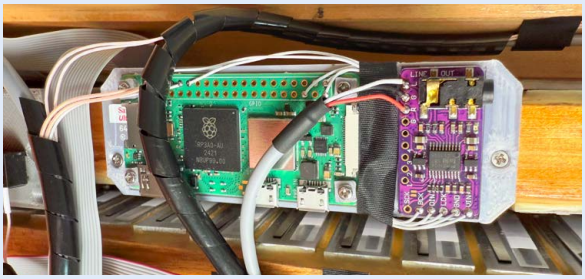
And while the instrument can be played electronically, the acoustic sounds still respond naturally to bellows movement while digital voices can be configured to ignore or follow the same motion. "It confirms the viability of this setup in a real, stage-ready instrument," he says.

Making a noise

1. Accordions work by using the instrument's bellows to force air through reeds. This produces a sound. In Sergey's system, there is a pressure sensor that can work out how the bellows are behaving.



2. The keys of an accordion control the sound's pitch. By having sensors on levers, Sergey's program can work out whether they're open or closed and interpret which keys are being pressed. A sound is then created.



3. All of the processing is carried out on the synthesizer developed using Raspberry Pi Zero 2 W. It was important to avoid sound delays greater than 20ms since they're noticeable and make live performances difficult.

R2-D2 VEX robot

The empty shell of an iconic film character formed the basis of an excellent Raspberry Pi and VEX-based robot build, learns **Rosie Hattersley**

Maker
Daniel Ramirez
Daniel enjoys creating robots and mechatronic projects and is a big advocate for using them as an educational tool.

rpimag.co/vexrobots

Younger years absorbed in various sci-fi films and TV shows such as *Forbidden Planet*, *Silent Running*, *Star Wars*, *Star Trek*, and *Lost in Space* led to embedded software engineer Daniel Ramirez's abiding interest in robots and his first forays into electronics. When he chanced upon an R2-D2 shell in his local hypermarket, Daniel saw a chance to combine his technological know-how with his sci-fi dreams. At first, the R2-D2 toy sat in his room "looking expectantly at me like Pinocchio looked at Geppetto, wondering when it could start moving around on its own". Feeling "a little bit guilty", Dan began looking for suitable parts with which to animate R2-D2. In the end, he chose Raspberry Pi and VEX Robotics construction kit components to bring the "trash-can sized" *Star Wars* robot back into use.

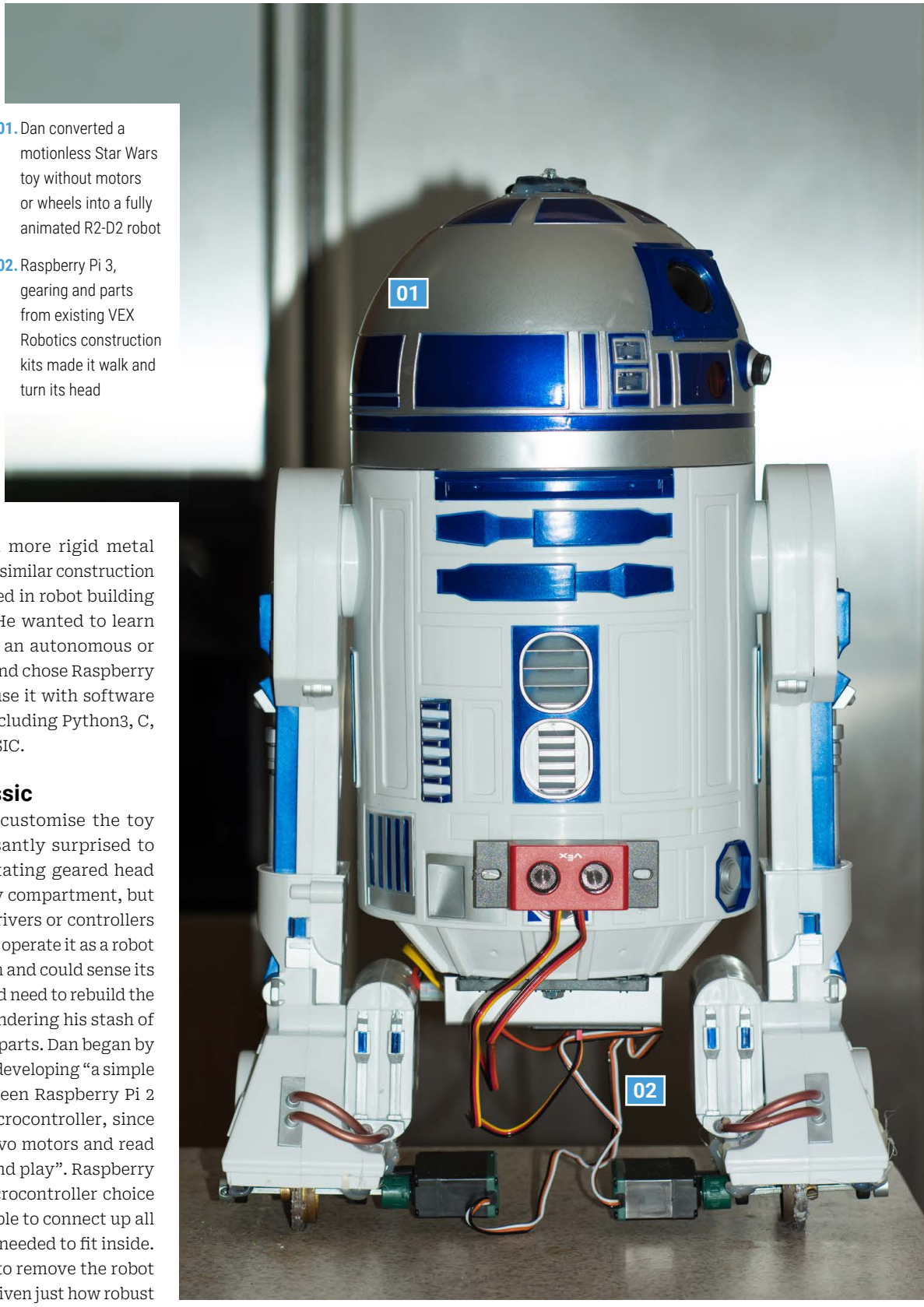
> *Daniel foolishly got his robot to chase his dog. In response, the dog – quite reasonably – bit off its antenna*

▲ The toy's chassis was roomy enough for Dan to add gearing to make its head turn

Beep beep beep!

As a child, Daniel and his brother had a Heathkit ET-18 HERO 1 robot their father bought to help them learn electronics and get through college. At the time, Daniel was struggling with maths and science, but the four-week project assembling and testing the robot from a kit easily paid off: he went on to a career with advanced technology companies in Massachusetts, as well as publishing articles about his various robot and electronics projects.

Dan finds VEX construction sets ideal for new robot and animatronics projects and for rapid prototyping new inventions (**vexrobotics.com**). He recommends the VEX user forum for inspiration and ideas: **vexforum.com**. Parts are inexpensive



01. Dan converted a motionless Star Wars toy without motors or wheels into a fully animated R2-D2 robot

02. Raspberry Pi 3, gearing and parts from existing VEX Robotics construction kits made it walk and turn its head

and stronger, "with more rigid metal structural parts" than similar construction sets and are often used in robot building contests in the US. He wanted to learn more about building an autonomous or tele-operated robot and chose Raspberry Pi because he could use it with software development tools including Python3, C, C++, Ada and FreeBASIC.

Reimagined classic

Daniel was keen to customise the toy robot and was pleasantly surprised to find that it had a rotating geared head and an empty battery compartment, but no wheels, motors, drivers or controllers installed. However, to operate it as a robot that moved on its own and could sense its surroundings he would need to rebuild the toy from scratch, plundering his stash of VEX Inventor kits for parts. Dan began by writing code in C and developing "a simple serial interface between Raspberry Pi 2 and the VEX EDR microcontroller, since it could drive the servo motors and read the sensors as plug and play". Raspberry Pi proved a good microcontroller choice since it would be simple to connect up all the components that needed to fit inside. However, he needed to remove the robot toy's base – not easy given just how robust

the plastic case is. Removing the battery compartment gave Dan access to the inside, where he discovered a small hole for gearing, presumably to make the head turn. VEX motors and an axle joining the legs enable the robot to walk.

Using the VEX construction system allowed Dan to get the electromechanical aspects going "pretty fast", but writing firmware for Raspberry Pi and the robot controller software required many iterations. In fact, his R2-D2 VEX robot began as a Raspberry Pi 2-based project that Daniel subsequently upgraded to Raspberry Pi 3.

▶ Cutting through the toy's base was "like cutting through bulletproof Kevlar," says Daniel

The project cost approximately $300. Daniel observes that used parts can be found on eBay fairly inexpensively as schools have upgraded to VEX Cortex and VEX V5 systems. "The R2-D2 shell was $50, but enterprising hobbyists with 3D printers could manufacture their own." He advises a slightly larger shell than the one he used: fitting the VEX parts into its 1ft 6in, 8in-diameter case was "a bit tight". Smaller motors that fit inside the hollow legs could make for an elegant alternative.

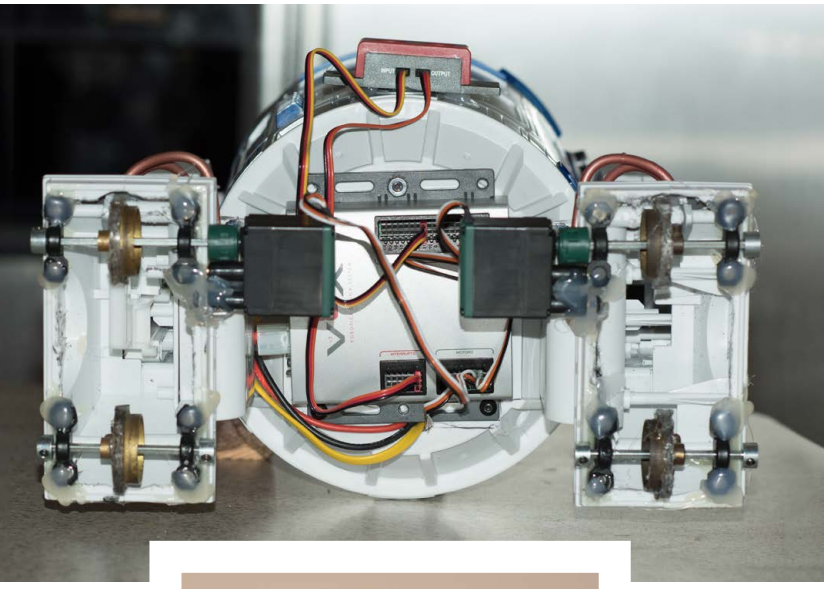
"I can't say enough about Raspberry Pi 3," enthuses Daniel. "It runs reliably and does not use much battery power, so I can run the robot for hours. Its software development tools are excellent!" However, "getting the robot to communicate between the two main controllers took a while to do".

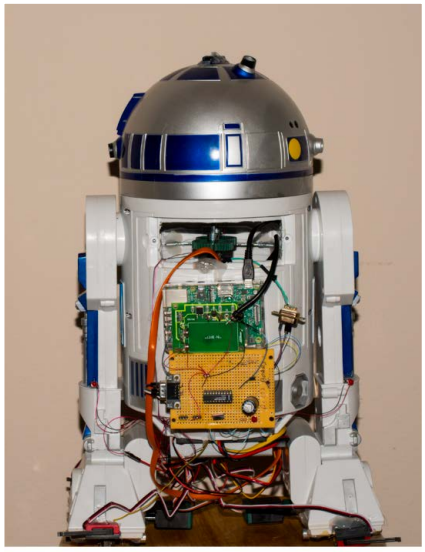
There is detailed documentation on the Vex Library (**kb.vex.com**). And you can see a YouTube video of Daniel's VEX-based R2-D2 robot in action at **rpimag.co/vexr2d2**.

New tricks

The original robot is still working. Having retired, Daniel upgraded it to Raspberry Pi 3 and is currently developing a new model that can play chess with a 6DOF (degrees of freedom) robot arm, wrist and gripper. He has recently upgraded his VEX robot with temperature and pressure sensors, object detection so it can move around autonomously, and the option to control it from a laptop or remotely, rather than a remote control.

Daniel's advice to someone keen to build their own robots and animatronics projects is to begin with construction systems such as LEGO, VEX or Meccano Erector sets so you become familiar with their plug-and-play motors, sensors, controllers and gears and structural parts. "Learn to adapt them to [your] own robots, mix and match various construction systems, or use scrap metal and surplus parts."



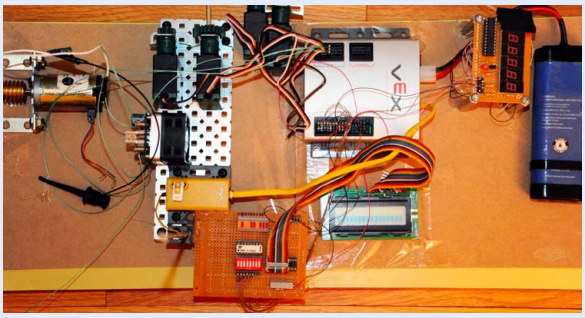


- Daniel inserted a VEX motor beside one of the robot's feet with an axle so it can walk
- The upgraded Raspberry Pi 3 version sports object detection, temperature sensors, and wireless controls

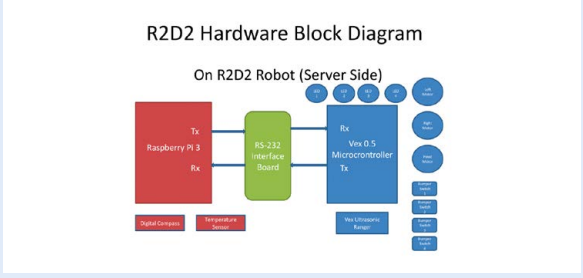
Quick FACTS

- Daniel foolishly got his robot to chase his dog
- In response, the dog – quite reasonably – bit off its antenna
- Now no robot is safe from the canine's attention
- Nonetheless, Daniel is currently upgrading his R2-D2 VEX
- Dog-detecting sensors are part of the new R2-D2 build

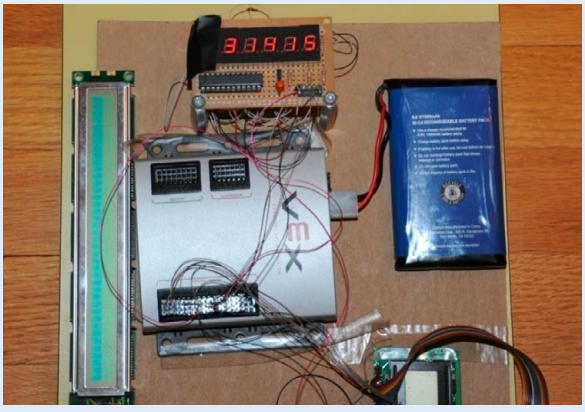
All set to VEX



1. You could use a VEX construction kit, Raspberry Pi 2 or above, stepper motors, gears and wheels, a 7.6V or 9.6V battery, and either a bought or 3D-printed shell for your robot.



2. Stepper motors and an axle can be used to get your robot to walk, while gears can make the head turn. Connect everything to Raspberry Pi using GPIO pins, adding any sensors and lights you wish.



3. Dan has kindly provided both downloadable hex file and the C code you need for the VEX controller. Once loaded, it shows the value 31415 (a pi pun). Get the code from **rpimag.co/github**.

Track the stars with a reflecting telescope

Gaze deep into the night sky with drainage piping and an affordable microcontroller.

By **Andrew Gregory**

Maker

Tim Ritson

When he's not working as a power systems engineer, Tim's cramming loads of complicated astrophysics into home-built projects like this one.

rpimag.co/esp32telescope

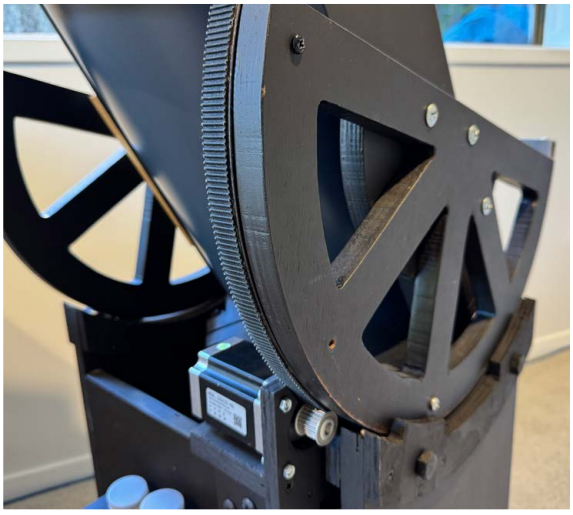
Telescopes come in many shapes and sizes. There are refracting telescopes, which use a series of lenses to make faraway objects seem larger – this is the type of device first used by Galileo to observe the planets. The telescope was improved by Sir Isaac Newton with the invention of the reflecting telescope, which used mirrors to reflect the light to an eyepiece. A larger aperture, and larger mirrors, means more light, and more magnification.

Now Tim Ritson has taken Newton's basic design and refined it with the addition of computerised motor control, Wi-Fi, and HTML.

"To start with, I really just wanted to see if I could build a basic telescope," he says. "Turned out that part was relatively easy. The mirror and a couple other components are a little expensive, but the rest was all just obtained locally. It was hard finding the right-sized tube to fit my mirror. I had to drive to a farm supplies store in the country and strap a 2m-long section of culvert pipe to the roof of my station wagon! But after that the scope came together with few hiccups, and it worked pretty much first time."

So what do you do with a reflecting telescope with a 1200mm focal length and 200mm diameter mirror? We suspect that most of us reading this would think about computerising it. And that's exactly what Tim did.

"I built a stand for it. Then I wanted to see if I could motorise it. If that worked, I would program it to track stars and find objects just by entering coordinates. One step at a time, just seeing how far I could get."



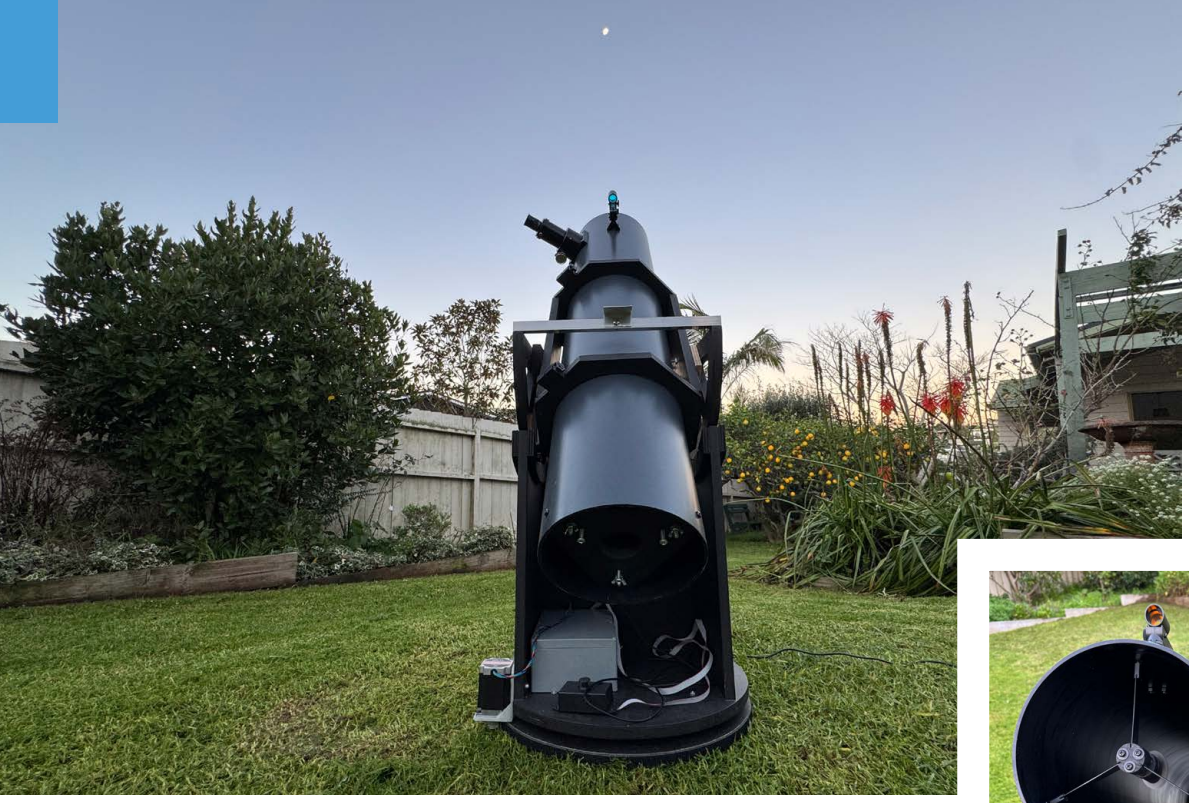
▶ The user can elevate the telescope from 0 degrees (horizontal) to 90 degrees (straight up)

I had to drive to a farm supplies store in the country and strap a 2m-long section of culvert pipe to the roof of my station wagon

01. You can see loads of celestial bodies though this telescope – the Orion Nebula is visible as a wispy grey cloud

02. One full circle of rotation can be divided into 160,000 steps – that's a lot of accuracy for a telescope made out of a drainage pipe!

Warning!
Electrical Safety
Please be careful when working with electrical projects around the home. Especially if they involve mains electricity.
rpimag.co/electricalsafety



If anything, the telescope is too powerful to look at the moon comfortably, as it appears too bright

No lenses here: the power of a reflecting telescope comes from mirrors

Search the stars

When you're looking at something a long way away, even a tiny range of motion makes a huge difference. "I used two 200-step NEMA23 motors from AliExpress, with TB6600 drivers that convert a logic 5V pulse from the ESP32, into the electrical signal the motor needs to move exactly one step," Tim explains. "They also have a 'micro stepping' feature which divides each step into up to 32 steps, so the motors have 6400 steps in one revolution.

"When combined with the gear ratio between the small 20-tooth cog on the motor to the timing belt with around 500 teeth per full circle... each step corresponds to moving about 8 arcseconds, or 0.002 degrees. To put it another way, if you did one step per second, it would take almost two full days to make a full revolution!

"In terms of altitude (up/down), it can move from horizontal to straight up (0–90°). And in terms of azimuth (think compass heading), it can rotate infinitely (I built in a slip ring so the power cable doesn't get twisted as it rotates). With these two movements, a full hemisphere of sky is within sight. If coordinates for an object that is below the local horizon are entered, the altitude calculation will give a negative number, so I have programmed it to not try and rotate to it. I don't want to find out which bit breaks first!"

Users are able to control the telescope manually using a joystick, but there's more to this build than that: "For automated control, the ESP32 hosts an HTML page that can be accessed from my phone when on the same Wi-Fi network (or it will create its own network if my home network is unavailable). This page has inputs for selecting a target and turning 'tracking' on and off, and gives me output data, such as the current position of the scope, and coordinates of the target."

Automatic astronomy

"I have programmed a list of the 50 brightest or interesting stars, which can be selected via a drop-down," adds Tim. "You can also enter coordinates (right ascension and declination) for any target which you can get online. Incidentally, it cannot currently track planets, as they move differently compared to background stars. Most stars essentially have fixed coordinates and don't move relative to each other (this is a slight simplification) so the altitude and azimuth of a star can be easily calculated, based on a given location and time. Planets trace more complex paths so will require a bit more programming to track accurately. This is on my to-do list!"

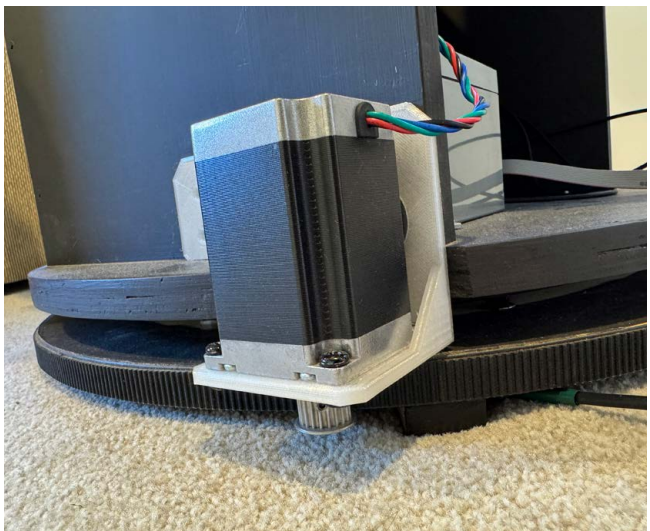
The maximum magnification of this telescope is 133×, which is good enough

Quick FACTS

- The world's largest telescope is in La Palma in the Canary Islands, with a primary mirror 10.4 metres in diameter
- Tim used an ESP32 for Wi-Fi and Bluetooth capabilities; if you're happier programming in Python than in C, you could use a Raspberry Pi Pico W instead
- Tim had always wanted a telescope, ever since seeing the moon through a friend's telescope as a kid
- An earlier attempt at controlling the telescope used a 3D-printed geared wheel, which took 24 hours to print...
- ...This didn't work, so Tim used a timing belt instead

to make out the number plate on a car parked 1km away. But that's not the most important feature according to Tim: "a wider aperture is also important as it collects more light. It sees objects in the sky that you wouldn't even know are there because they are too faint for the naked eye. It's like revealing an image drawn with invisible ink.

"My first target was the moon – but when full, the large aperture reflects so much light into the eye piece it is slightly uncomfortable. I quickly turned to planets, Saturn and Jupiter. I could see the rings and moons of Saturn. Unfortunately at the moment, Saturn is in a part of its 30-year orbit around the sun where the rings are almost side on to us, so they just look like a line. The stripes of Jupiter were clearly visible, as were its moons. They pretty much look like stars, except they form almost a perfect line through the planet. I have also looked at Mars and Venus, but they are less interesting. Once I had done the planets, I turned to star clusters and deep space objects. I have ticked a few off, including the Jewel Box (a tight group of stars near the Southern Cross), Omega Centauri (a globular cluster, which looks like countless tiny points of light which form a brighter centre and fade out towards the edges), and the Orion Nebula (not quite as colourful as all the Hubble pictures you see, more like a wispy grey cloud). I also managed to catch a comet, C/2024 G3 (ATLAS). I haven't seen a galaxy yet – I absolutely can't wait for this."

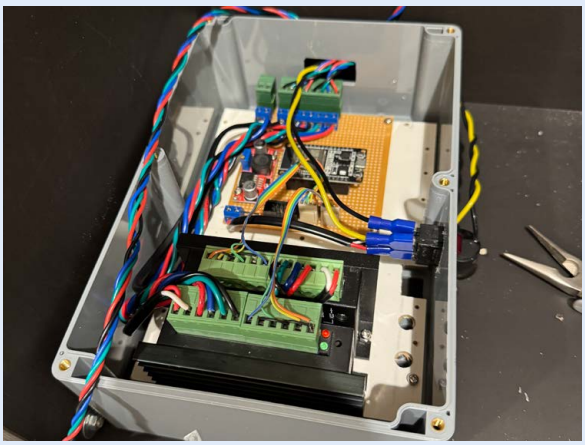


▼ The stepper motors need driver boards to convert the signal from the ESP32 to the correct voltage

Reach for the stars

1. Users can control the telescope manually using a joystick wired to the controller...

2. ... or via a drop-down menu of 50 stars that Tim has coded into the software.



3. There's an ESP32 board controlling stepper motors, and taking input via Wi-Fi and the joystick.

Cassette MagSafe stand

By EBengineering

rpimag.co/CassetteMagsafeStand

You might have heard of Apple: it's a company that makes sleek, functional gadgets, including a line of phones and watches, some of which use conductive charging to... well... charge. What Apple doesn't make is a brilliantly silly 3D-printed phone stand in the shape of an audio cassette on which the user can rest their phone while it's charging.

This shocking oversight has at last been rectified by EBengineering, who has filled the gap in the market with this whimsical piece of design. Any electrical functionality is provided by the chargers that owners of these devices already possess; all it does is hold the cables, and look nice.

Actually, it does do one thing: when you put a pencil into the cassette sprocket and turn it the way we used to do in the Olden Days when tapes got stuck, out pops a hidden stand for a watch charger. Daft, but delicious.

▶ This is one of those builds that straddles the line between silly and brilliant


6:20
16:20


16:54
16:54

Network mapper

By Maximilien

rpimag.co/NetworkMapper

We are, to put it mildly, bored with looking at screen after screen of glowing pixels. We understand that humans are very good at taking in information through their eyes, and that the invention of the alphabet made reading and writing a super-efficient way of transmitting data, but after staring at the TV, our phone, and occasionally our work computers, we sometimes dream of a better way. And here is that better way: a network map showing the status of, and bandwidth between, a series of data centres in Switzerland.

Like many projects, this one began life not out of a need, but out of finding a stash of cool components and wanting to do something with them. In this case, the component haul was a tray of MD0657C2-R displays from a surplus component shop. Add a few MAX6952 chips to drive the displays, and six Raspberry Pi Pico Ws, and you've got the guts of a unique visual display that feels like it came from the set of *Superman 3*.

Maximilien housed these displays and their associated electronics in frames made out of wood and plywood, finished off with painted, laser-cut acrylic panels. It's backlit with RGB LEDs that are controlled by the main Raspberry Pi Pico W, which also grabs the data to display from the data source and updates it in real time.

As data displays go, it certainly beats a spreadsheet.

▲ It's not as efficient as reading a table of figures, but we love this display anyway

Picocomputer 6502

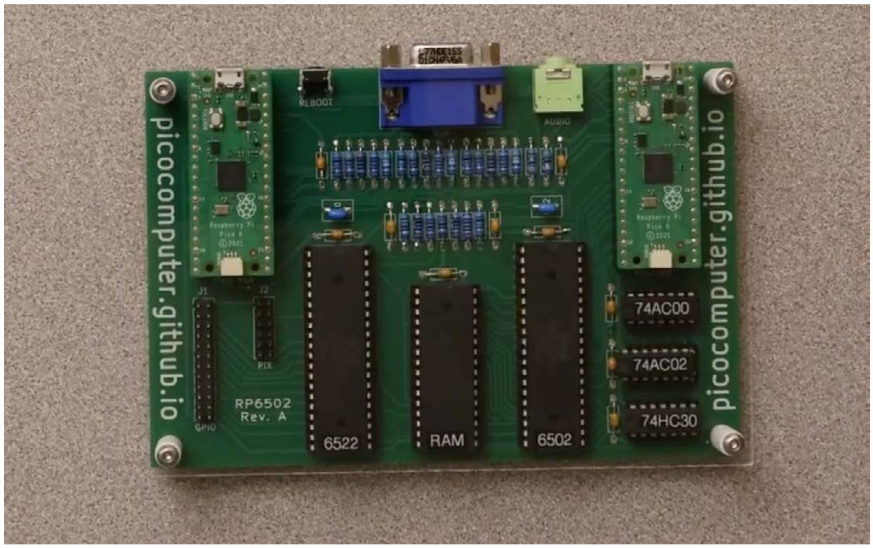
By Rumbledethumps

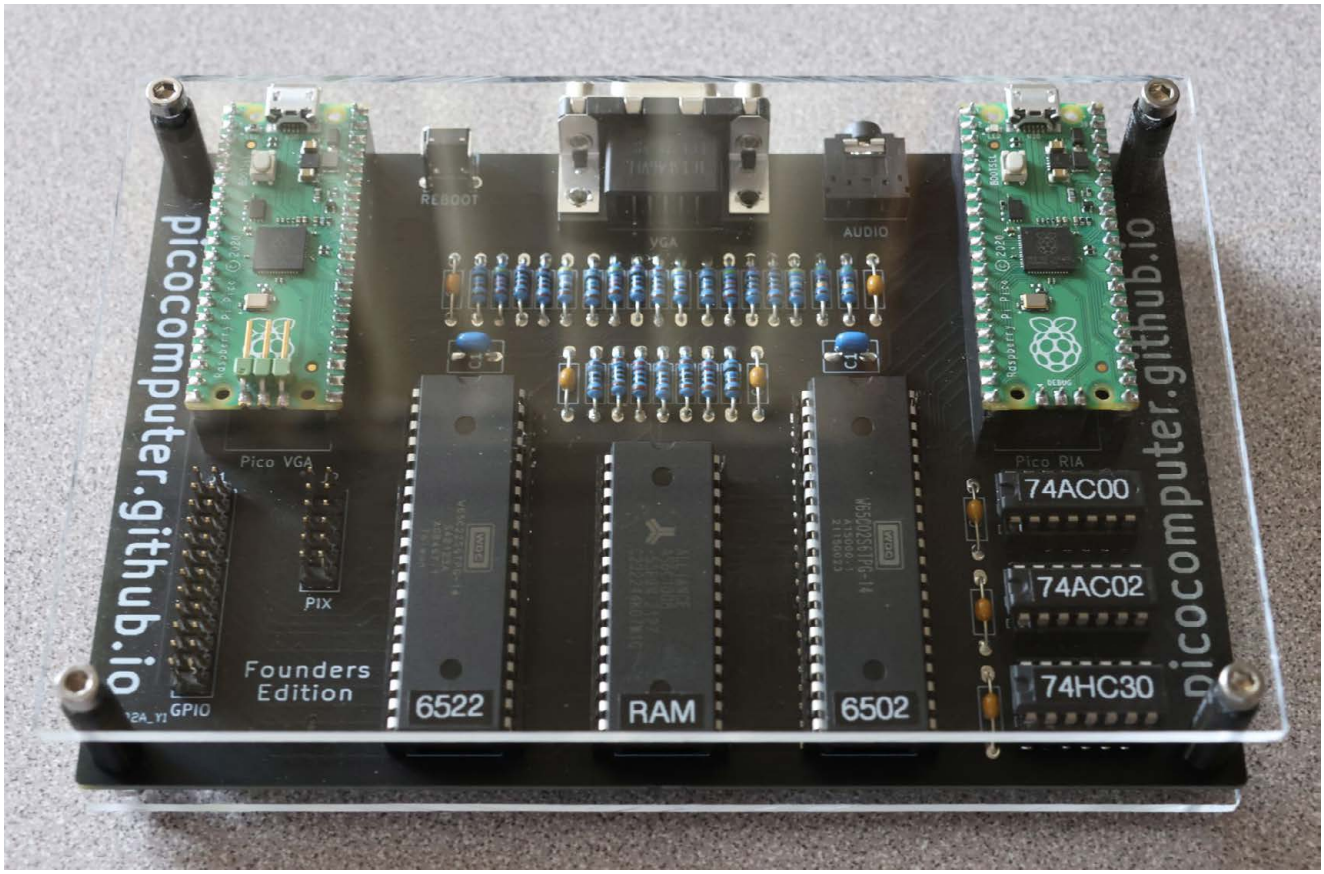
rpimag.co/PicoComputer

The MOS 6502 was an 8-bit microprocessor first introduced in 1975. It was the backbone of loads of classic computers and gaming consoles, including the Atari 2600, Nintendo Entertainment System, Commodore 64, and BBC Micro. And now you can get your get your hands on a computer that works the same way as those old machines did, which slots together with no soldering. It's a miracle, and it's brought to you by retro computing enthusiast Rumbledethumps.

The Picocomputer 6502 is truly open-source hardware: just download the design files from GitHub, send them to the PCB manufacturing service of your choice, slot in the components (which are all common and available from, among others, Mouser), and you've got a machine that will bring a tear to the eye of anyone who played with computers as a child of the '80s.

The fact that anyone can build it themselves is testament to some brilliant design work by Rumbledethumps. And, of course, we're delighted to see a pair of Raspberry Pi Pico microcontroller boards as part of the build.





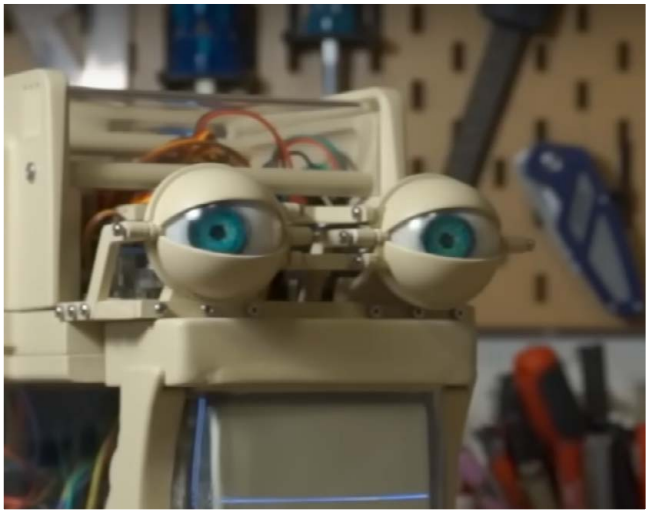
▲ The Picocomputer 6502 now comes with Wi-Fi – though without a browser, you'll not be able to use it to waste time on social media

Tommy-B-003

By Exercising Ingenuity

rpimag.co/TommyB003

"Ever since I was a kid, I've loved robots," begins Exercising Ingenuity in the build video that accompanies this astonishing creation. It's heavily inspired by Thomas Burns's Alexatron robot, which also used 3D-printed animatronic eyes with a sound-wave displayed on a CRT screen representing the robot's mouth. Yes, this awesome-looking machine is a front end to the power-hungry, occasionally useful AI service, ChatGPT.



The Tommy-B-003 also uses a CRT, this time taken from a Panasonic TR-003C portable television with a 3-inch pop-up screen. CRTs can store charge for a long, long time, so the creator of this robot had to follow all the safety guidance, making sure to discharge it properly by grounding the high-voltage anode.

The maker followed Will Cogley's guide to 3D printing, painting, and casting in epoxy resin to get a realistic (some would say uncanny) pair of eyes.

The body is made out of laser-cut plywood, upholstered with canvas and black vinyl to recreate the look of a vintage piece of electronics such as an oscilloscope from the 1950s.

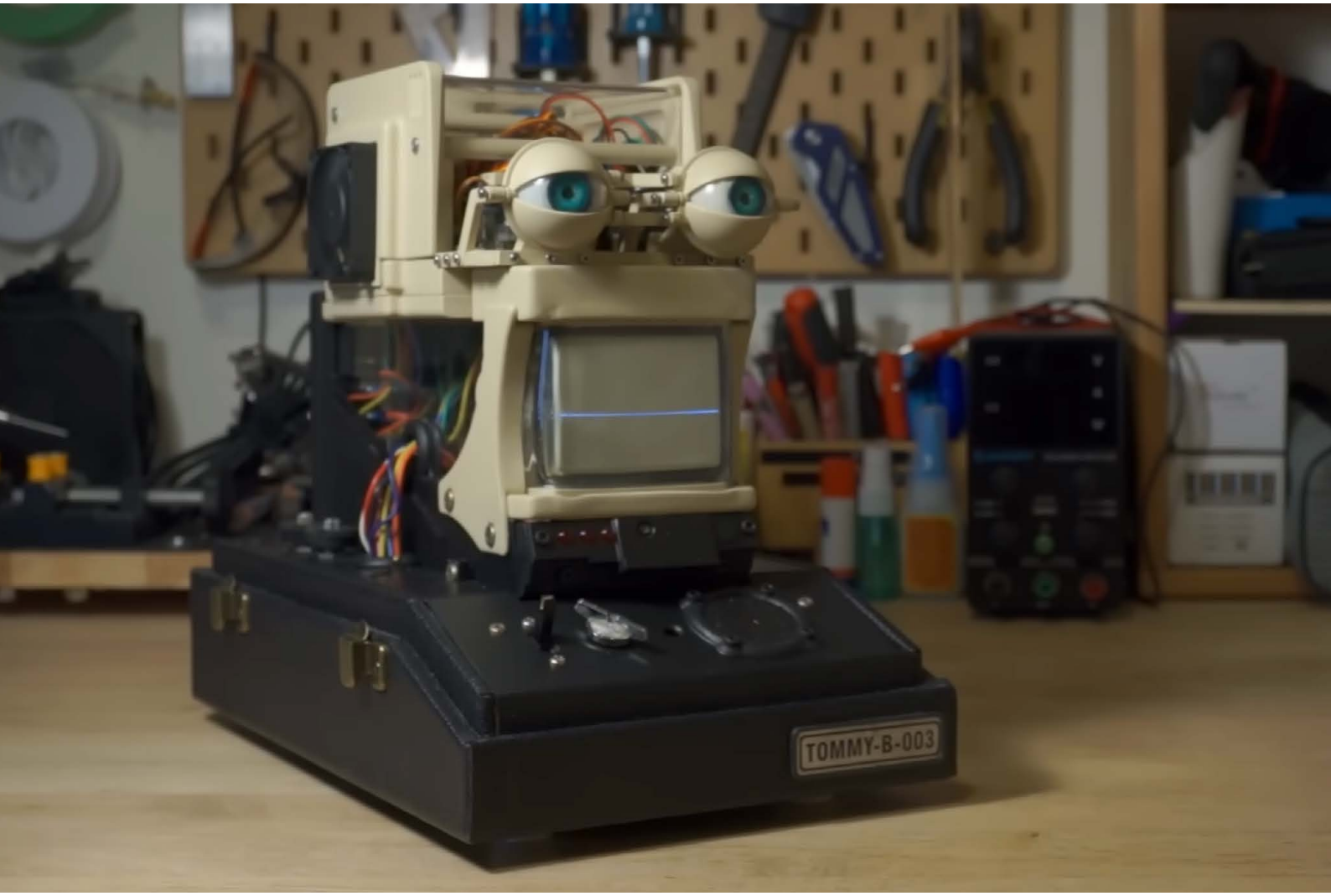
A Raspberry Pi Model 4B connects to ChatGPT, runs the servos for the eyes, and accepts input from the Useful Sensors Person Sensor, which performs facial recognition. The electronics run off a 12V drill battery, with buck converters to adjust that to the voltages required by each of the systems in the robot.

Warning!

Cathode ray tube

Be careful with projects involving old televisions and CRT equipment. Opening up a CRT can be dangerous, risking electric shock even if the TV is not plugged in.

rpimag.co/crtsafety



▲ The maker tried to reuse as many parts as possible from the original TV, including the original audio speaker

3D print

Have a 3D printer? Build your own power tools!

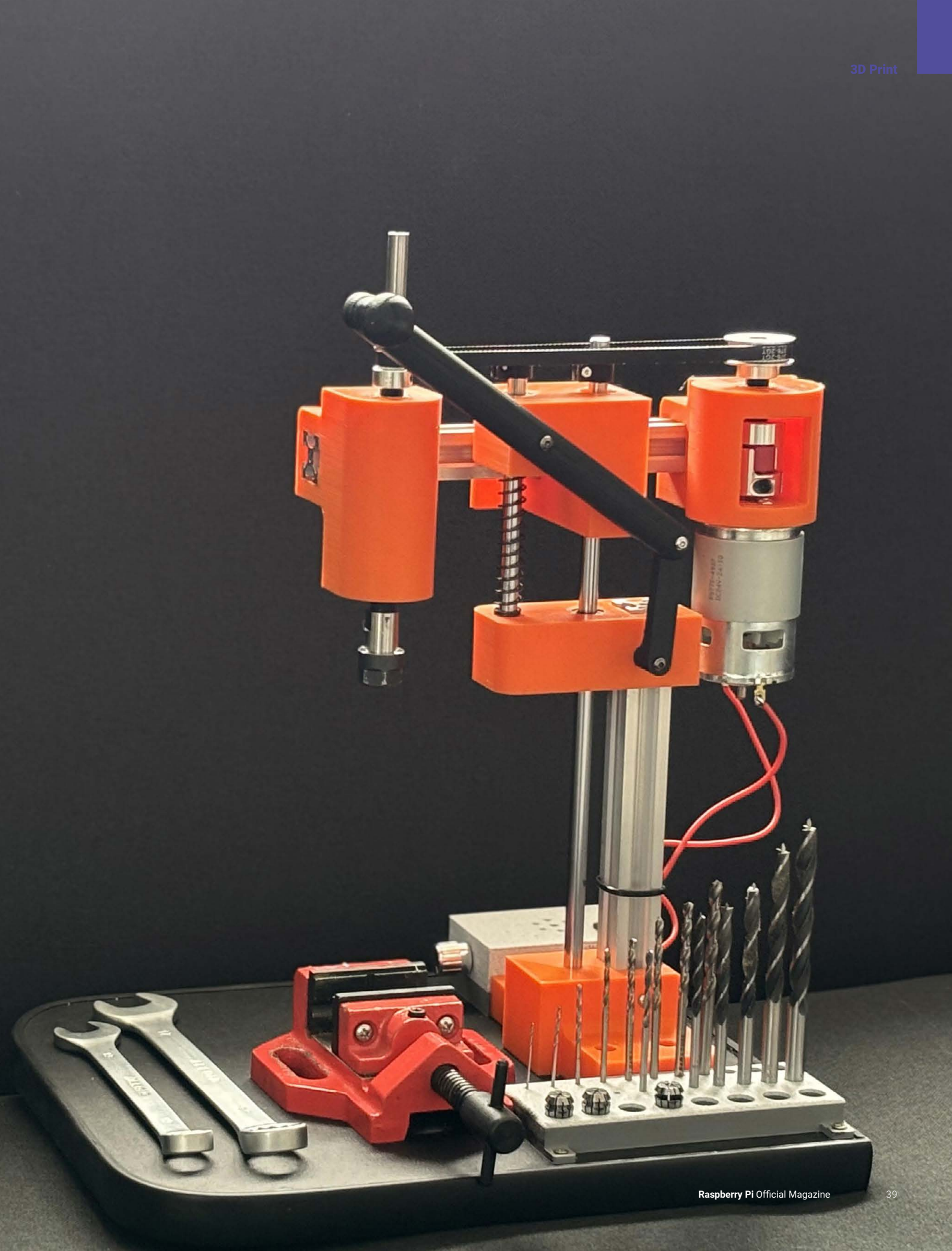
rpimag.co/DrillPress

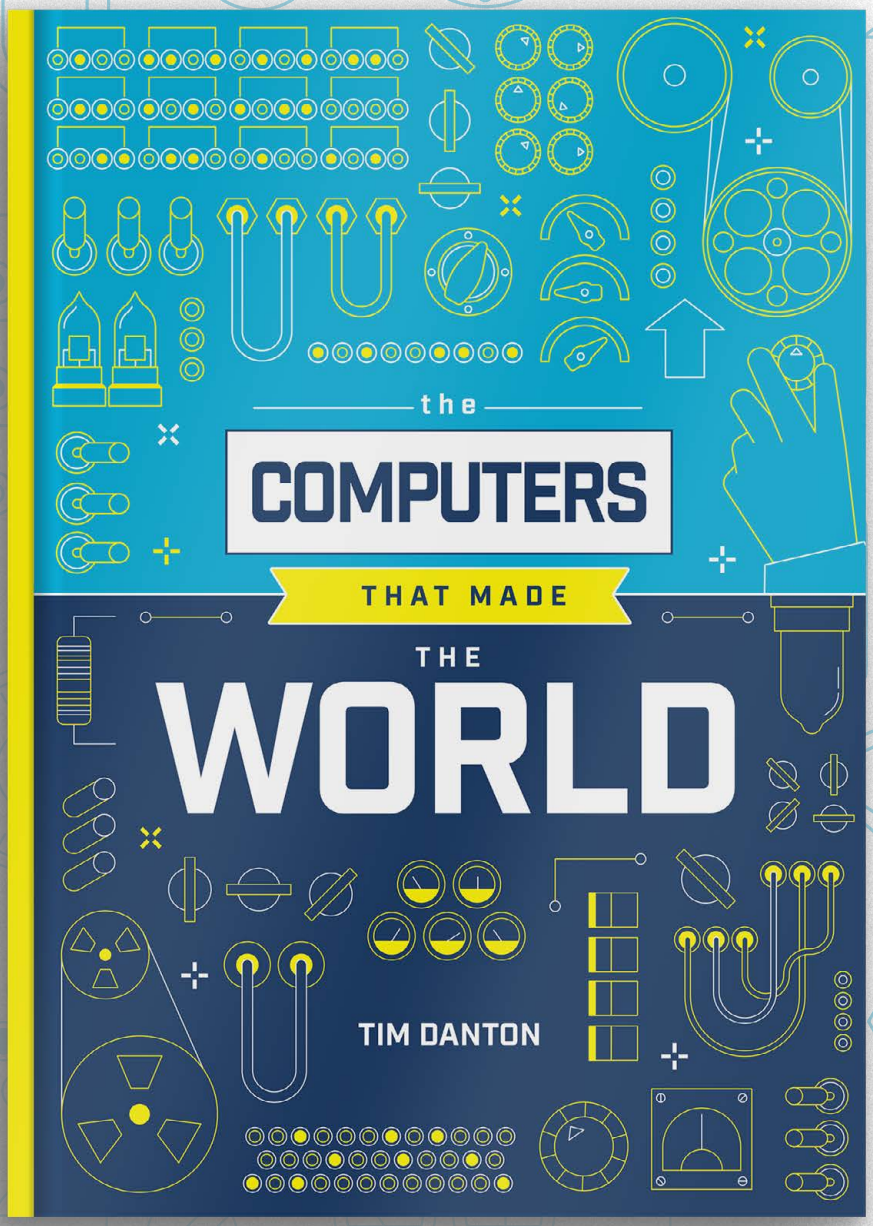
Drilling holes accurately is hard. We've taped a spirit level to our hand drill before now to keep us at a relatively flat angle, and sometimes resorted to clamping a set square on to the workpiece to give us a rough estimate of a 90-degree angle. Even then, the results have been mixed, and every time we end up with a wonky hole, we wish we'd just spent the £100 or so and bought a cheap pillar drill.

We don't know whether Ukrainian home electronics and 3D printing enthusiast DC Sets is as bad at drilling straight as we are, but we do know that they have solved the problem in a far more creative way than we ever could: by 3D-printing a pillar dill. Designed in Fusion 360 and assembled with just $44.55 worth of filament and components, this drill works well enough to drill holes up to 8mm diameter in wood.

For the core of the drill, DC Sets used a 24V, 10,000rpm 775 DC motor with a 5mm shaft; a PWM motor controller with support for bidirectional movement; a DC barrel jack, a couple of pulleys, and a coupling. As the maker says in their video, "it would have been easier to connect the chuck directly to the motor, but a belt should in theory reduce vibrations, isolating the motor from axial forces."

The frame is made up of aluminium extrusion, and two cylindrical shafts that the drill travels up and down on linear bearings. The result is a drill that still has room for improvement, but can easily handle wood and at a pinch can manage brass and aluminium. DC Sets has identified a couple of refinements and will get to those when time allows, but for now, let's just marvel that with a desktop 3D printer and a few power tools you can make a fully-functional drill press.




the
COMPUTERS
THAT MADE
THE
WORLD
TIM DANTON

The Computers that Made the World

How twelve pioneering computers built between 1939 and 1950 helped shape modern technology

In 1940, a *computer* was someone who ploughed through gruelling calculations each day. A decade later, a computer was a buzzing machine that filled a room. This book tells the story of how our world was reshaped by a dozen such computers — and the geniuses that brought them into being, from Alan Turing to John von Neumann. But this isn't just a story about how these computers came to be, or the people behind them: it's a story about how a new world order, built on technology, sprang into being.

This world tour through the modern history of computing begins in 1939 with the first electronic digital computer, the Atanasoff-Berry computer (ABC). From there, it moves on to the Berlin-born Zuse Z3 and Bell Labs' Complex Number Calculator, before we enter the World War II era with Colossus, Harvard Mark I, and then ENIAC, the first general-purpose digital computer. You'll also discover the fascinating stories behind the Manchester Baby, EDSAC, EDVAC, UNIVAC, Princeton IAS, and Alan Turing's Pilot ACE and the birth of artificial intelligence.

In *The Computers that Made the World*, you'll not only learn about the computers that shaped the world we live in, but what happened behind the scenes.

The smarter desktop

Get things done with Raspberry Pi.

By **Rob Miles**

Raspberry Pi is the little computer that has got massively more powerful over the years. While retaining a tiny desktop footprint, Raspberry computers sip electricity, use a secure Linux-based operating system that you get for free, and are much cheaper to buy, maintain, and recycle than traditional bulky desktops.

Raspberry Pi is the ultimate working computer, either on its own or acting as a thin client for a remote service.

Let's find out how to get started and what you can do with it.

Raspberry Pi is the ultimate working computer, either on its own or acting as a thin client for a remote service

COMPUTERS, ASSEMBLE

You'll need a few things to get started building your Raspberry Pi desktop:

- Raspberry Pi 500 or 5
  rpimag.co/raspberrypi500
  rpimag.co/raspberrypi5
- HDMI monitor
  rpimag.co/monitor
- Micro HDMI to HDMI cable
  rpimag.co/microhdmicable
- USB-C power supply
  rpimag.co/powersupply
- microSD card or SSD storage and M.2 HAT
  rpimag.co/sdcards
  rpimag.co/ssd
  rpimag.co/m2hat
- A keyboard & mouse
  rpimag.co/keyboard
  rpimag.co/mouse
- A case (for Raspberry Pi 5)
  rpimag.co/case

QUICK TIP!

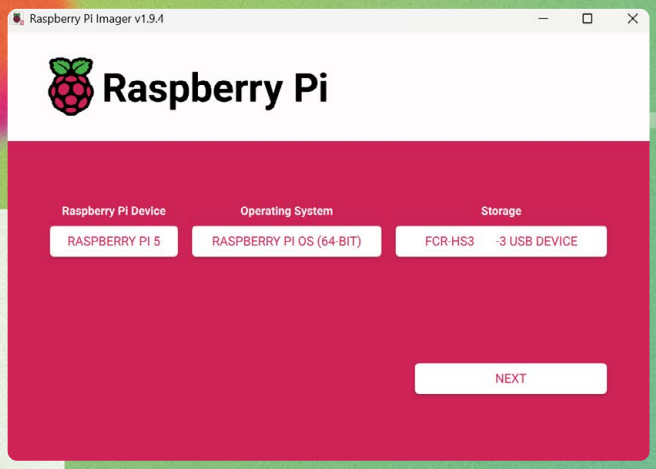
Kit up

Raspberry Pi 500 Desktop Kit comes in a nice case with a keyboard and provides everything you need apart from a monitor (and there is a matching Raspberry Pi monitor you can get too).
rpimag.co/raspberrypi500kit

Install the OS

Now you've got the hardware together, the next thing you will need is software to make it work. A computer on its own is not useful. It needs an operating system to control it. There are several different operating systems available for Raspberry Pi.

Raspberry Pi OS is the official operating system. It is based on Debian Linux and is fast thanks to its light weight. Raspberry Pi OS is packed with Raspberry Pi specific tools and support such as the Bookshelf app that features PDFs of our books and magazines. We think this is the best option, but Ubuntu is another popular option with a more densely packed feature set (**rpimag.co/ubuntupi**).



▲ **Figure 1:** There are versions of Raspberry Pi Imager for Windows, Mac, and Linux machines (including Raspberry Pi)

Network Install

If you want to install Raspberry Pi OS and have a wired Ethernet connection, then Network Install is the easiest way to get Raspberry Pi OS up and running.

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

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

Once you're connected to the internet, your Raspberry Pi will download Raspberry Pi Installer. If the download fails, you can repeat the process to try again. Once you finish downloading Raspberry Pi Installer, your Raspberry Pi will automatically start Raspberry Pi Imager.

Learn more: **rpimag.co/networkinstall**.

OS customisation

In Raspberry Pi Imager, you can specify the username and password to be used to log in to the new machine, along with its hostname, Wi-Fi settings, and even Secure Shell (SSH) keys to enable remote access.

The OS customisation menu lets you set up your Raspberry Pi before first boot. You can preconfigure:

- a username and password
- Wi-Fi credentials
- the device hostname
- the time zone
- your keyboard layout
- remote connectivity

See **rpimag.co/imagerconfig** for more information on how to configure Raspberry Pi OS during the installation process.

Install using Raspberry Pi Imager

Raspberry Pi Imager enables you to use another computer to set up a microSD card for a Raspberry Pi. You select the target model of Raspberry Pi you want to use, the operating system, and the storage device where the image is to be written.

You can also customise the operating system, removing the need to make settings on the device itself.

Raspberry Pi OS can be loaded onto the microSD card using Raspberry Pi Imager software on another computer. Imager is available for Windows, macOS, and in Raspberry Pi OS.

Download the latest version from **rpimag.co/software** and run the installer.

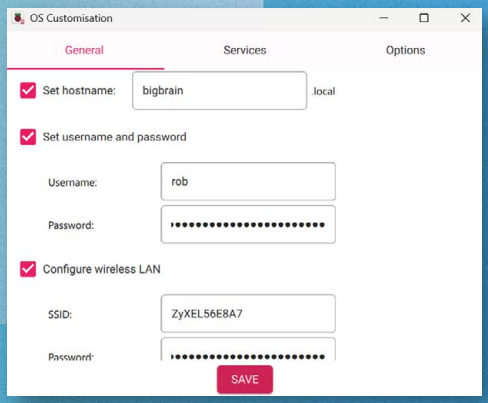
Install it from a terminal using your package manager, e.g. `sudo apt install rpi-imager`.

Once you've installed Imager, launch the application (**Figure 1**) by clicking the Raspberry Pi Imager icon or enter `rpi-imager` into a terminal window.

1. First, click on Choose Device and select your Raspberry Pi model from the list.
2. Next, click on Choose OS and select an operating system to install. Imager always shows the recommended version of Raspberry Pi OS for your model at the top of the list.
3. Connect your preferred storage device to your computer. For example, plug a microSD card in using an external or built-in SD card reader.
4. Click on Choose Storage and select your storage device.
5. Click Next.

In a pop-up, Imager will ask you to apply OS customisation. We strongly recommend configuring your Raspberry Pi via the OS customisation settings. Click the Edit Settings button to open OS customisation (**Figure 2**).

If you don't configure your Raspberry Pi via OS customisation settings, Raspberry Pi OS will ask you for the same information at first boot during the configuration wizard. You can click the No button to skip OS customisation.



▲ **Figure 2:** The settings information is retained, making it easy to create similar images for multiple machines with different hostnames

Storage: How big is big enough?

The Raspberry Pi you need to have really depends on what you intend to do with it. If you want to edit text files and use the command line for everything, then a very modest device will suffice. You can even do word processing on a Raspberry Pi Zero W, but it is not a great experience. For simple tasks (office work and small program development), a Raspberry Pi 4 with 4GB will suffice. But if you want to use services (for example email) via the Chromium web browser, a Raspberry Pi 5 makes the most sense. Your device should have at least 4GB of memory and should be paired with a microSD card of at least 64GB capacity.

Up and running

On first boot, you will see the standard Raspberry Pi OS desktop (see **Figure 3**). The interface has a lot in common with machines you may have already used. You should find that desktop muscle memory from other operating systems will serve you well. Pressing the **SUPER** key on your keyboard (the one with a Raspberry Pi logo) will open the program menu. Pressing **ALT+TAB** will step through open programs and controls in the corners of windows, allowing them to be maximised and minimised. Hold down **SUPER** and press the arrow keys to position application windows around the desktop.

Icons at the top right of the desktop let you manage Bluetooth and Wi-Fi. Icons at the top left provide direct access to the File Manager, the web browser, and a command prompt.

Now that we have a working system on a network, let's add some software.

▲ **Figure 3:** Click on the menu icon in the top left-hand corner to start things happening

Setup Wizard

If you did not go through the OS customisation process in Raspberry Pi Imager, you will be presented with several dialogs before you can get to the Raspberry Pi OS desktop:

- **Wireless keyboard and mouse.** If you do not have a wired keyboard or mouse connected, you will be prompted to connect a Bluetooth keyboard and/or mouse. Put them into pairing mode and wait for them to connect.
- **Set Country.** Choose your Country, Language, and Timezone. You can also choose to 'Use English language' (if you want to use English instead of the default language for your country), and 'Use US keyboard' (if you want to use a stock US keyboard instead of the default for your country).
- **Create User.** This is a very important step in setting up your new computer. Enter a username and password (see **Figure 4**). These allow you to protect your machine from unauthorised access. Once the system is running, you can create details for additional users who will each have their own individual space on the machine.
- **Select Wireless Network.** Choose your wireless network from the list and enter the network password. Click Skip if you are using a wired internet connection.
- **Choose Browser.** Both Chromium and Firefox are pre-installed on Raspberry Pi OS. Chromium is based on Chrome but has limitations (in particular, you cannot sync settings).
- **Update Software.** While you can click Skip, it's a good idea to click Next to check for software updates. They may take a little while to download, so it's a good time to grab a coffee.

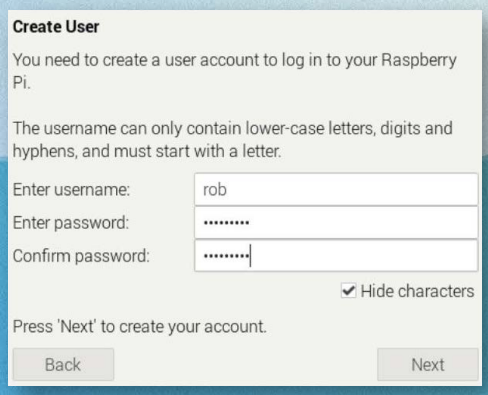
A lighter word

If you need a small, fast word processor that will run on lower-specification models, look at Abiword (**abiword.org**), which is old but works fine for simple documents. You can install this in Raspberry Pi OS using APT. Open a terminal window and enter:

```
sudo apt install abiword
```

Enter **Y** and press **ENTER** to install. You'll now find it under the Office section of the menu alongside LibreOffice.

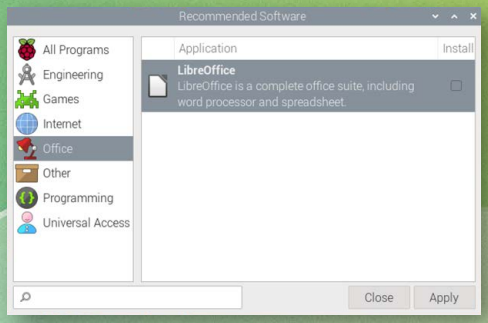
▶ **Figure 4:** Creating a user in the installation process



QUICK TIP!

Change the desktop

The default desktop background is a lovely picture, but if you fancy a change, you can right-click on the desktop, select Preferences, and pick a different one from Appearance Settings.



◀ **Figure 5:** The dialog updates automatically to make sure you always get the latest version

QUICK TIP!

Bookshelf
For something to read, look in Help > Bookshelf. There you can find past issues of Raspberry Pi Official Magazine plus lots of great books.

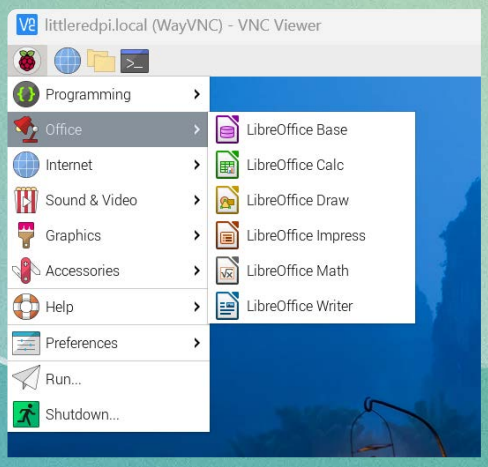
Selecting software

Raspberry Pi OS has a program called Recommended Software (see **Figure 5**). This contains a curated selection of software packages. Access it from the desktop by selecting Preferences > Recommended Software. In the Office section, you will find the LibreOffice and other productivity applications. LibreOffice is a large suite (taking up around 1GB) comprised of six applications. Users of other large office suites will find the interface quite familiar. Check the Install box and click Apply to add the software to Raspberry Pi OS.

Figure 6 shows the six main elements of LibreOffice after installation. They are fully-featured and work well.

QUICK TIP!

Add/Remove
The Preferences > Add/Remove Software dialog provides access to lots more applications.



▲ **Figure 6:** The applications work directly with files from other suites and word processors

You've got mail

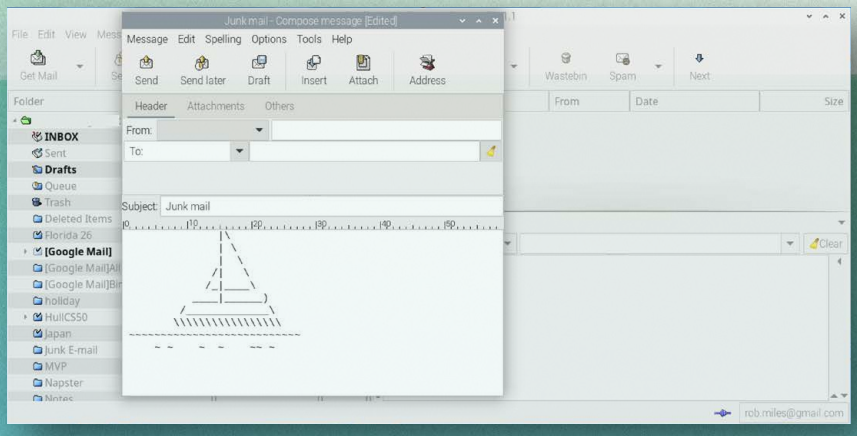
If you want a local email service, with mail messages stored locally on your machine, you should use the Claws Mail client (**claws-mail.org**, see **Figure 7**), which is included in Recommended Software. When you first boot Claws Mail, it will present you with an email setup wizard.

1. **About You.** Enter your name and email address and an optional organisation.
2. **Receiving Mail.** You'll need to decide which Server type to use: IMAP (Internet Message Access Protocol) or POP3 (Post Office Protocol v3). Typically, IMAP is a better choice because it leaves messages on the server, enabling you to use multiple email clients. Click Auto-configure and enter your password.

If you want to use Claws with mail services such as Google Mail or Microsoft Office that use two-factor authentication (2FA), you need to create an app-specific password on the service for the Claws client to use. This is a custom password created by the service for use with a single app.

App-specific passwords can be generated on the website of the service. For Gmail, you should head to **myaccount.google.com**.

The app password is entered where you would normally put your password in the connection settings. Remember, if you don't use 2FA, you can just use your email password as normal.



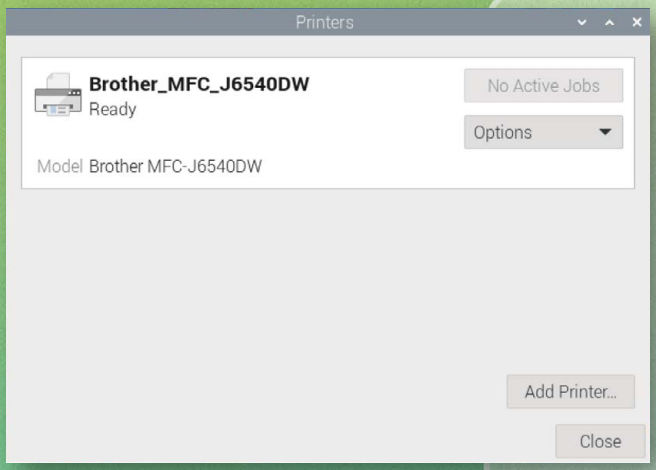
▶ **Figure 7:** You can connect to multiple mail services at the same time in the Claws Mail client

Shutdown and out

You should use the desktop Shutdown button at the base of the program menu to close all active applications and prepare Raspberry Pi to be powered off. Raspberry Pi 5 also has a physical power button which triggers a shutdown dialog on the desktop. Earlier versions of Raspberry Pi do not have any kind of power switch.

Figure 8 shows the shutdown screen. A Raspberry Pi system will usually survive an unexpected power failure, but just turning off the power runs the risk of losing unsaved data and, if you're very unlucky, preventing the machine from booting the next time it is turned on. See the 'Getting your backup' section (overleaf) for protecting yourself against data loss.

▲ **Figure 8:** If you log out, another user can log in and use the machine with their profile



▲ **Figure 9:** You can open the Printers dialog from the Preferences section of the main desktop menu

Getting into print

Raspberry Pi operating system uses CUPS (Common UNIX Printing System) for printed output. This system works with AirPrint/IPP Everywhere printers. You can find a list of supported printers here: **pwg.org/printers**.

Figure 9 shows the Printers dialog, here indicating that a local Brother printer has been detected and is ready for use. This printer appeared without the need to install any drivers in Raspberry Pi OS.

In the AirPrint system, the printer prints a PDF (Portable Document Format) file produced by the computer. This means that you don't have to worry about missing printer fonts, or the printed output looking different from the preview on the screen. You can select printer options such as 'photographic quality' from the printer options menu, although their effect might vary from one printer model to another. The printer integration extends into the browsers, making it easy to print from websites and browser-hosted applications.

Sounding off

Raspberry Pi will send audio output over its HDMI connection to the monitor. You can connect external speakers, microphones, and headsets over Bluetooth, but if you want to connect a wired microphone or speaker to your machine, you must use an audio adapter which plugs into a USB port on Raspberry Pi. These are available at a low price and are automatically detected when they are plugged in. See **rpimag.co/usbaudio** for one option.

QUICK TIP!

Reboot after install

The CUPS system is installed when you install LibreOffice. You will need to reboot after installing LibreOffice for local printers to be detected.

Prompt action

You can use the Raspberry Pi desktop to perform most routine tasks, but you should also try to learn how to use the command prompt because there are some tasks that can only be performed using typed commands. And it's a powerful advantage to using a Linux or GNU/UNIX-based operating system.

The command prompt is also known as the command-line interface (CLI) or the program you use to access it: Terminal.

For example, if you want other users to share your Raspberry Pi workstation, you can use the `adduser` command.

```
sudo adduser jim
```

The command above adds a new user with the username `jim`. The `adduser` program asks for some details for the new user and then creates it. Each user will have their own desktop environment and private space where they can store their files.

Take a look at our new book, *Conquer the Command Line (Third Edition)* for a thorough grounding in using the command-line interface: **rpimag.co/commandlinebook**.

The first word of the command statement above, `sudo`, asks Raspberry Pi OS to perform the `adduser` command in the role of a superuser. Only users with superuser permissions can use the `sudo` prefix on commands. The user `jim`, when it has been created, will not be able to create new users because it will not have superuser status. We can give `jim` superuser status by issuing another command:

```
sudo usermod -aG sudo jim
```

This adds `jim` to the supervisor group. Note that you'd only do this if you trusted Jim to manage the system. The username created when the system image was built (i.e. the one you typed into the Raspberry Pi Imager) always has superuser status.

> *There are some tasks that can only be performed using typed commands*

QUICK TIP!

Regular users

It is best not to give other users the system image password, but instead create users for them which do not have superuser permissions. The system will ask for a superuser password if they try to do something only superusers can do.

Luxury items

You can create a workstation with just a Raspberry Pi, monitor, keyboard, and mouse. But you can improve your life by picking up a few luxury items.

- **Raspberry Pi Active Cooler:** Raspberry Pi is designed to slow down when it detects that the processor is getting too hot. This stops things catching fire, but also reduces performance. Adding a fan, as in the Active Cooler, will help the processor to stay cool and maintain speed under a heavy workload. See **rpimag.co/activecooler**.
- **Wired network connection:** Wi-Fi on Raspberry Pi works well, but you can get higher performance and a more reliable connection by using a wired Ethernet connection.
- **SSD:** Raspberry Pi uses a microSD card to store the OS and user files. This works, but you can now add high-performance NVMe solid-state disks (SSDs) that reduce boot time and speed up program loading. Installation is not difficult. See **rpimag.co/ssdkit**.
- **SD card reader:** this lets you copy images to microSD cards from Raspberry Pi. Very useful for making a system backup or for experimenting with alternative operating systems. See **rpimag.co/sdreader** for one option.
- **Second monitor:** Raspberry Pi 4/400 and 5/500 support dual monitor connections. Having two monitors allows you to keep some programs always open while you work on others. See **rpimag.co/monitor** for the official one.

Getting your backup

You can use the SD card copier tool at Accessories > SD Card Copier to copy the entire contents of your microSD card onto an external storage device.

If you are planning to write the next great novel or keep your company accounts on your Raspberry Pi, you should consider how you are going to back up your precious data. The simplest way to do this is to copy important files off your Raspberry Pi onto an external storage device, which could be a USB memory stick. Simply plug the stick into your Raspberry Pi and drag important files onto the drive that appears on your desktop.

If you are concerned about your data falling into the wrong hands, you can create encrypted archives or use an encrypted USB storage device.

QUICK TIP!

Multiple microSDs

Get a multi-pack of microSD cards. Make a copy of the system as soon as you have it set up and then regularly after that. Rotate your cards so that you always have a couple of backups. And keep the cards in a secure place.

Backups work best if they are part of your workflow. If you spend each day interacting with customers, you could create folders for each customer and then back these up each day. If you are working on the next great novel, you should get into the habit of copying updated versions onto your backup.

If you want to automate your backup process (and add encryption), check out BorgBackup: **borgbackup.org**. If you want a full document management system (which could support a group of workers from a single document server running on a Raspberry Pi), you should investigate Paperless-ngx: **docs.paperless-ngx.com**.

Send in the clouds

You can store your work in the cloud for free using GitHub: (**github.com**). This platform is popular with programmers, but it can be used to store any kind of data, as long as individual files aren't more than 50MB or so. This makes it good for documents, although images and video will quickly exceed your allotted space.

GitHub provides version management and is particularly powerful when used to underpin group projects. You can create private repositories and choose who you share them with.

QUICK TIP!

GDPR

If you store personal data on your machine (for example, names and addresses of customers), you must manage it in accordance with UK GDPR (United Kingdom General Data Protection Regulation) practices. Find out more here: **gov.uk/data-protection**.

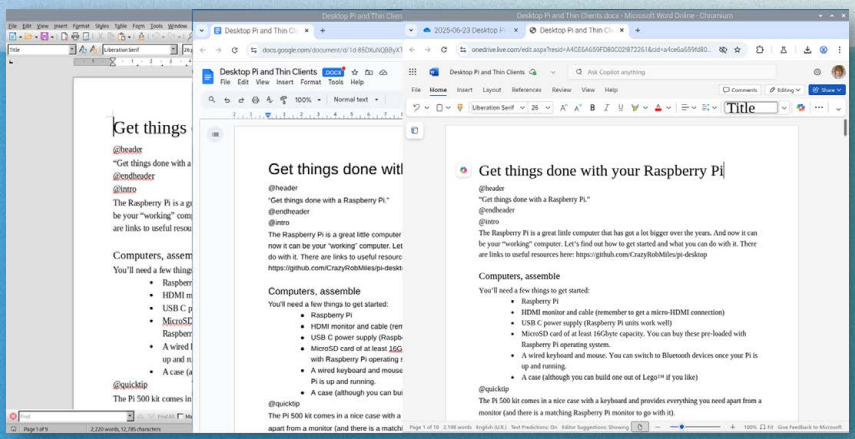
Cloud working

Many modern programs and office environments are provided via cloud apps. These are typically interactive websites that provide application-like functionality. Google Docs is a classic example, as are Office 365 and iCloud.

The programs are running on a distant machine, and your web browser is providing a user interface.

Figure 10 shows an early draft of this article being edited using LibreOffice, Google Docs, and Word Office 365. All the applications were able to open the document file, and their printed outputs were close to identical. The web-based applications were as responsive as LibreOffice running locally on Raspberry Pi. And they handled a 250-page document with no problems.

There are cloud-based solutions for a huge range of tasks and some of these can be converted into Progressive Web Applications (PWAs) which can be installed on the machine and run locally.



► **Figure 10:** You can use LibreOffice or cloud apps to edit documents

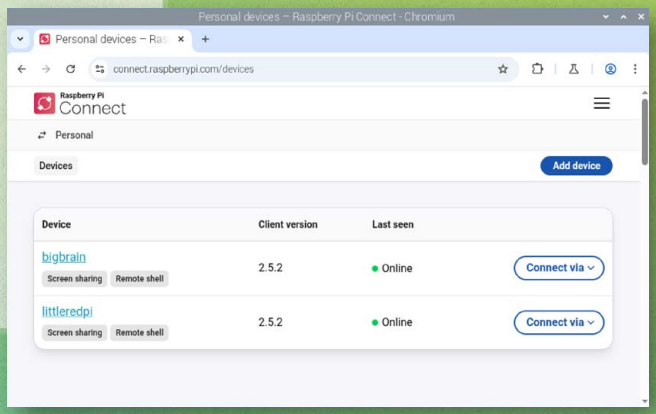
Virtually there with Raspberry Pi Connect

Having a desktop machine at home is all very well, but what if you want to access it remotely? Raspberry Pi Connect lets you connect to your Raspberry Pi from anywhere in the world. You sign up for the free service and add your machines to your account. Then you can connect to them from your web browser.

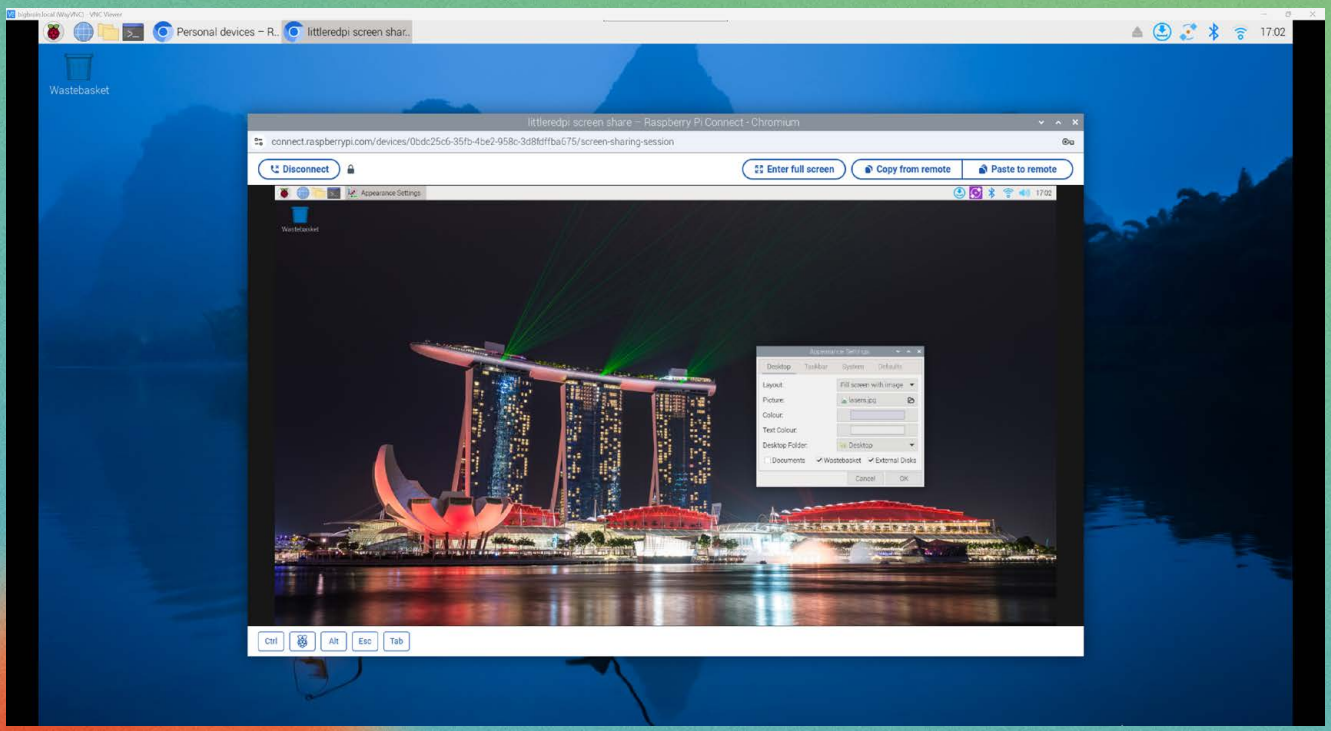
Figure 11 shows Raspberry Pi OS's Connect dashboard displaying two devices that have been registered and are available for connection. We can connect to Raspberry Pi's desktop interface or command console

Figure 12 shows a Raspberry Pi being used to view the desktop of another via the Chromium browser. This is extremely powerful for remote management and providing help for users. Find out more at **rpimag.co/connectdocs**.

▼ **Figure 11:** You can access Raspberry Pi Connect from any web browser to connect remotely to your registered Raspberry Pi computers



▼ **Figure 12:** We have connected to the littleredpi machine and changed its desktop background remotely



Deploy thin client computers

Use Raspberry Pi to access remote computing power. By **Simon Burgess**

Organisations around the world use Raspberry Pi technology as thin clients, replacing traditional personal computers.

A thin client is a device that primarily accesses applications and data that is hosted remotely, either on servers located on the company's premises or increasingly in the cloud.

When users interact with a thin client, they access a remote desktop environment. The server provides each user with a personalised session that feels like a typical desktop experience, even though the actual processing is happening on the server. This is known as 'desktop virtualisation'.

Thin clients have a number of benefits, including reduced hardware costs, centralised management, improved security and, in the case of Raspberry Pi, the benefit of energy-efficient client devices. As applications and data are held centrally, all maintenance, updates, and patches are applied once, then available to all users.

Raspberry Pi has established specialist partners who provide enterprise-grade solutions, giving businesses the confidence that they can use their technology to access virtualised desktop environments such as Citrix, Microsoft, and Omnissa (previously VMware EUC).

It's not just about running servers on a screen; it's about unleashing efficiency

▼ NComputing's RX420(RDP) Thin Client, powered by Raspberry Pi, is a purpose-built endpoint for Microsoft AVD, Windows 365, and more –offering seamless dual display support

A Raspberry Pi-based thin client solution attached to the back of a monitor

Make the switch

With Windows 10 support from Microsoft coming to an end in October, companies are looking at how they can move to Windows 11 without refreshing their whole desktop estate. One solution is to adopt a thin client strategy, where they can repurpose some existing PCs as thin clients and then gradually introduce new low-cost Raspberry Pi based devices. By moving to Windows 11 in the cloud, organisations can boost efficiency, scalability, and security utilising Windows 11's advanced features while lowering hardware demands, simplifying IT management, and enabling flexible remote or hybrid work setups.

One partner is NComputing, which has a range of products based on Raspberry Pi 3B+ computers, Raspberry Pi 4B computers, and a recently introduced Compute Module 5-powered thin client. A company it has helped is Arcos Dorados, the world's largest independent McDonald's franchisee and quick service chain, operating in Latin America and the Caribbean. By adopting Raspberry Pi-based NComputing RX series thin clients, the company has standardised its IT infrastructure and simplified management across its locations.

Using thin clients to virtualise its restaurant operations across multiple markets, Arcos Dorados saved 50% compared to buying PCs, reduced its energy usage, reduced its management costs, and also reduced the physical space needed due to the size of the thin clients.

"Adopting virtualisation technology opens up a realm of limitless possibilities for businesses. It's not just about running servers on a screen; it's about unleashing efficiency, flexibility, and innovation," says Ignacio Caccavelli, IT Infrastructure Manager LATAM, Arcos Dorados.

Other thin client partners, such as NEXINEO, Cendio, ThinLinX, and Losingthewires, offer virtualised desktop solutions with their own remote management software. They offer anything from dedicated classroom solutions for schools, and general virtual Linux desktops, to a fully managed Chromium-based sovereign workplace thin client offering.

For more information on how Raspberry Pi can help with your thin client solution, contact **simon.burgess@raspberrypi.com**.

Thin clients enable virtual apps and virtual desktops to run remotely on Raspberry Pi hardware

Make a digital jukebox

Create a music-playing box of tricks with your Raspberry Pi

Maker

Phil King

A long-time Raspberry Pi user and tinkerer, Phil is a freelance writer and editor with a focus on technology. He loves a good jukebox.

philkingeditor.com

YOU'LL NEED:

- Raspberry Pi (4 or 5 recommended)
- microSD card
- Fruitbox software
- Music tracks
- USB thumb drive
- Touchscreen (optional)
- Push-buttons and connector wires (optional)

Joan Jett may have advised us to put another dime in the jukebox (baby), but these traditional mechanical music-playing marvels are not quite as commonplace as they once were, largely thanks to many bars and venues now streaming music instead. While some classic jukeboxes are now collector's items that can cost tens of thousands, there is a much less expensive option: build your own digital jukebox using a Raspberry Pi.

The free and open-source Fruitbox software (GitHub repo at **rpimag.co/fruitboxv2**) we're using here is fairly easy to set up, works on a range of Raspberry Pi models, and offers a range of different skins to emulate classic and more modern jukeboxes. It can even play OGV format video files, although we won't cover that in this guide.

You can display your digital jukebox on a standard HDMI monitor, or use a touchscreen such as the Raspberry Pi Touch Display. There's also the option of mounting your display in a DIY enclosure or cabinet and adding physical buttons connected to the GPIO pins.

QUICK TIP

Useful keyboard controls include **BACKSPACE** to skip a track, **SPACE** to play a random song, left/right arrows to switch between groups of tracks, and **+/–** to adjust volume.

Back in time

The first thing to note is that you can't use the latest version of Raspberry Pi OS Bookworm, which is incompatible with Fruitbox. Therefore, you can either use the legacy Bullseye version of Raspberry Pi OS, available in the Raspberry Pi Imager tool, or an earlier version of Bookworm. As we used a Raspberry Pi 5, we opted to install the 15 March 2024 64-bit version of Bookworm, which does work with

▲ Fruitbox with the default SB-M100 jukebox skin; just enter the alphanumeric code for a song to play it or add it to the queue

You can press a letter followed by a number to select the relevant song

▼ Want a different look? You can add the file paths to other skins to the **fruitbox.ini** config file

```
pi@raspberrypi: ~/fruitbox
File  Edit  Tabs  Help
 GNU nano 7.2                    fruitbox.ini *
[attract mode]
  Enable = Yes
  Choice = Random
  Interval = 1.0 Minute
  MaxVolume = 50
  FadeIn = 5.0 Seconds
  FadeOut = 10.0 Seconds
  FadeInPosition = 60.0 Seconds
  FadeOutPosition = 70.0 Seconds
  SkipLoad = Yes

[skins]
  File = skins/SB-M100/fruitbox.cfg
  File = skins/Cassette/button_fruitbox.cfg

[buttons]
  Quit = KEY_ESC
  Coin1 = KEY_F1
  Coin2 = KEY_F2
  Coin3 = KEY_F3
```

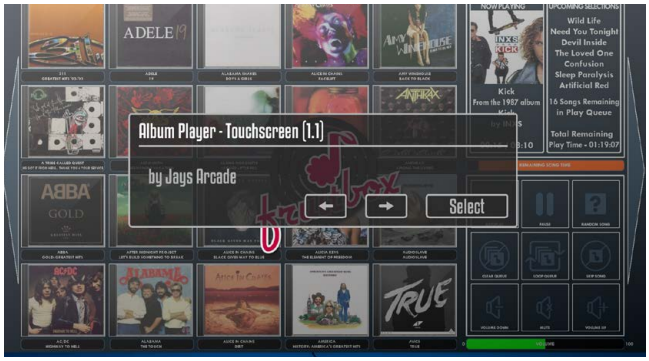
QUICK TIP

For more details on all the options in Fruitbox, including a list of default controls, visit the Fruiboxt4 Dummies site: **rpimag.co/f4d**. There's even a guide to creating your own skins.

Fruitbox. For this, go to the official Raspberry Pi OS downloads page (**rpimag.co/rpiosimages**), click on **raspios_arm64-2024-03-15/**, and then select the top file (**2024-03-15-raspios-bookworm-arm64.img.xz**) to download the OS image. You can then write it to a microSD card in Raspberry Pi Imager, via the Choose OS > Use Custom option. In the OS customisation settings, we found it's best to stick with 'pi' as the username so you don't need to change any Fruitbox default file paths later on.

Picking fruit

Once you've booted up your Raspberry Pi with your fresh build of Raspberry Pi OS, you're ready to install Fruitbox. Note that there are both 64-bit and 32-bit versions available for Raspberry Pi 4 or 5, so you'll need to install the one matching your OS. For the 64-bit version, enter this terminal command:



▲ With multiple skins added, launching Fruitbox will show a skin selector to choose one; some are designed for touchscreen (or mouse) control

```
wget https://github.com/chundermike/rpi-fruitbox-v2/raw/main/install_fruitbox_pi4
```

Even though it's labelled 'pi4', it will also work on Raspberry Pi 5. If you need the 32-bit version instead, enter:

```
wget https://github.com/chundermike/rpi-fruitbox-v2/raw/main/install_fruitbox_pi4_32
```

You then need to make the install script executable:

```
chmod +x ./install_fruitbox_pi4
```

...or (for 32-bit version):

```
chmod +x ./install_fruitbox_pi4_32
```

Now run the script:

```
./install_fruitbox_pi4
```

...or (for 32-bit version):

```
./install_fruitbox_pi4_32
```

Fruitbox will take a little while to install, then you'll be able to run it with:

```
cd ~/fruitbox && ~/fruitbox/fruitbox
```

A startup screen will then appear with an error message saying 'No songs found'. Time to add some...

Add some music

Copy a few of your own (legally obtained) MP3 files to a USB thumb drive and insert it in your Raspberry Pi. You can always add more later. By default, Fruitbox looks in the **/home/pi/Music** folder for songs. So you can either copy all of your files over to that, or change the path in the **fruitbox.ini** configuration file. For the latter, enter `nano fruitbox.ini` to edit it; under '[general]', change the MusicPath. To point it at a folder called 'Music' in our USB thumb drive, for instance, we used:

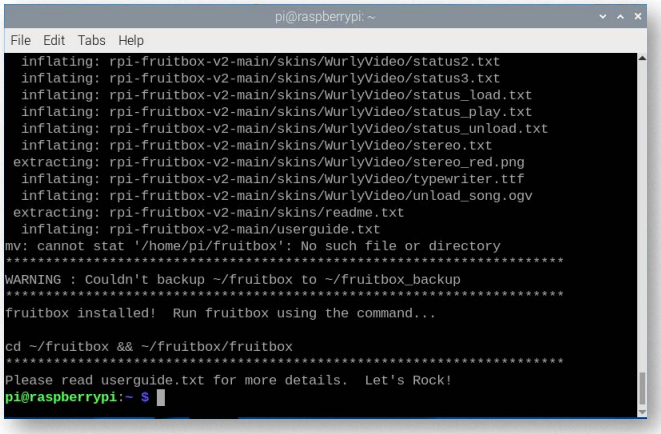
```
MusicPath = /media/pi/USB_Drive/Music
```

Change this to your own file path for your music files (which you can discover by opening their folder in the desktop File Manager). Note that the files do need to be in a folder, not loose on the drive. In addition, you can opt to organise them into artist and album folders – which you'll need to do if using an album-based skin.

With your song files in place, you can now restart Fruitbox and it will find them, add them to its database, then present you with the tracks loaded into the default jukebox skin. Just like on a standard jukebox, you can press a letter followed by a number to select the relevant song. It will then be played on a pretend vinyl record. You can press more combinations to add songs to the queue. By default, free play mode is enabled, so you don't even need to add any credits – although you can change this in the settings (press **TAB** to bring up the main menu).

QUICK TIP

To bring up a Search menu, press the **/** (slash) key. You can then search the database for the song you want – useful if you have a very large collection of music tracks.



▲ Fruitbox is relatively easy to install, although you'll need an earlier version of Raspberry Pi OS

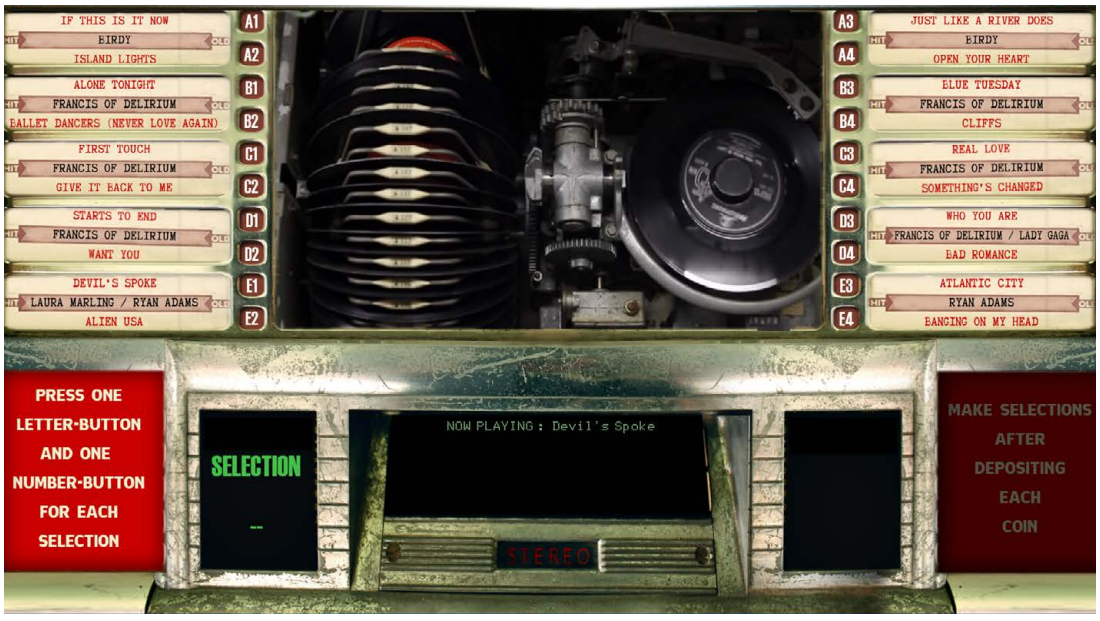
Change your skin

While the default SB-M100 jukebox skin is pretty cool, there are plenty of others to choose from. To add more, edit the **fruitbox.ini** file again and add their file paths under '[skins]'. Just take a look in the **skins** folder beforehand to see what's available. Once you have more than one skin listed, you'll get a 'skin selector' when you start up Fruitbox – use the left/right arrow keys to browse them, and **ENTER** to select.

Some skins are designed to be used with a touchscreen, after enabling touchscreen control in Fruitbox – either in the Controls menu or in **fruitbox.ini**. We tried hooking up our Raspberry Pi 5 to a Touch Display 2 screen, mounted in a sleek Pibow Frame (**rpimag.co/pibowframetd2**), but had issues getting the Fruitbox skins to scale to the correct size and work with touch input. So a bit of tweaking may well be needed. For audio output, we used a Bluetooth speaker, since Raspberry Pi 5 lacks a 3.5mm jack.

Finally, there's the option of using chunky push-buttons connected to Raspberry Pi's GPIO pins, for that true jukebox feel. You could then fit them into a 3D-printed or wooden enclosure, as some makers have done. However you implement it, Fruitbox is a lot more fun than your average music player.

▲ This cassette player skin is a fun choice, and there's no danger of the tape spooling out!



▼ The classic Wurly skin features a neat record-changing visual in the middle

Other Raspberry Pi models

While a Raspberry Pi 4 or 5 is recommended, Fruitbox will also work on any model from a Raspberry Pi Zero through to Raspberry Pi 3. For those, you'll need to use a legacy Buster version of Raspberry Pi OS Lite, however, due to sound issues on later versions. You should also set the GPU memory to 256MB: enter `sudo raspi-config`, then select Performance Options > GPU Memory.

QUICK TIP

On Raspberry Pi 5, opening the button mapping tool from the main menu will crash Fruitbox, so you'll need to change button settings (such as for GPIO pins) in the **fruitbox.ini** config file.

Settings storage

Manage the settings in your embedded Python applications

Maker

Rob Miles

Rob has been playing with software and hardware since almost before there was software and hardware.

robmiles.com

In this session we'll take a look at settings storage. We'll consider a device that needs internal storage and build a system to store settings values for it. Along the way we'll discover files, JSON, and how to use web pages to manage device settings. We'll finish with a look at security options for Python programs running in embedded devices such as the Raspberry Pi Pico.

The LLP (large light panel)

Some technical developments are driven by a burning desire to advance the cause of humanity. The large light panel was developed because the author found a source of very cheap 8×8 pixel boards. By stringing these together, he wanted to create a remote-controlled light panel. You can find the software for the panel, along with case designs and the sample programs from this article, in the following GitHub repository: **rpimag.co/picosettingsstorage**.

Figure 1 shows the light panel. It uses three 8×8 pixel arrays and is controlled by a Pico running a CircuitPython program that connects to the local network and hosts a web page which can be used to set the light colour.

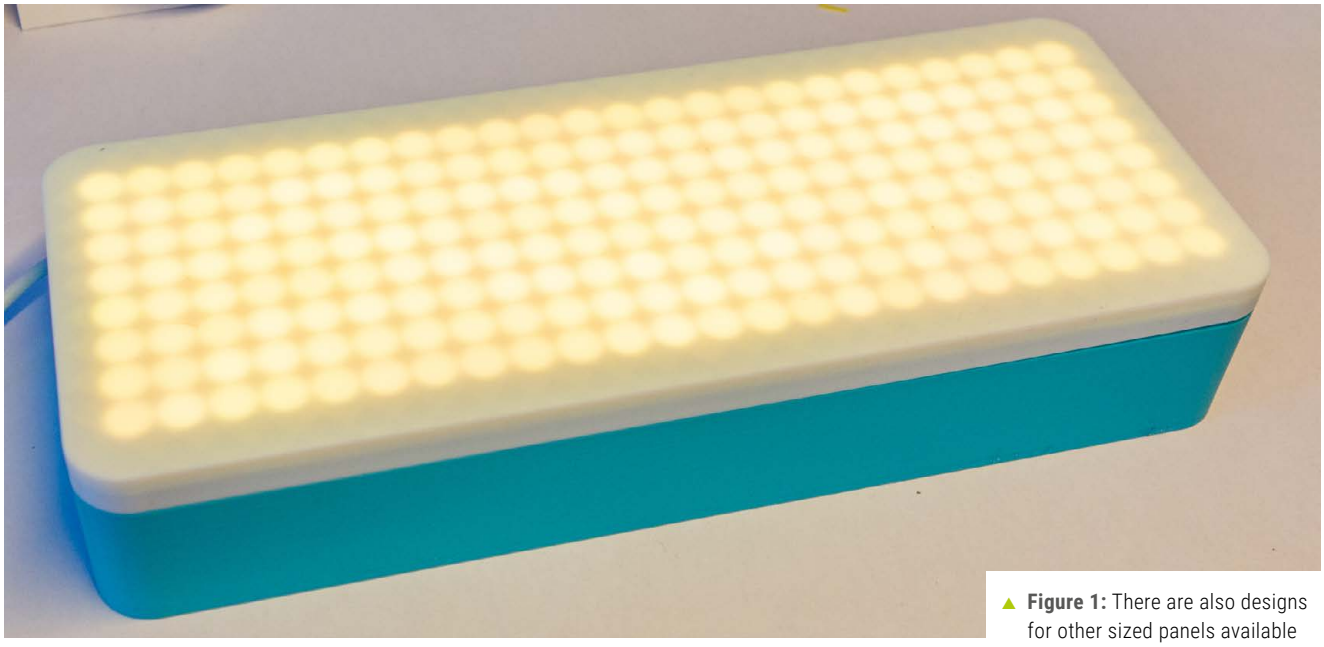
Figure 2 (overleaf) shows how the light is controlled from a browser. The web page is hosted by a CircuitPython program running on a Raspberry Pi Pico W. You can find the complete solution in the repository for this article. We are just going to focus on how settings are stored. The light uses Wi-Fi, which means it needs a Wi-Fi SSID (Service Set IDentifier – the name of the access point) and the network password to connect to the network.

QUICK TIP

Your program could also use files to store data which can be imported into a desktop PC later. This is very useful for data-logging applications.

Obfuscation vs encryption

It is important to understand the difference between obfuscation and encryption. Obfuscation is a process where you take something and make it hard to understand. Encryption makes something impossible to read unless you have the key.



▲ **Figure 1:** There are also designs for other sized panels available

The light uses Wi-Fi, which means it needs a Wi-Fi SSID and the network password to connect to the network

```
import wifi
ssid = "YourWiFiName"
password = "YourWiFiPassword"
print("Connecting to Wi-Fi...")
wifi.radio.connect(ssid, password)
print("Connected! IP:", wifi.radio.ipv4_address)
```

The CircuitPython code above connects a Pico W to a Wi-Fi network. The Wi-Fi SSID and password are written in the program code in the variables `ssid` and `password`. This works, but it means that the program can only be used on one specific network. We might want to add the ability to change these values. We can do this by using a file to store settings values.

File fun

Modern microcontrollers like Pico contain non-volatile (saves its contents when the power is off) storage which is available to Python as a file system. Programs can store data that they want to use when the device is next powered on.

```
import storage
# Save to a text file
with open("/settings.txt", "w") as
settings_file:
    settings_file.write(f"{ssid}\n{password}\n")
```

The code above saves the `ssid` and `password` values in a text file called **settings.txt**. The `\n` characters in the string being written cause the SSID to be written on the first line of the file, and the password to be written on the second line.

```
with open("/settings.txt", "r") as settings_
file:
    ssid = settings_file.readline().strip()
    password = settings_file.readline().strip()
```

The code above loads the `ssid` and `password` values back from the file. Each line is read from the file by the `readline` function and then stripped of any excess whitespace characters by `strip`. If you wanted to store more values than just the Wi-Fi credentials, you could add more lines to your settings file. However, this would become hard to manage because you need to ensure that values are read in the same order they were written. So, let's look at a way of adding structure to our saved settings.

Dictionary corner

We can make our settings easier to manage by storing them in a Python dictionary rather than as individual values.

```
settings = {
    "ssid": "YourWiFiName",
    "password": "YourWiFiPassword"
}
```

The code above creates a dictionary called `settings` which holds the settings information. The dictionary contains two items: `ssid` and `password`.

```
ssid = settings["ssid"]
password = settings["password"]
```

The statements above fetch the `ssid` and `password` values out of the `settings` dictionary. This doesn't seem to have made our lives much easier just yet, but we can also use the `json` library to convert the `settings` dictionary into a string of JSON (JavaScript Object Notation) text. JSON is widely used on the internet to transfer data.

```
import json

settings_json = json.dumps(settings)
```

The code above converts the `settings` dictionary into a string of JSON text using the `dumps` function from the `json` library. The `settings_json` string looks like this:

```
'{"ssid": "YourWiFiName", "password":
"YourWiFiPassword"}'
```

This string can be stored in a file and then the `json.loads` function can be used to create a new dictionary from the string when it is loaded back.

```
settings = json.loads(settings_json)
```

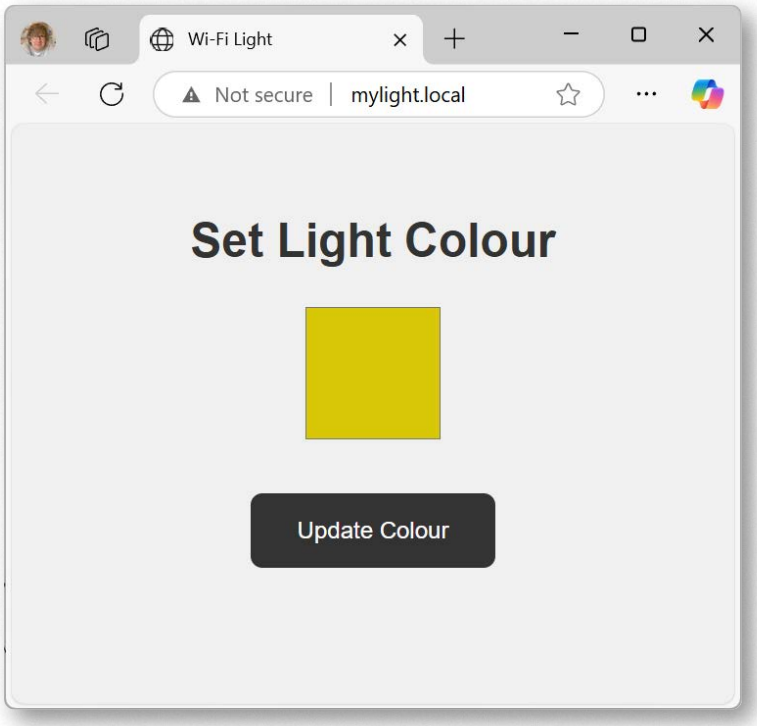
The great thing about this approach is that we can add additional values to the `settings` dictionary and our save and load code stays the same. The JSON encoding and decoding process preserves the type of the data elements stored, which can be strings, numeric values or the Boolean values True/False. You can even put a dictionary inside a dictionary, so let's make some dictionaries for all the settings needed for the light:

```
col = {
    "red":130,
    "green":100,
    "blue":50
}
```

This dictionary above holds the colour information for the light as red, green, and blue values. We can make a separate dictionary to hold network settings:

```
network = {
    "ssid": "YourWiFiName",
    "password": "YourWiFiPassword",
    "hostname": "mylight",
}
```

The dictionary above holds all the network settings that the light needs. The third setting, `hostname`, gives the network name for the light. You can see this in the address bar in the browser screenshot in **Figure 2**. If you want to have multiple lights, you can give each one a different hostname. Now we can create a dictionary which brings the settings together:



▲ **Figure 2:** You can connect to the light using any device on your local network

```
settings = {
    "col":col,
    "network":network
}
```

The `settings` dictionary contains the `col` and `network` dictionaries so that we can now store the colour of our lamp as well as the Wi-Fi settings. This is a great way to structure complex setting information.

Magic with self-describing data

JSON is 'self-describing data'. A JSON document contains values of the data and the names for them. This makes it possible to create something that uses the JSON file to create a user interface for working with it.

Figure 3 (overleaf) shows a settings page which has been sent the JSON settings from a light and created a user interface for the settings values. The JSON settings document is transferred from the light using the same USB connection that is used to load CircuitPython programs into it.

When the Connect button is pressed, the page pops up a list of connected serial devices and the user selects the one to which the CircuitPython device is connected.

When the Load button is pressed, a GET command is sent from the browser to the connected device, which replies with a JSON document containing the settings for that device. A JavaScript program in the web page works through the settings document, generating text boxes for each of the setting elements.

When the Save button is pressed, the web page creates an updated JSON document which is sent back to the device to be stored in it.

You can use this to make it very easy for users of your device to modify the settings in it. The repository for this article contains CircuitPython code you can use to send and receive settings values. The settings web page can handle strings, numeric, and Boolean (True/False) values.

QUICK TIP

There is no way to guarantee the security of data stored in a Pico using CircuitPython or MicroPython programs. Pico does support secure storage, but presently this is not available to Python programs.

Writing files in CircuitPython

When you connect a CircuitPython-powered device to a desktop PC, the device appears on the PC as a USB storage device onto which you can write your program and data files. This makes it very easy to set up, but it also prevents CircuitPython programs running in the device from writing data, because only one thing at a time is allowed to write to files stored.

We can fix this by putting a **boot.py** file on the device. When a CircuitPython device starts running, it looks for a **boot.py** file. If it finds one, it runs the code in it. We put commands in **boot.py** to disable the USB storage.

```
import storage
import usb_cdc

# Disable USB mass storage
storage.disable_usb_drive()

# Keep USB REPL enabled to allow deploying
files via REPL tools
usb_cdc.enable(console=True, data=True)

# Remount the filesystem so CircuitPython
code can write to it
storage.remount("/", readonly=False)
```

The code above does three things. Firstly, it stops the Pico appearing as a USB drive. Next, it makes sure that your development machine can still use the Python REPL (Read-Evaluate-Print-Loop) interface to interact with the Pico. This means that tools like Thonny can still work with files on the Pico. Finally, the file storage is remounted as writable so that CircuitPython programs can write files.

If you want to be able to control whether a device appears as a USB drive, you could add a button to the device which is read when the device boots and used to trigger the drive behaviour if required.

If you are using MicroPython, there is no need to disable USB drive behaviour, as MicroPython does not provide USB support.

Enter the DeviceConfigurator

The settings web page is used in conjunction with a `DeviceConfigurator` class which runs in CircuitPython, manages setting storage, and connects to the browser. The class source file, `device_configurator.py` is available from the repository for this article. You can add it to your CircuitPython projects to allow their settings to be configured via the browser. The class is added by importing it into your program:

```
from device_configurator import
DeviceConfigurator
```

Now you can create an instance of the configurator and use it to manage the settings in your device.

```
config = DeviceConfigurator(settings)
```

The statement above creates a `DeviceConfigurator` instance called `config` and passes the `settings` dictionary it is to work with. The initial `settings` dictionary holds the 'default' values for the settings. Next, we need to load the settings:

```
result = config.setup()
```

The statement above calls the `setup` method from the `DeviceConfigurator` instance referred to by `config`. The method will try to load the settings from a file called **settings.txt** and if the load fails, it will try to connect to the browser settings program and load the settings from there. The `setup` method returns the loaded settings or the value `None` if it can't get the settings and it can't contact the browser.

The setup behaviour is usually only performed when the settings file is missing. If you want to force a settings reset, you can do this by holding the GPIO6 pin on the Pico low when you restart your device. If you wanted to provide a settings reset

Home security

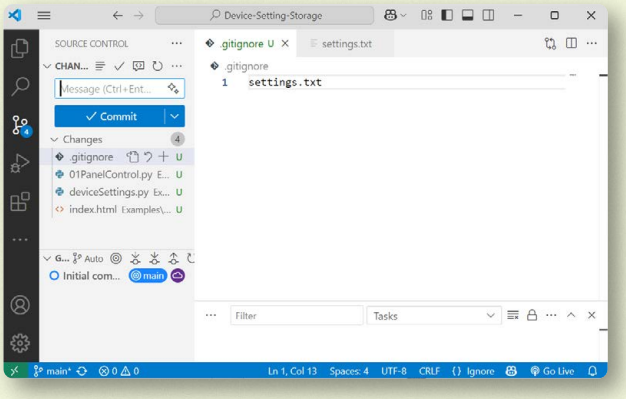
You can improve your network security (or at least have a better way to manage problems) by creating a Wi-Fi network just for your embedded devices. Most home routers (the device which connects to your internet provider) can host an additional 'guest' network. That way, if someone gets a password out of one of your embedded devices, they don't have access to all your systems.

QUICK TIP

If you plan to release updates to your device, you should add a version number to your settings information so that later versions of the code can add new settings values as required.

GitHub .gitignore file

If you share your programs on GitHub (**github.com**) for the world to see (and you should), you must make sure that your settings files are not shared as well. You can add a **.gitignore** file to a project folder to give GitHub a list of files that should not be stored in the repository.



▲ Remember the full stop (period) at the start of the .gitignore file name

Above, you can see Visual Studio Code being used to edit a **.gitignore** file. The **.gitignore** file contains just one name, **settings.txt**. The **settings.txt** file exists in the folder, but it is not included in the list of file changes for the repository because Git has been told to ignore it. You should do this with any project files that you don't want to be made public. You can use wildcards in file names (so you could say **settings.*** to ignore any type of file that has the name 'settings').

You can also use **.gitignore** to prevent library files, or intermediate files being stored by Git. GitHub provides a set of **.gitignore** templates you can use with different programming languages and frameworks.

button, you would connect it between GPIO6 and GND. You can choose other pins for settings reset by adding a parameter to the `DeviceConfigurator` constructor.

```
config = DeviceConfigurator(settings,
safe_pin=board.GP6)
```

The `DeviceConfigurator` will read GPIO6 to trigger a reset.

Save yourselves

The `DeviceConfigurator` provides a method called `save` which can be called if the program makes any changes to the settings values.

```
config.save()
```

In the lamp, this method is called when the user changes the colour of the light.

Adding security to setting storage

We can't stop people from reading information out of the files stored on a Pico. In other words, anyone could read the **settings.txt** file in the light and get the Wi-Fi credentials from it. However, we can make it harder for them to make sense of the file contents by obfuscating them. Note that this doesn't make them impossible to read, just harder. You would have to read and understand the CircuitPython code that works on the obfuscated data, rather than just reading password text out of the files. The `DeviceConfigurator` will perform obfuscation of settings storage if required:

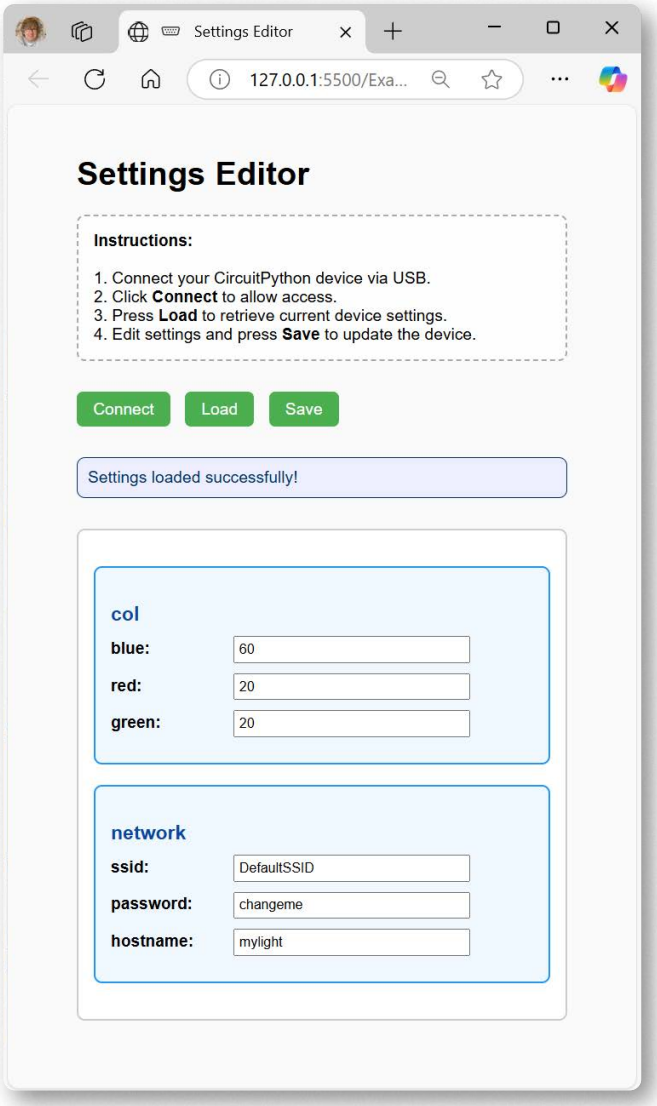
```
config = DeviceConfigurator(settings,
use_obfuscation=True)
```

The above statement requests that settings are stored as binary, obfuscated, values. The obfuscation is quite simple. It combines settings characters with pseudorandom numbers.

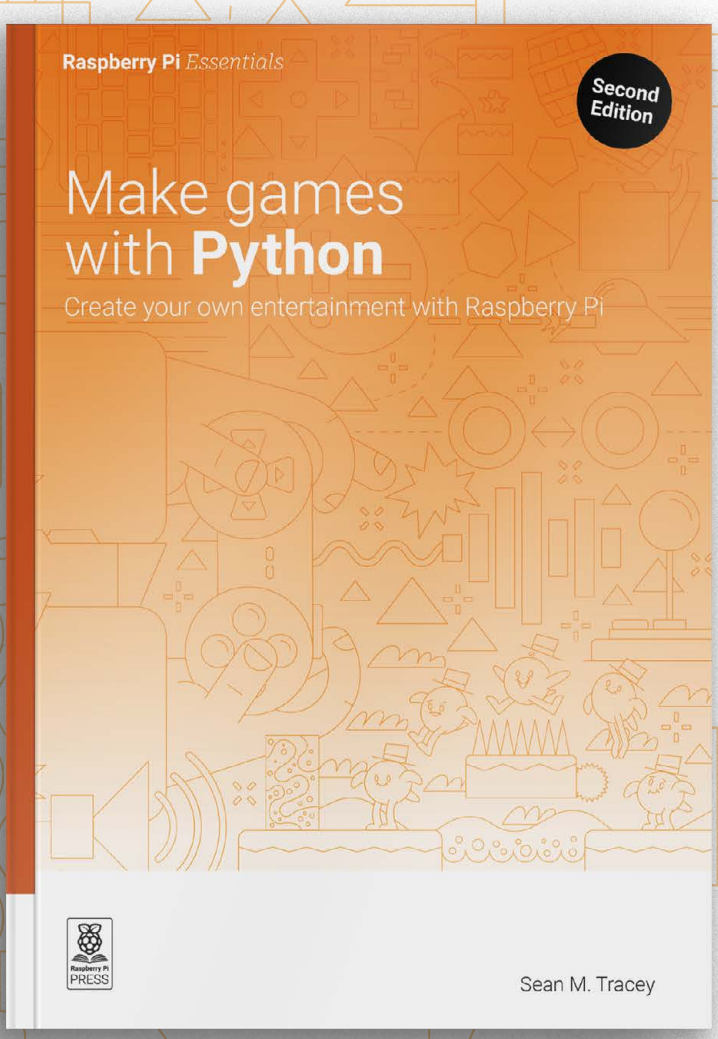
Settings satisfaction

When you start building an embedded device, it is very sensible to consider what settings you may have to store and how they'll be managed. It can be tricky to add settings storage to an application once it has been built. Basing all your settings storage around a dictionary and using something like the `DeviceConfigurator` is a great way to ensure settings satisfaction.

When you connect a CircuitPython-powered device to a desktop PC, the device appears as a USB storage device



▲ **Figure 3:** You can host this page on your own desktop computer. The page is also available at **robmiles.com/settings**. It works with Chromium based browsers such as Chrome and Edge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Second Edition
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Sean M. Tracey

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Part 02

Hack a robot arm

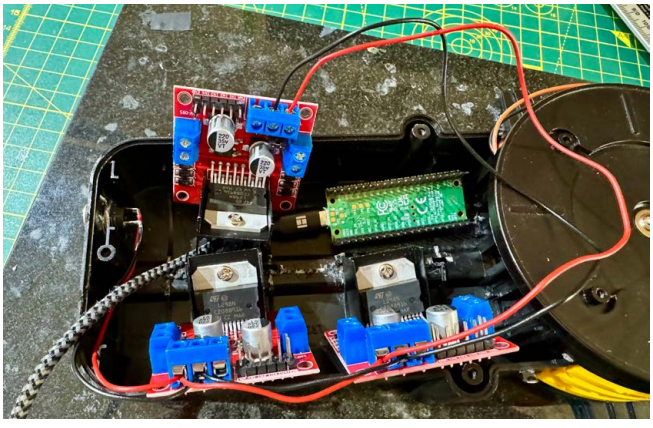
Now the wiring is sorted, it's time to assemble our robot arm and give it some smarts

Maker

PJ Evans

PJ is a writer, software engineer, and maker. The robot arm keeps knocking his coffee over and he's worried it's doing it on purpose.

mastodon.social/ @mrpjevans



▲ Placing the circuit boards takes time and patience (and a multimeter!)

Last month we started the process of upcycling the common OWI-535 robot arm into something a bit more internet connected. There's still a little assembly to do and we're yet to tackle the software. Although this is a specific project, the examples given here can be transferred to a multitude of different robotics projects. The actual assembly of the robot arm is irrelevant, as the Raspberry Pi Pico has no idea about that; all it's doing is controlling a series of DC motors. So whatever you can think of that uses motors like these, you can automate with Raspberry Pi.

Last time on robot arm hacking

Follow the tutorial in Raspberry Pi Official Magazine issue #155 (**rpimag.co/155**) to set up your robotic arm. Hopefully, by now you've been able to wire up the five motors to your Raspberry Pi Pico W. Remember all the motors need to be connected to motor drivers on the H-bridge circuits, the Raspberry Pi Pico must be wired to the IN and EN pins (three per motor) and the 12V supply to the 12V IN on each H-bridge board. Finally, they need to share a common ground, connecting the Raspberry Pi Pico's GND pin to the GND for the PSU. Once you've checked all of this (again, and again) you're ready to continue. A multimeter is very useful here!

Check each motor

Using the MicroPython test script we used in the previous issue, change the wiring values to test each motor individually. If you followed the same wiring pattern as us, this should be as listed in the code snippet overleaf. One-by-one, update the values and run the script. Each motor should make a small back-and-forth movement. Repeat until each motor is working, and make a note of which motor you have connected to which circuit (the order is not important). Starting from the bottom, we've named them the base, shoulder, elbow, wrist, and grip.

Our goal – an upcycled web-connected robot arm

Once fitted, insulate the boards with cardboard or plastic

Software time

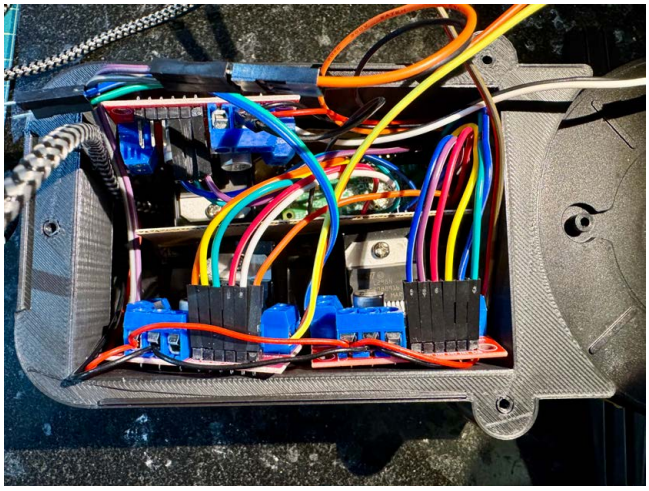
Before we assemble the arm, we should make sure the final software implementation is working. Take your time on this step, there's no rush to get all the circuits in place and it gives you space to debug both the electronics and the software (as you'll still have easy access to your Pico's USB port). In fact, there's no real need to assemble it all if you are not planning on a permanent installation: the arm will work just fine without. For now, make sure your Pico is hooked up to your computer and that the Thonny IDE can see it (see previous issue).

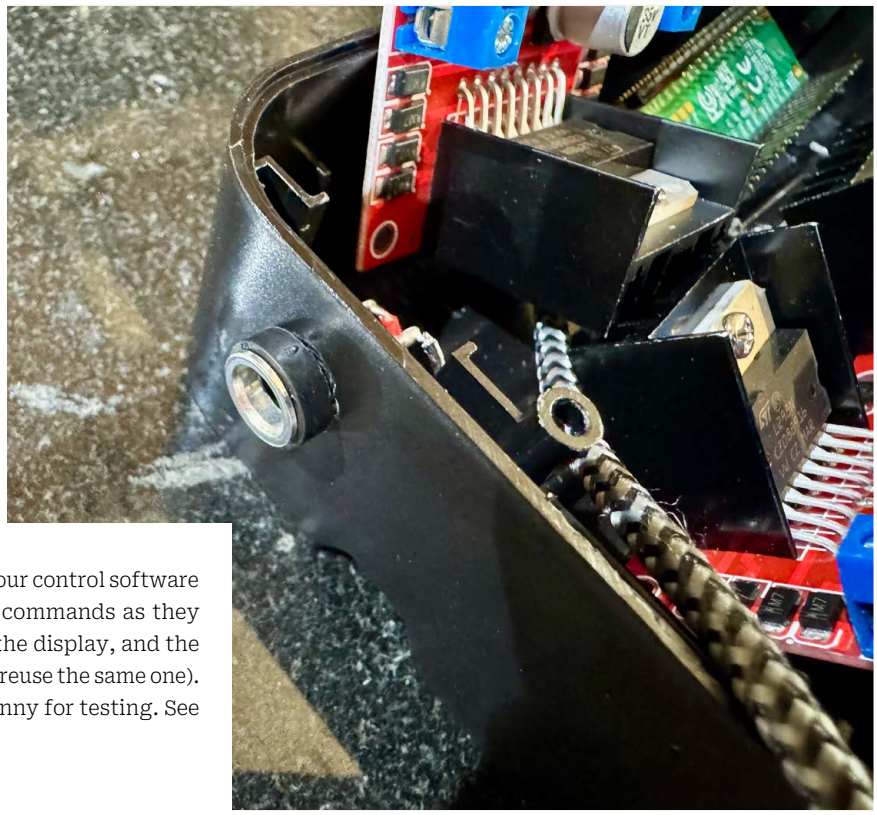
Just add web

The easiest way to control the arm is using a simple web server. Raspberry Pi Pico W surprisingly has enough power to not only control the arm, but to run a little web server too, so you can use any web browser or even your phone to make the arm move around. We've prepared the server for you, so download the code from GitHub (**rpimag.co/owi535gpioweb**), or clone the whole **owi535gpio.git** repository:

```
git clone git@github.com:mrpjevans/owi535gpio.git
```

Control your robot arm from any web browser in your home, even your phone!





▶ Add a barrel connector for a neat finish

There are a few files to deal with. Firstly, our control software that runs the web server and handles the commands as they come in, the HTML template that controls the display, and the configuration file **WIFI_CONFIG.py** (you can reuse the same one). For now, you can run the web server in Thonny for testing. See the README if you need more help.

Remote control

When the server starts, you should see Pico's IP address being used in Thonny's console window. Open up a web browser on your computer and enter **http://** followed by the IP address. You'll then see a simple web interface. Making sure your 12V PSU is powered up, then try pressing the buttons. It's possible they do not match the motors you have connected. You can either swap the motor wiring about or change the wiring assignments in the code to match; it's completely up to you. If everything is working as expected, you can now control your robot arm from any web browser in your home, even your phone.

Final step

Feel free to tinker with the code. There's lots of scope for making it look better, or changing the default behaviour. You could even have a look at the included MQTT example to see how you could control the arm using an MQTT server over the internet (or even hook it up to Home Assistant!). When you've settled on an approach, the final step is to edit **main.py** and change it to read:

```
import owi535_web
```

Save **main.py** and transfer it to your Pico. Now the Pico will run the web software whenever power is applied, so it can run off a normal 5V power adapter (you will still need a 12V supply for the motors).

Tidy-up time

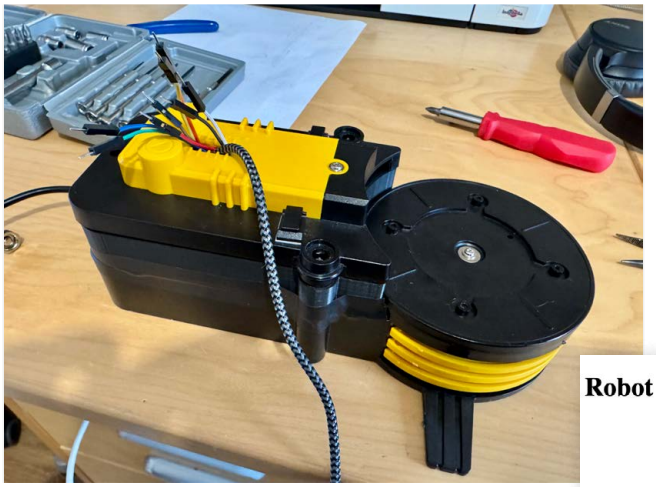
When you are confident that everything is working, it's time to assemble the final project. If you've 3D-printed the extension module from last issue (**rpimag.co/owi535stl**), you can place that on top of the main base. Remove all the circuitry in top section to create as much space as you can. The H-bridge circuits can be carefully placed vertically in the 'well' of the base with the Pico alongside, towards the arm itself. Please take your time doing this. Throwing it all in there and jumping up and down on it will almost certainly cause a short circuit. We also recommend placing a piece of cardboard or thin plastic in the centre so the opposing circuits do no touch. For a finishing touch, drill a hole (beforehand!) in the base to mount a barrel connector for your power supply. You can now add the original top of the base, feeding the wires through the hole in the centre.

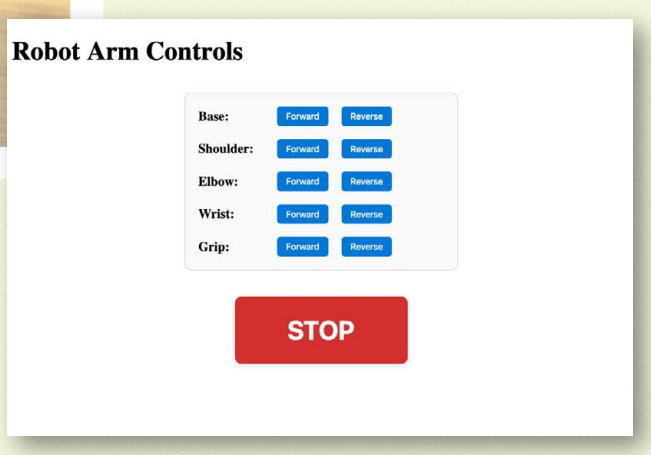
Over to you

Congratulations, you have a web-connected robot arm, but that's only the beginning! This project is ripe for improvements. Here's some things to try.

- How about adding timing controls to stop the arm when it travels too far in one direction?
- Better still, add microswitches that stop the arm in certain positions
- You could add cameras and use machine learning to detect objects
- With a more powerful Raspberry Pi, you could add full autonomous movement
- Use MQTT to extend control to other devices using Home Assistant

As ever, the possibilities are endless. Have fun!





▲ The completed base can be hooked up to the arm. Pico needs its own power

▶ A simple web interface, just waiting for customisation

owi535_test_all.py

> Language: **MicroPython**

DOWNLOAD THE FULL CODE:

rpimag.co/owi535testpy

```
001.  from machine import Pin, PWM
002.  from time import sleep
003.
004.  from dcmotor import DCMotor
005.
006.  # Pins (Motor 1 , Motor 2, Enable)
007.  base = [2, 3, 1]
008.  shoulder = [7, 8, 9]
009.  elbow = [11, 12, 10]
010.  wrist = [13, 14, 15]
011.  grip = [17, 18, 16]
012.
013.  # Choose the motor to test
014.  motor_pins = base
015.
016.  frequency = 1000
017.  speed = 10
018.
019.  motor = DCMotor(Pin(motor_pins[0], Pin.OUT),
      Pin(motor_pins[1], Pin.OUT), PWM(motor_
      pins[2], frequency))
020.
021.  print("Forward")
022.  motor.forward(speed)
023.  sleep(0.5)
024.
025.  print("Backward")
026.  motor.backward(speed)
027.  sleep(0.5)
028.
029.  print("Stop")
030.  motor.stop()
```

Unusual tools: hole-punching flange joggler

The workshop tool that sounds like a piratical insult

Maker

Dr Andrew Lewis

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

lewiswork.etsy.com

QUICK TIP

Most hole-punching flange jogglers are badged imports and have the same basic spec: a 10mm flange with 5mm hole punch. If you're riveting the panels, that hole will fit a 4.8mm blind rivet.

Aside from its glorious name, the hole-punching flange joggler is actually one of the most useful tools that you've probably never heard of unless you work in a sheet metal workshop. Available as a manual tool or as an air tool, it takes the pain out of working with large panels and literally stops you from ending up with your butt on the line when you're joining multiple flat sheets.

Joining together flat sheets of metal is a fundamental metalworking process. Sometimes you can just butt joint pieces together and stitch-weld the whole line, but that's easier said than done with thin sheets of metal and it doesn't always create the best joint for the job. An alternative is to drill through and spot-weld the sheets first, then go back and stitch the seams together if you need more strength.

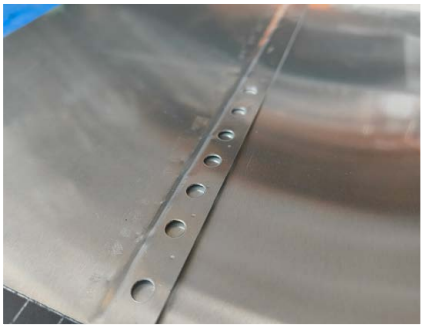
The problem with this is that you end up with one plate sitting on top of the other, which might be fine for a rough bit of farm welding, but not so good for the bonnet of a custom car. For a smooth finish, you really need to put a flange on the edge of one panel so that the point of overlap leaves the surface of both panels at the same height, and then cut holes through for spot welding. You could do this with a drill, a hammer, and a form, but that's going to result in a lot of effort spent hammering and drilling to make a relatively small feature.

Adding a flanged detail to the edge of a metal panel increases the rigidity of the panel

Enter the flange joggler

This is where the hole-punching flange joggler comes in. The hole-punching flange joggler edges your panel with just the right amount of kink for a second panel to lay flat against it, and it also punches holes for spot-welds or rivets without the mess of using a drill. If you're working with a manual flange joggler, you might find the pressure needed to bend the flange

A heavyweight hand tool, but extremely useful for saving time when working with metal panels. The air tool version of a hole-punching flange joggler uses high pressure to punch and bend metal. Beware small compressors, as the low refill rate might slow you down on a long run

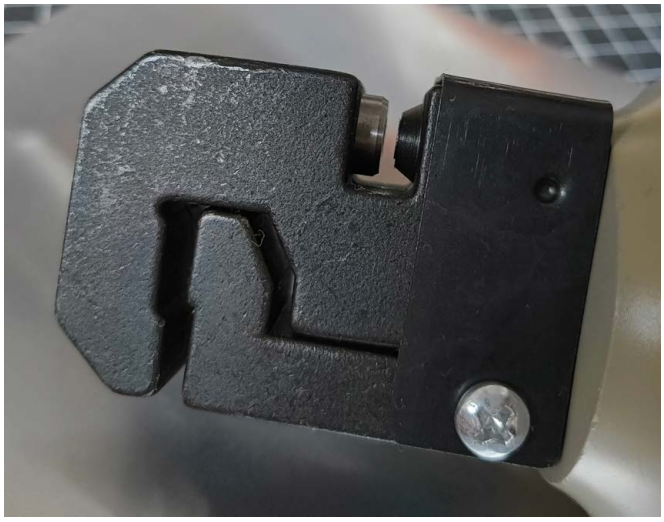


An advantage of using this overlap technique (rather than just butt-jointing the plates) is that you'll have more metal thickness to soak up the heat of the weld and reduce the chances of blowing a hole through the sheet accidentally

is quite uncomfortable unless you have particularly strong hands. For anything but the thinnest of panels, it's probably best to use an air-powered version.

While the most typical use of the flange joggler is for welding or riveting, it's not the only situation where you might find the tool useful. Adding a flanged detail to the edge of a metal panel increases the rigidity of the panel. Think about the difference in strength between a piece of flat aluminium and a piece of angle – the shape of the edge reduces flex in the sheet. You can also use the flange joggler to reinforce the edges of any holes you cut in sheet metal, and generally make them look more professional. One example might be a hole cut out for a power socket in a vehicle panel, or a water fitting. Increasing the rigidity of the panel around these types of fitting will give you a more professional-looking and sturdy end-result than simply drilling through.

While the manual version of the flange joggler can be difficult to get along with, the air tool version is easier to use. The tool is quite large and heavy, but the working head is quite small and the trigger lever requires very little effort to press. The head has two slots, one of which is a shaped die to produce the 10mm flange



The head of the air tool is sturdy and compact, which means it can usually fit into smaller spaces than the manual version of the tool

shape, and the other is a (usually) 5mm hole punch. Creating a flange is as simple as inserting the panel all the way into the flanging slot, and pulling the trigger. Move the head along the panel and repeat the process until you have created a flange of the desired length. Using the punch is equally simple. Insert the metal sheet in the slot used for punching and pull the trigger briefly. The hole should be punched cleanly through the sheet and the punched section will be ejected out of the machine. Punching holes like this is much faster than using a drill, and using the punch tool will knock hours off the amount of time it takes to rivet large sections of panel.

Part 04

Build an Enigma machine in RISC OS

During World War II, the Enigma machine was key to decoding top-secret German messages. Now you can recreate it with your RISC OS Raspberry Pi

Maker

Ian Osborne

Ian's been working in tech and video games magazines for far longer than is healthy. As well as Raspberry Pi, he also writes about other computers, retro gaming, and anything else that pays.

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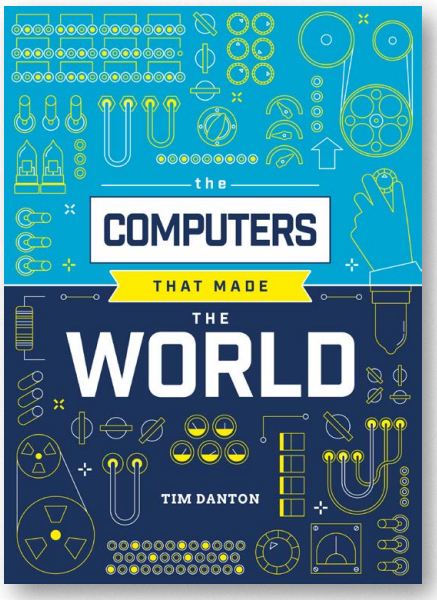
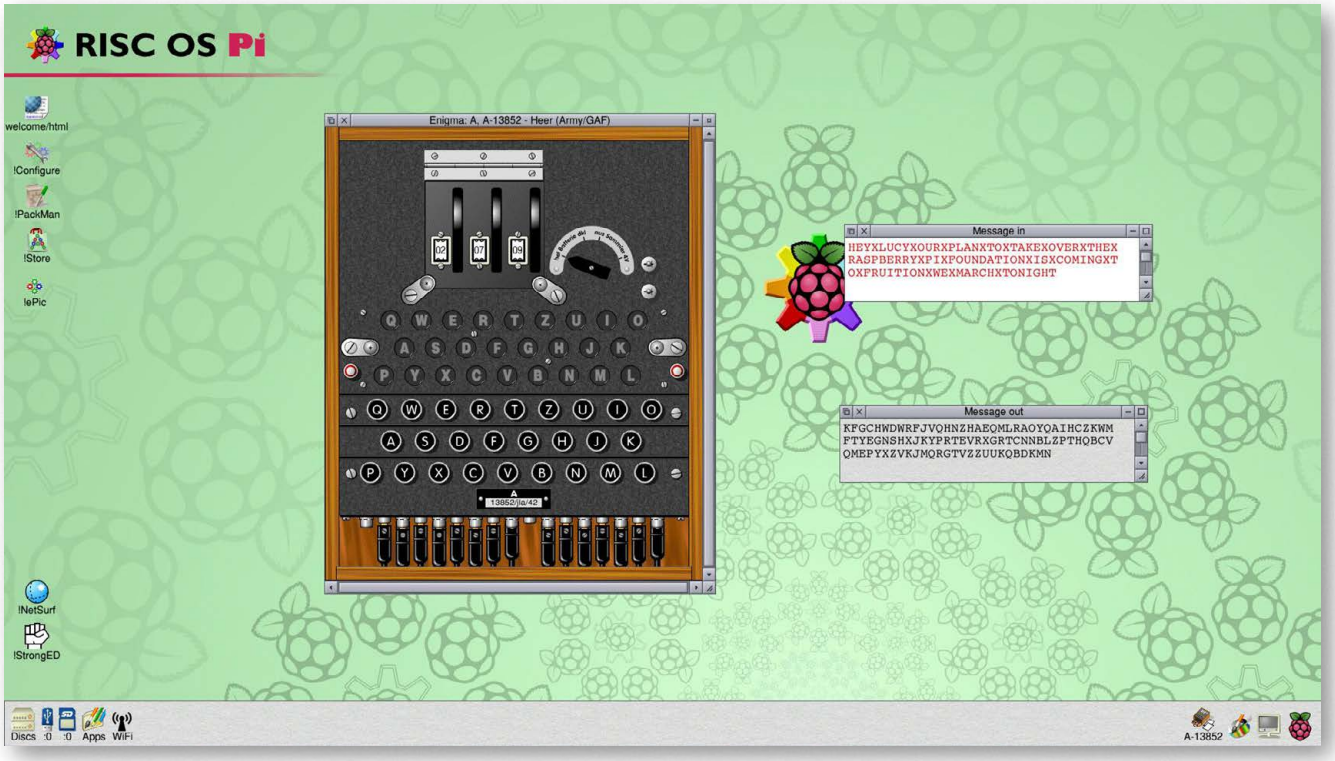
If you've seen the movies *The Imitation Game* or *Enigma*, you already know what the Enigma machine is. If you haven't, put them on your to-do list – they're both great.

Enigma was a cypher device used in Germany before and during the Second World War. Used extensively by both the army and the navy, it featured a complicated encryption method that made it very hard to crack. The Enigma machine was unspectacular to look at, resembling an oversized typewriter, but under the hood it boasted incredible technology. Every time you press a key, the Enigma machine indicates which letter is to replace it in the coded message. It's encoded using a minimum of three rotors, which turn each time a key is pressed, changing the way the next letter is encoded. Each rotor had 26 positions, meaning there were 17,576 different combinations before the encryption process repeated itself. There were also 158 million, million, million ways it could be set up, and each Enigma machine was reset every day. When a message was fully coded, it was sent by Morse code to a recipient with another Enigma machine, which was used to decode it. If that message was intercepted along the way, it didn't matter as there was no way to read it without an Enigma machine and the day's settings.



▶ Read more about the Enigma machine, and how its code was cracked, in *The Computers that Made the World*



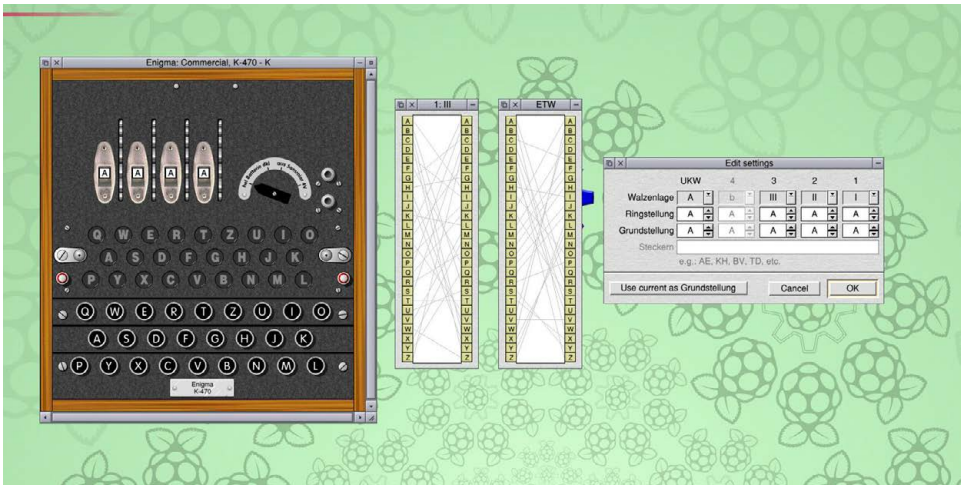
There's plenty to see and do in the simulations

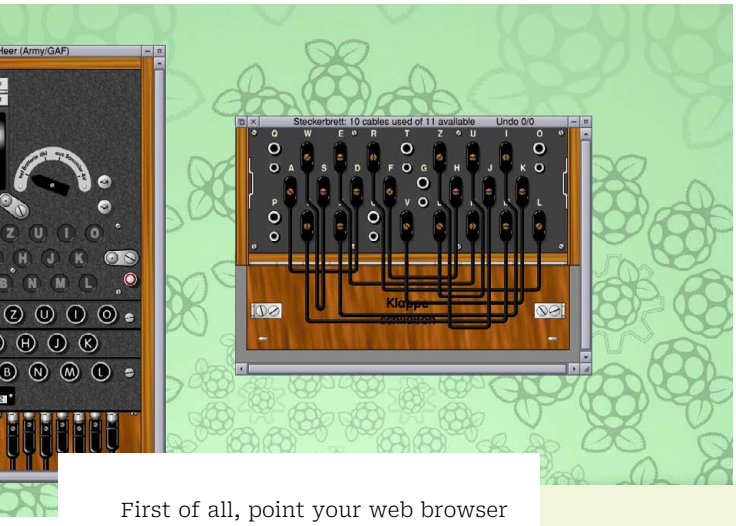
- Coding a message with a simulation of Enigma I
- The Enigma I model was in use from 1930
- Edit the Enigma's settings, and watch what its rotors are doing

The Battle of the Atlantic

The German navy used Enigma encryption extensively during the Battle of the Atlantic, with German naval intelligence transmitting coded information to its U-boats. Britain was, at the time, heavily dependent on imports from the USA and Canada. The U-boats were wreaking havoc on incoming merchant shipping, so cracking the Enigma code was essential to the Allied war effort.

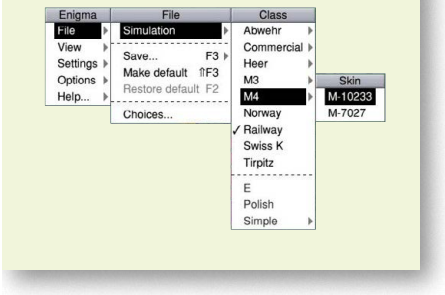
But why are we telling you all this in a Raspberry Pi magazine? Over at Crypto Museum (**cryptomuseum.com**), they've come up with an Enigma emulator for RISC OS. If you've installed the Raspberry Pi version of RISC OS on your favourite single-board computer, you can recreate the intricacies of these incredible coding devices at home.





◀ The Enigma's all-important peg board is recreated too

▼ There are plenty of Enigma models to choose from



First of all, point your web browser to **rpimag.co/cryptoriscos** and scroll to near the foot of the page. There are three zip files to download, but they're all small: Enigma Simulator for RISC OS, Examples of Enigma Files, and the User Manual (in HTML format). The examples are fascinating in themselves. They're actual messages from World War II that used Enigma encryption to keep them safe from prying eyes. Can you decrypt them using the supplied settings and your Enigma Simulator for RISC OS? They're in German (of course), but that's what Google Translate is for.

Simulating Enigma

Let's get started with the Enigma Simulator. It's easy to install. If you downloaded the zip file on a machine other than your Raspberry Pi, transfer it across. Unpack it using an unarchiving utility such as !SparkFS. As there's an excellent chance you've already got this app, and installed it with RISC OS, simply double-click tche zip file and see if it opens before you open the PlingStore and look for an unarchiver.

When the zip file unpacks, you see an icon labelled !Enigma. Drag this onto your SD card, placing it wherever you see fit (the Apps folder seems a logical choice). Like all RISC OS apps, you open it by double-clicking its icon. You can open it multiple times if you wish, which is useful for comparing the behaviour of the different Enigma machines that are simulated. Enigma is a family of incompatible coding devices rather than a single machine, and Enigma Simulator for RISC OS recreates all currently known variants. This, of course, includes the most famous models, the M3 and M4 Enigmas used by the Kriegsmarine, the German navy, 1935–1945.

With the Enigma machine open, you can access the app's main menu by middle-clicking on its window. Go to File > Simulation > Class to change the model of Enigma you're using.

As well as the main Enigma window, when looking at the default Enigma I machine there are two further windows. One's called 'Message in', and the other's called 'Message out'. When you type a message by clicking on the simulated machine's keys, what you type is displayed in Message In, and the encoded version in Message Out. Note that there's no punctuation and no spaces, as these things would give the enemy clues about how to decode the message. Instead of a space, you type an **X**.

The Enigma family

Enigma is a series of machines, all of which can be recreated on your Raspberry Pi using Enigma Simulator for RISC OS. The list of historical Enigma devices that are reproduced is:

I (Army, GAF)

M3 (Navy)

M4 (Navy)

Commercial Enigma D

Commercial Enigma K

G (Abwehr, G-312, G-260, G-111)

Zählwerk Enigma

Norway version

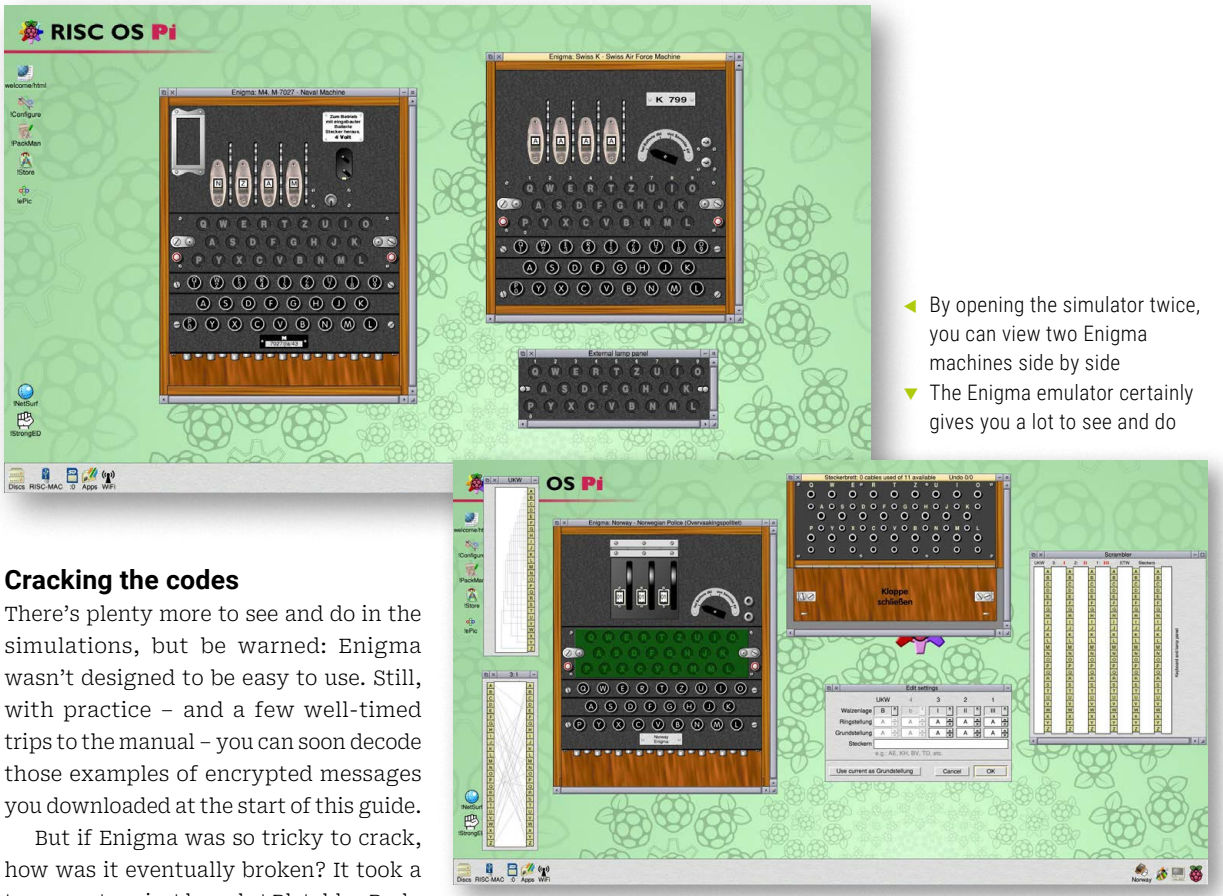
Railway version

Swiss K

Tirpitz (Japanese Enigma)

Polish Enigma Clone

It can also simulate Enigma-E, a post-war electronic device which itself simulates an Enigma machine, and a simpler version of Enigma with a single wheel, so you can get an idea of how it works in its most basic form.



- By opening the simulator twice, you can view two Enigma machines side by side
- The Enigma emulator certainly gives you a lot to see and do

Cracking the codes

There's plenty more to see and do in the simulations, but be warned: Enigma wasn't designed to be easy to use. Still, with practice – and a few well-timed trips to the manual – you can soon decode those examples of encrypted messages you downloaded at the start of this guide.

But if Enigma was so tricky to crack, how was it eventually broken? It took a top-secret project based at Bletchley Park, and a staff that was around 9000 strong by 1944, working in three shifts around the clock. As well as including professional mathematicians and scientists, code-breakers were chosen from the best puzzle-solvers in the country, picked for their adept command of crossword puzzles and chess. To break the codes, they designed and used electromechanical code-breaking machines called bombes, and later, the Colossus. Designed by Tommy Flowers, Colossus is described by the Encyclopaedia Britannica as "the first large-scale electronic computer".

Taking care not to make it obvious the codes had been broken, High Command was able to use messages unencrypted at Bletchley Park to guide convoys past the U-boat blockade, and also direct Allied bombers into areas where the U-boats were likely to be found. It's been estimated that breaking the Enigma codes shortened the war by around two years, and saved around 14 million lives.

Alan Turing

The person most associated with breaking the Enigma code is Alan Turing. A Cambridge and Princeton educated mathematician, during the war he worked at Bletchley Park where he led Hut 8, the section responsible for German naval cryptanalysis. He invented several devices and techniques that speeded the breaking of Enigma encryptions. His use of probability in cryptanalysis contributed to the creation of Colossus, a family of computers built between 1943 and 1945. GPO engineer Tommy Flowers was the lead architect for Colossus and led the team that built it.

It's been said that Colossus was 'the world's first programmable, electronic, digital computer'. Valid arguments are also made for Konrad Zuse's Z3 or the Atanasoff-Berry Computer, and other machines. See *The Computers that Made the World* book: **rpimag.co/ctmtw**.

Turing continued to design and build computers after the war, including the Automatic Computing Engine (ACE), one of the first designs for a stored-program computer, whose creation is also covered in the book.

In March 1952 he was convicted of 'gross indecency', that is, homosexual acts, which were illegal in the UK at the time. Given a choice between prison and probation with hormonal 'treatments' intended to reduce libido (colloquially known as 'chemical castration'), he chose the latter.

Turing died on 8 June 1954, aged 41 by ingesting cyanide. In 2009, the then-Prime Minister Gordon Brown acknowledged society's treatment of Alan Turing was 'appalling', and he was eventually pardoned in August 2014.

Part 02

Conquer the command line: Read and write text

In this part, we get working on files — copying, viewing, removing, editing, and organising

Maker
Richard Smedley
A tech writer, programmer, and web developer with a long history in computers, who is also in music and art.

about.me/RichardSmedley

Now that we can navigate folders and list files, it's time to learn how to create, view, and alter both files and folders. Once more, it's not that the task is difficult, rather that the forms of the commands (particularly when editing) are unfamiliar, coming from an era before Common User Access (CUA) standards were created to ease switching between applications and operating systems.

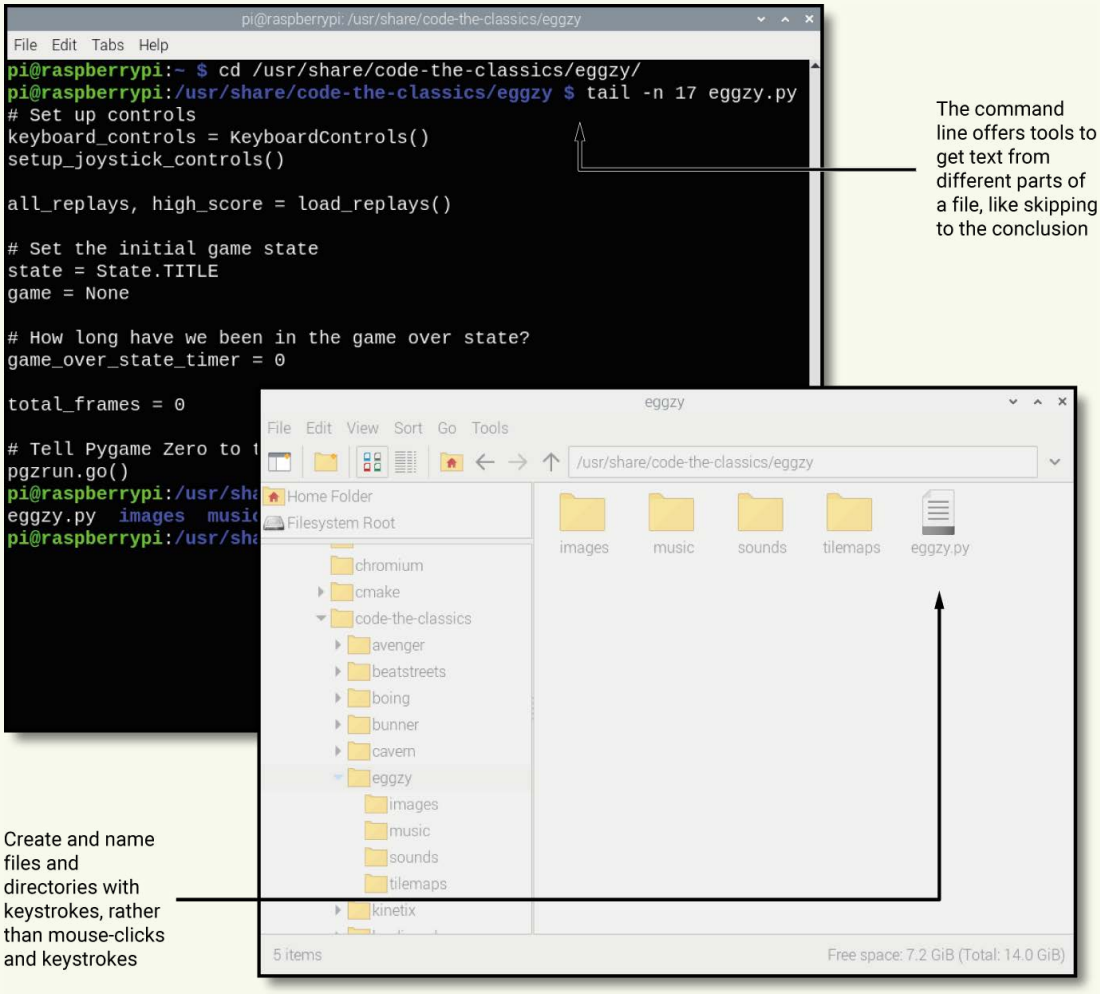
Stick with it: with just the first parts of this tutorial series under your belt, you'll be able to do plenty of work at the command line and start getting comfortable there.

We're going to dive straight into working with files and folders

Creating a directory

We're going to dive straight into working with files and folders by creating a new directory. Assuming you already have a terminal open (see 'Quick Launch' box), and you're in your home directory (`pwd` to check, `cd ~` to get back there if necessary), type `mkdir tempfolder` and have a look with `ls`.

`mkdir`, as you've probably guessed, makes a new directory or folder. Let's use it to experiment with altering some Python games. Don't worry: we're not going to be programming Python,



▲ Working with the contents of files

just making a small change by way of illustration. `cd tempfolder` (use tab completion: `cd t` then hit the **TAB** key). In the following example, we'll be copying some files to this directory.

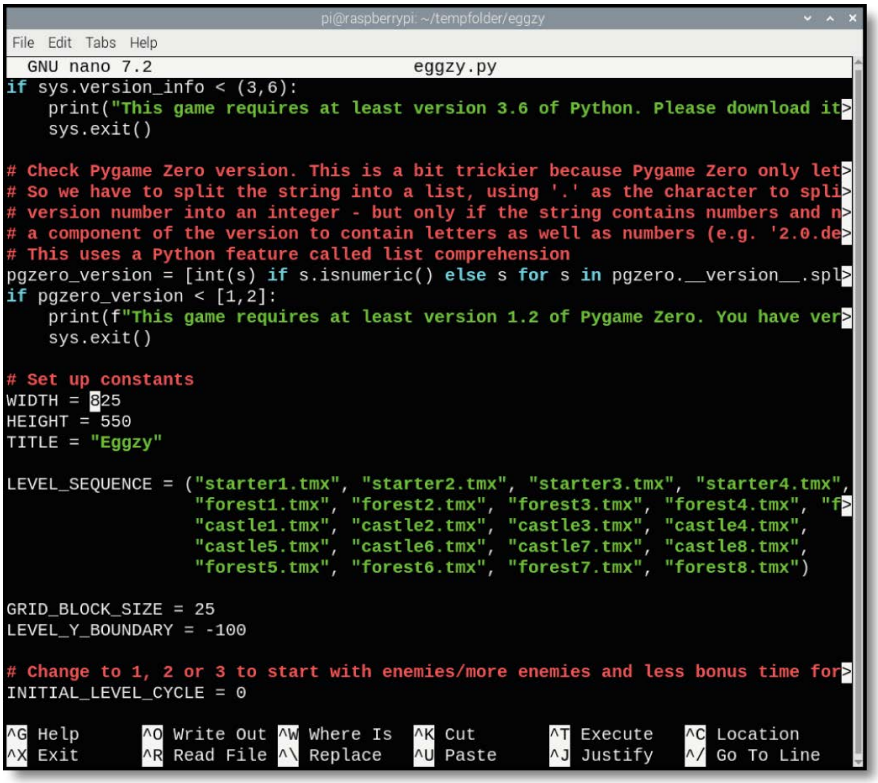
First, make sure Code the Classics is installed — if not, click the top-left Raspberry Pi icon on the desktop, select Preferences, then Recommended Software, tick the box next to both Code the Classics I and II in the list, and then click Apply to install it.

Next, copy over some files from the **code-the-classics** directory using the `cp` (copy) command:

```
cp /usr/share/code-the-classics/soccer/so* .
cp -r /usr/share/code-the-classics/eggzy .
```

QUICK LAUNCH

Although you can open the terminal emulator from the menu — Accessories > Terminal — pressing **CTRL**+**ALT**+**T** will open it instantly.



◀ **Figure 1:** The default editor, nano

Wildcard

The `.` (dot) at the end of the commands refers to your current working directory (**~/tempfolder**), which is where we want the files copied. Also, `so*` is interpreted by the shell as 'every file beginning with `so`' — the `*` is known as a *wildcard*, and this one represents any number of characters (including none); there are other wildcards, including `?`, which means any single character. You'll get an error with the first command:

```
cp: -r not specified; omitting directory
    '/usr/share/code-the-classics/soccer/sounds'
```

This is because `so*` matches both **soccer.py** and **sounds**, but only the first of these is a file; you must use the `-r` (recursive copy) switch to copy directories. The second command uses that switch to make a copy of the entire **eggzy** directory. Remember to use `-r` when copying directories.

Use `cd eggzy` and then try `python eggzy.py` and you'll see you can run the local copy of the game. To change the game, we need an editor — sidestepping the UNIX debate about which one is best, we'll use Raspberry Pi's built-in editor: nano. Unless you've previously used the old Pico editor, which accompanied the Pine email client on many university terminals in the 1980s and 1990s, it will seem a little odd (**Figure 1**). That's because its conventions predate standard keyboard shortcuts such as **CTRL+C** and **CTRL+V** found in most modern programs. Nano has unusual command shortcuts, but they're worth learning, as you'll find nano installed on virtually all GNU/Linux boxes, such as a web host. Bear with us.

Editing and paging

`nano eggzy.py` will open the game for editing; use the arrow keys to go down several lines and find the `WIDTH` value of `825`. Change it to `1000` (both the **Backspace** and **Delete** keys will work in nano). The last two lines of the screen show some shortcuts, with `^` (the caret symbol) representing the **CTRL** key. **CTRL+O**, followed by **ENTER** or **RETURN** will 'write out' (save) the file; then use **CTRL+X** to exit. Now, `python eggzy.py` will open an oversize window. However, the main game will not take up the rest of the screen, so it's not very useful: go back and reset `WIDTH` to `825`.

If you want to take a look through the **eggzy.py** listing without entering the strange environment of nano, you can see the entire text of any file using `cat`: e.g., `cat eggzy.py`. Unfortunately, a big file quickly scrolls off the screen; to look through a page at a time, you need a 'pager' program. `less eggzy.py` will let you scroll up and down through the text with the **Page Up** and **Page Down** keys. Other keys will do the same job, but we'll leave you to discover these yourself. To exit `less`, hit **Q** (this also works from man pages, which use a pager to display text).

Cats, heads & tails

If editor wars are a UNIX tradition we can safely ignore, there's no getting away from another tradition: bad puns. `less` is an improvement over `more`, a simple pager; the respective man pages will show you the differences. One advantage the relatively

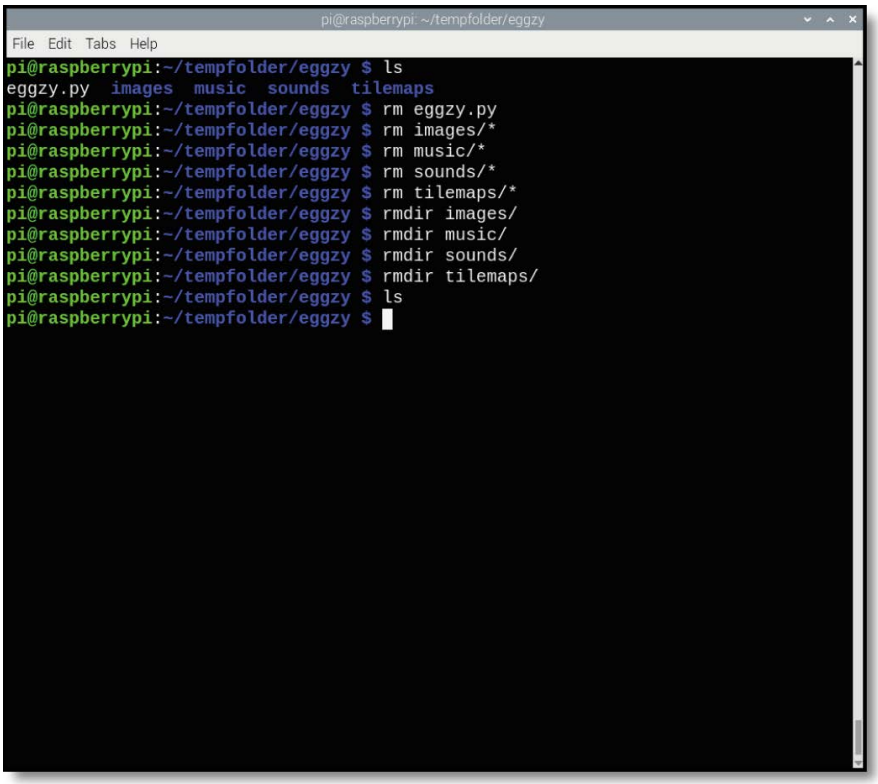


Figure 2: `rm` is a powerful removal tool: use with great care!

SWITCHING HELP

You don't need to wade through the man page to see what switches are available: type `--help` after the command to see your options, e.g. `rm --help`.

primitive `more` has is that at the end of a file it exits automatically, saving you reaching for the **Q** button. Admittedly, this is not a huge advantage, and you can always use `cat`.

Fortunately, `cat` is not a feline-based pun, but simply short for 'concatenate': use it with more than one file and it concatenates them together. Used with no argument – type `cat` – it echoes back what you type each time you press **ENTER**. Hit **CTRL+C** to exit when you've finished typing in silly words to try it. And remember that **CTRL+C** shortcut: it closes most command-line programs, in the same way that **ALT+F4** closes most windowed programs.

You can peek at the first or last few lines of a text file with `head` and `tail` commands. `head eggzy.py` will show you the first ten lines of the file. `head -n 5 eggzy.py` shows just five lines, as does `tail -n 5 eggzy.py` with the last five lines. With `head`, you can omit the `-n`, so `head -5 eggzy.py` will also work.

Remove with care

We've done a lot already (at least, nano makes it feel like a lot), but it's never too early to learn how to clean up after ourselves. We'll remove the files we've created with `rm`. The remove tool should always be used with care: it has some built-in safeguards, but even these are easy to override (**Figure 2**). In particular, never let anyone persuade you to type `rm -rf /` — this will delete the entire contents of your Raspberry Pi, all the programs, everything, with little to no chance of recovery.

Have a look at what files we have: if you're still in the **eggzy** subdirectory of the **tempfolder** you made, then `ls` will show you the files you copied here. Remove the program, then the contents of the subdirectories with careful use of the `*` wildcard.

```
rm eggzy.py
rm images/*
rm music/*
rm sounds/*
rm tilemaps/*
rm eggzy-replays
```

(The **eggzy-replays** file will only exist if you played the game.) Next, remove each of the subdirectories with `rmdir`:

```
rmdir images
rmdir music
rmdir sounds
rmdir tilemaps
```

If you run the `ls` command, you'll see that the **eggzy** directory is now empty.

`cd ..` to get back to **/home/pi/tempfolder** and `rm -r eggzy` will remove the now empty folder. The `-r` (recursive) option is necessary for directories, and will also remove the contents if any remain. That still leaves the file **soccer.py**. You can delete **tempfolder**, including **soccer.py**, by using `cd ..` to get back to **/home/pi** and running `rm -r tempfolder`.

In the next issue, we'll delve into file permissions and updating software from the command line.

Flower pressing

Press and preserve your blooms, measuring moisture with Raspberry Pi Pico

Maker

Nicola King

Nicola is a freelance writer and sub-editor. She's also the gardener in the family, trying to create a very tiny slice of Kew Gardens in deepest Dorset.

@holtonhandmade

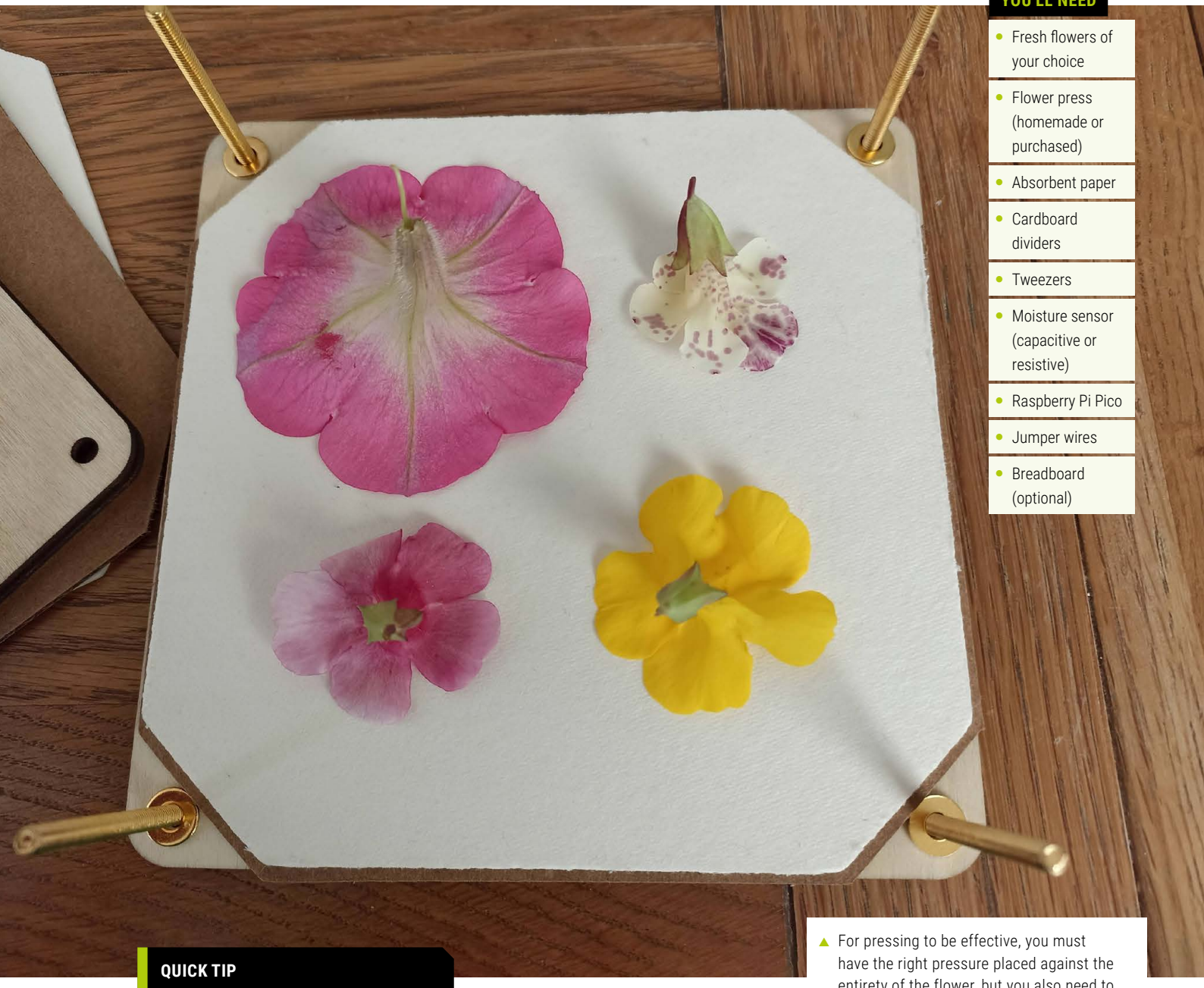
At this time of year, our garden is bursting with flowers, and we sometimes wish we could preserve just a little bit of that colour and beauty to look back on later on. Aside from taking some snaps, there is a way... flower pressing or, more grandly, botanical preservation. This is another very traditional craft, but one that will always be relevant when we have beautiful flowers that we want to preserve, whether for sentimental reasons or because you want to create a record of what you've grown. It's also a very inexpensive pastime as you need very little aside from some flowers, from a garden or a bouquet, and something to press them with. In this tutorial, we are going to dabble in flower pressing, but we'll also engage a Raspberry Pi Pico and a sensor in our project while we are drying our blooms, to monitor the levels of moisture within the petals and leafage.

> *A moisture sensor can be placed onto petals to measure how damp they are*

As to the type of flowers that you can press, some are more suitable or successful than others, and our research suggests that the optimal choices are often those that only have one layer of petals, as they are able to lay flatter in the press. Also, some flowers have more moisture within them, such as bluebells for example, so they will take much longer to dry out. A few flowers that pretty much guarantee pressing success for a beginner include daisies, pansies, cosmos, violas, asters, poppies, ferns, leaves and grasses, buttercups, single-petal roses, or snapdragons.

QUICK TIP

When choosing flowers, make sure they are at their peak and close to full bloom, and ideally pick them in the morning on a dry day. Avoid any which have any blemishes or have started to wilt.



YOU'LL NEED

- Fresh flowers of your choice
- Flower press (homemade or purchased)
- Absorbent paper
- Cardboard dividers
- Tweezers
- Moisture sensor (capacitive or resistive)
- Raspberry Pi Pico
- Jumper wires
- Breadboard (optional)

▲ For pressing to be effective, you must have the right pressure placed against the entirety of the flower, but you also need to use effective paper within it to absorb the moisture. You can use absorbent kitchen towel, copier paper, or more expensive blotting paper. Avoid parchment paper or anything shiny, as it won't absorb the moisture and may cause mould to develop

QUICK TIP

Pressed flowers are extremely delicate, so take care when you peel them from the paper, and plan your flowery designs before you remove them.

This is a tool that hasn't really changed much over the centuries. Vintage presses were actually quite small, were known as 'field presses', and were used by botanists and amateurs alike while out in the great outdoors. Bear in mind that if the wood panels are thicker, it will result in more weight and pressure and a more effective press

QUICK TIP

We also read that some people use felt or cotton fabric in their presses – highly absorbent and you don't need to swap them out as often as paper.

Freedom of the press

There are various ways that you can press flowers. We have chosen to use a wooden press, but the choice is yours:

1. A bookish approach

A tried and tested method of pressing flowers, this involves opening up a heavy book somewhere towards the back, then placing two sheets of blotting paper on top of the page, carefully setting down your flowers individually onto the paper face down, then placing two more sheets of paper over the top. If you want to press other flowers, open another page and repeat these actions. You then close the book delicately, place it somewhere warm and well-ventilated, and maybe put a couple of other books on top to weight it down even further, but do try to make sure the weight is even. Generally, it's suggested that you leave these for two to four weeks to fully dry out.

2. Let's iron it out

Astonishingly, one way of pressing flowers that gives instant results is to use a clothes iron – placing fresh flowers between two sheets of baking or greaseproof paper, and pressing the iron on a low heat (with no steam) over the paper for around 10–15 seconds. Leave to cool, then repeat. The flowers may need an additional two or three days to fully dry out. Not a traditional approach, and results may be patchy as this method may remove some colour because the iron does not dry evenly, and you could turn the blooms brown if you aren't careful, but it's still worth trying if your options are limited.

3. Traditional press

From what we have read on the subject, traditional flower presses do work better when it comes to colour preservation and they result in less wrinkling, so that's what we opted for. We actually purchased our inexpensive (around £10) generic press some time ago and, unassembled, it consists of some squares of plywood with holes already drilled, bolts and wing nuts, blotting paper, and some cardboard – essentially basic

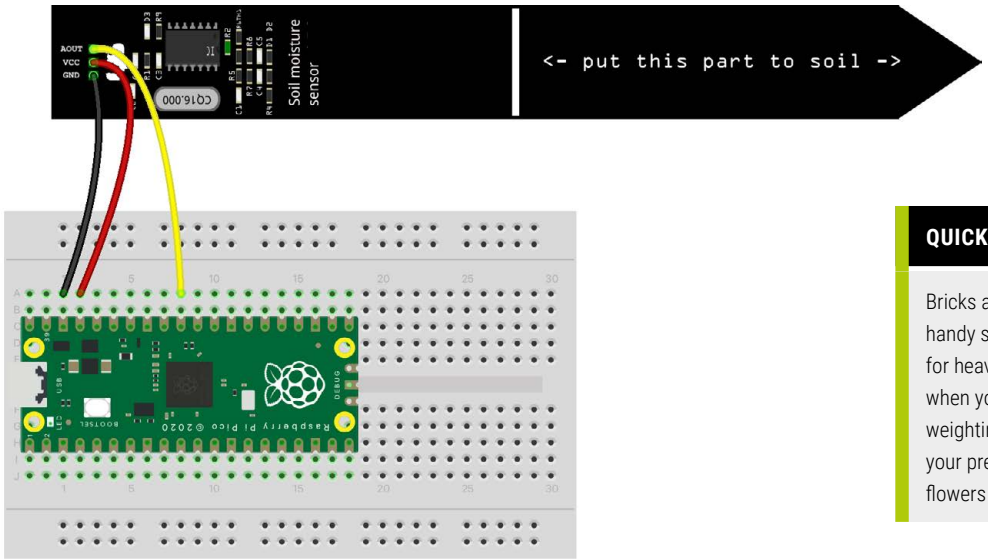


Figure 1: The wiring diagram for Pico and the capacitive moisture sensor

QUICK TIP

Bricks are a handy substitute for heavy books when you are weighting your pressed flowers down.

ingredients that you are likely to have laying around already, so just upcycle whatever you have to hand. We do talk about creative approaches to flower presses in the second boxout, so take a look for inspiration.

Nip it in the bud

So, with your chosen press to hand, the actual act of pressing the flowers could not be easier. We put our press together in a matter of minutes, and placed a layer of cardboard on the bottom, followed by a piece of blotting paper. Carefully placing the flowers that we'd picked early in the morning on that, we then laid a second piece of paper over them and another cardboard divider. We completed further layers, placed the top plywood layer on, and tightened the wing nuts. It's important to note that the paper sheets will need to be changed every couple of weeks to stop the flowers turning brown.

Moisture management

As the craft of pressing flowers is essentially very simple, we thought it would be interesting to see how we could use Raspberry Pi Pico to improve our flower-pressing experience. As the key to successful flower pressing is the elimination of any

Pressed for time

As with many of the crafts that this author has written about, flower pressing is an old one… a very old one. In fact, it's something that people have been doing for thousands of years, and was probably a pastime that the ancient Greeks and Egyptians dabbled in, as preserving flowers was linked historically to rebirth and purity.

Back in 16th century Japan, flower pressing was an art form called 'oshibana' and they used dried flowers to make whole pictures and landscapes. In more recent times, Grace Kelly, aka Princess Grace of Monaco, practised oshibana as it presented her with a valuable creative outlet, and she actually wrote a book on the subject entitled *My Book of Flowers* in 1980.

Carrying on the royal theme, but going back a couple of hundred years, flower pressing really became a quintessential pursuit during the Victorian era when it became hugely popular, particularly amongst women in Victorian society. Indeed, Queen Victoria herself was a flower-pressing fan, and some of the blooms that she squished, including ferns and irises, are still preserved (**rpimag.co/victoriaflowers**). So, if you store these things correctly, they can literally last hundreds of years. Back then, people often thought of specific flowers as having certain meanings, and preserving them meant that they could also preserve their precious memories and sentiments, and that of course still holds true today.

Aside from looking pretty, pressed flowers also became important from the botanist's scientific angle, for documenting native flora and observing and sharing plant knowledge. Herbariums, or collections of plant specimens, have been a crucial tool for the study of plants, and one of the earliest has been traced back to 16th century Italy. Closer to home, Kew Gardens' herbarium receives many scientific visitors each year, as it contains over 7 million specimens (**data.kew.org**).

▶ You'll need to remove the upper layers of the press to test the moisture levels of the flowers with your Pico-connected sensor after a few days; be careful not to press it on the petals too hard or for too long

QUICK TIP:

Don't use sticky tape to attach pressed flowers to any surface as it will discolour your flowers – PVA glue is a great option.

moisture within the flower leaves and stem, that seemed to be where Pico could assist us.

A moisture sensor is typically placed in soil, but can be placed onto petals (or other items) to measure how damp/dry they are. Moisture sensors come in two main types: resistive (with two prongs) and capacitive (one prong). We used a capacitive one from The Pi Hut (**rpimag.co/pihutmoisture**).

In our code we read the sensor's analogue output signal on GPIO 26 as an unsigned 16-bit integer every two seconds, which we convert into a voltage figure (in millivolts) that's printed to the shell so you can view it.

Connect the sensor to Pico as in the **Figure 1** wiring diagram – the breadboard is optional, as you could wire the sensor straight to Pico's pins if you want. The sensor's VCC pin is connected to 3.3V power on Pico, and GND to GND, while the AOUT analogue output goes to GPIO 26, one of Pico's analogue inputs. With Pico connected to a computer, create the following MicroPython program in an IDE (we used Thonny):

```
import machine, time
moisture = machine.ADC(26)
conversion_factor = 3300 / (65535)

while True:
    voltage = moisture.read_u16() *
conversion_factor
    print("Voltage is", voltage, "mV")
    time.sleep(2)
```

Pressing the sensor onto a damp petal results in a lower reading when using a capacitive sensor (or higher with a resistive one). By inserting the sensor into our flower press, we can check the current moisture level.

Whether you want to use your pressed flowers in some art work, embed them in soap or candles, incorporate them into some homemade paper, make some jewellery, or add them to a journal of herbarium sheets recording what you've grown, there are plenty of uses they can be put to.

▲ If you have a bumper crop of flowers, think about preserving some with a flower press

Creative flower press options

Aside from the book method or using a flower press that you've purchased for your pressing projects, another option might be to make your own press:

- If you are pushed for time or just can't be bothered to wait for your foliage to dry out, take a leaf (preferably pressed) out of this maker's book: they have created a 3D-printed press that can go in the microwave to speed up the drying process – **rpimag.co/3dprintedflowerpress**. It's been designed using Tinkercad and everything that you need to get under way is detailed in the Instructable. So, if you have access to a 3D printer, get printing and then pressing!

- Alternatively, this maker has created their own laser-cut press from some plywood, nuts, bolts, paper, and cardboard – **rpimag.co/lasercutflowerpress**. They have chosen a lovely botanical image to laser-cut on the top. You could press some flowers and seal them onto the top of the press with some varnish.

- If money is no object, this made-to-order solid oak flower press is a beautiful object for any workshop – **rpimag.co/oakflowerpress**. The black finish is created by oxidising the wood.

- We could not end without also mentioning this fantastic idea: upcycling a vintage hardcover book, that might be missing a few pages, into a flower press – **rpimag.co/bookflowerpress**. They've cleverly drilled holes in each corner, and have used wing nuts, washers, and screws to create a press for smaller blooms. Aesthetically, this really hits the spot and the heritage/vintage vibe is right up our street.

Industrial 3D printing for hobbyists

Get access to high-end 3D-printed parts without having to buy a new 3D printer

Maker

Ben Everard

Ben 3D-prints things that should not be 3D printed. He once had to spend a day with his hands in his pockets because his entirely 3D-printed belt snapped while crawling through a cave.

glowingart.co.uk

By far the most popular 3D printing technology is Fused Deposit Modelling (FDM). In this process, a print head heats up plastic and squirts the molten material through a nozzle. It moves around the print volume, building up your print layer-by-layer. This is a great, well tried-and-tested method that millions of makers use every day. It's (fairly) reliable, (fairly) easy to use, and (fairly) cheap to run. However, while the parts can be great for some uses, if you have demanding requirements, they can fall a little short. In this article, we're going to look at some industrial 3D printing techniques that are now available to makers.

Performance plastic

Nylon can be printed on an FDM printer, but it's a particularly horrible material to work with. It warps a preposterous amount, will suck moisture out of the air at any given opportunity, and will just generally make your life miserable. It's far more suited to a style of printing called Selective Laser Sintering or SLS (this is different to Stereolithography SLA). In the SLS process, a layer of powder is spread over a surface, then a laser melts the material in the first layer. The bed then drops and another layer of powder is spread, which is then melted by the laser. This process repeats until your object is fully built up.

Nylon SLS parts are robust, durable, and can have complex shapes (as overhangs are automatically supported by unsintered powder). They're also well suited to medium-run manufacturing as they can batch-print parts vertically as well as across the print bed.

Like nylon, TPU can be printed on FDM printers, but with some caveats. TPU has a habit of bending as it prints, meaning thin features can end up as a succession of blobs. With careful

When 3D-printing, it's often possible to print a delicate part that might survive, but also might not

If you just want one part with a particular technology – such as a transparent case for your Raspberry Pi – getting the part made for you can be cheaper and easier than buying a new printer (or even a bottle of resin)

slicing, chunky designs are possible, but more delicate designs can be challenging. Again, SLS comes to the rescue, allowing much more complicated and intricate parts to be printed of this flexible material.

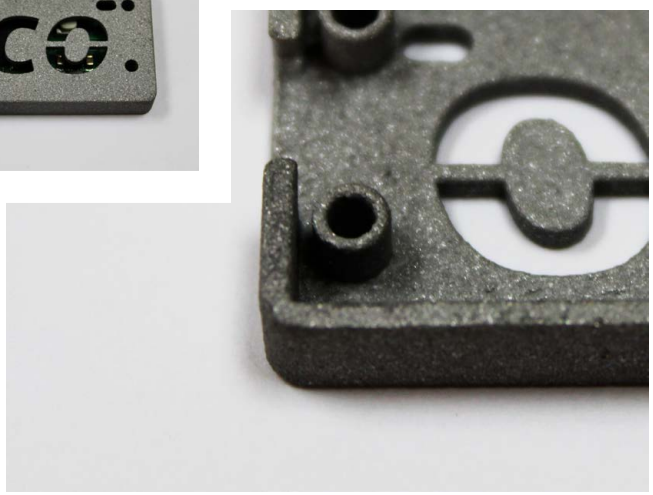
The problem with SLS printers is that they're expensive and messy. Fortunately, you don't need to have an SLS printer to create SLS prints – you just need a company that does.

There are a few companies that offer industrial-level printing services to makers. We're going to take a look at PCBWay.

Head to **pcbway.com**, then use the CNC | 3D Printing > 3D Printing menu to get to the quote page. Most of the time, this will give a full quote for your part, but if you have unusual requirements, you might get 'RFQ' as the price total. This stands for Request For Quotation and means that someone will get back to you with the final price.

PEEK

Polyether ether ketone (PEEK) is perhaps the ultimate FDM material. It's strong, stable at high temperatures, and resistant to a lot of chemicals. It is, however, an absolute pain to print. We have seen some people manage something approximating successful prints in PEEK on home 3D printers, but really it needs a very high-end setup to work well, and even then it can take some dialling in. If you just need the full capabilities of PEEK for a few parts, it's probably not worth the time and effort to do it yourself, so why not let someone else do the hard work? After all, it's eye-wateringly expensive for a spool (expect to pay over £500 per kg), so it only takes a few failed prints for it to be cheaper for someone else to do it who can get it right first time.



▲ If you want ultimate protection for your parts, 3D-printed metal is incredibly strong – just be careful that you don't accidentally short-circuit any of your components

▲ SLS metal prints have a rough surface texture, and feel a little strange to the touch

First you need to upload your design file. This will usually be your STL or STEP rather than a pre-sliced file. You don't have as much control over the slicing as you might do if you have your own printer, but this is usually a good thing. It means that parts are printed with tried-and-tested slicing settings. If you do need anything specific, you can add it to the Other Special Requests box at the bottom of the page, or open up a chat session with the support.

Next, you need to enter the quantity of parts you need. This is the number of copies of the same part you want. If you want different parts, you need to add them separately to your order. The cost per part does decrease as you order more copies, but not significantly.

Selecting the material will give you options for the process, colour and surface treatment. For example, if you choose Nylon, you'll get the option for PA12, HP-PA-12 and Glass Fibre Nylon. If you're not sure what you want, click on one, then in the Selected Material box you can click on Show Material Description to find out more including viewing the material data sheet.

There is the option to upload a technical drawing, but for most cases, the 3D design uploaded first should contain all the information needed. However, a technical drawing is needed if you want PCBWay to tap threads, add heat-set inserts, silkscreen or laser engrave your parts, or if you want PCBWay to assemble your parts. With these options, it's easy to see how the 3D print service from PCBWay could be part of a small-scale manufacturing line.

CNC machining

3D printing is a type of 'additive manufacturing'. This means that you start with nothing and add material to build up to your desired shape. An alternative is subtractive manufacturing, where you start with a block of material and remove material until you have the part you want.

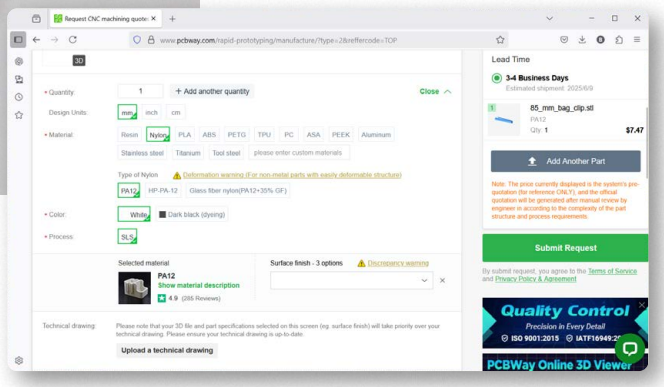
Just as 3D printing has limits on what it can produce, so does CNC machining. The limits depend on the machine, but on common mills, the limits depend on the number of axes. For example, in a three-axis CNC mill, the tool head (the bit that holds the spinning bit that removes material) can move like the print head on a 3D printer. This can remove material from the top of the part, but not underneath. As you add more axes to the machine, you can make more complex shapes.

You can get quotes for CNC machining parts online at PCBWay and other sites.

When 3D-printing, it's often possible to print a delicate part that might survive, but also might not. PCBWay has minimum wall thicknesses and thread pitch (if you're printing a threaded hole). If you want to push these limits, you can, but you just need to be prepared to accept the risk that they may not work. This author has gone beyond the limits a few times and nothing untoward has happened, but it's up to you whether or not to take the risk. If you want to, make sure the Wall Thickness Risk Taken or Non-Standard Printed Threads Risk Taken boxes are checked. The actual minimums vary by printing technology. Hover over the 'E.G.' text next to each option for more information.

The final option is perhaps the strangest. You need to select a Product Description category. This is for customs purposes when your prints are sent to you. Depending on where in the world you live, selecting different options may impact what happens when the package arrives in your country.

- SLS nylon is significantly tougher than most FDM 3D prints and can be a cost-effective way of doing a small run of plastic parts
- The same part printed with different techniques can have startlingly different properties



With all that entered, you can submit your request. Most of the time, the final price will be the displayed price, but if your part is unusual, it sometimes comes out a bit differently. The final price is usually sent over within a day or so.

The price doesn't include delivery and you may also have to pay import duty. In some cases, you can pay the import duty directly through PCBWay and they'll get it delivered straight to you. In other cases, you'll have to organise this with your local customs.

Metal

Sooner or later, you'll probably want to make something out of metal. Whether this is for strength or purely looks (this author has 3D-printed jewellery previously), this technology is pretty hard to use at home or even in a small workshop. Again, industrial 3D printers come to our rescue. Quite a few metals can be 3D-printed, and PCBWay has options for Stainless Steel, Tool Steel, Titanium, and Aluminium.

The basic technique for this is known as Selective Laser Melting, and is quite similar to the SLS process used for nylon and TPU. There's a powder that's melted by lasers and built up layer by layer. This does give quite a rough surface finish (though you can polish this up by hand if you wish to).

Commercial 3D printing for hobbyists is now at a point where it's a cost-effective way of getting access to advanced techniques. If you just need a few parts, it can be cheaper than buying a new spool of filament or bottle of resin, and save you hours of messing around with uncooperative materials. There will always be a place for home 3D printing, but this can be a great way to augment your builds with higher-end parts.

PolyJet

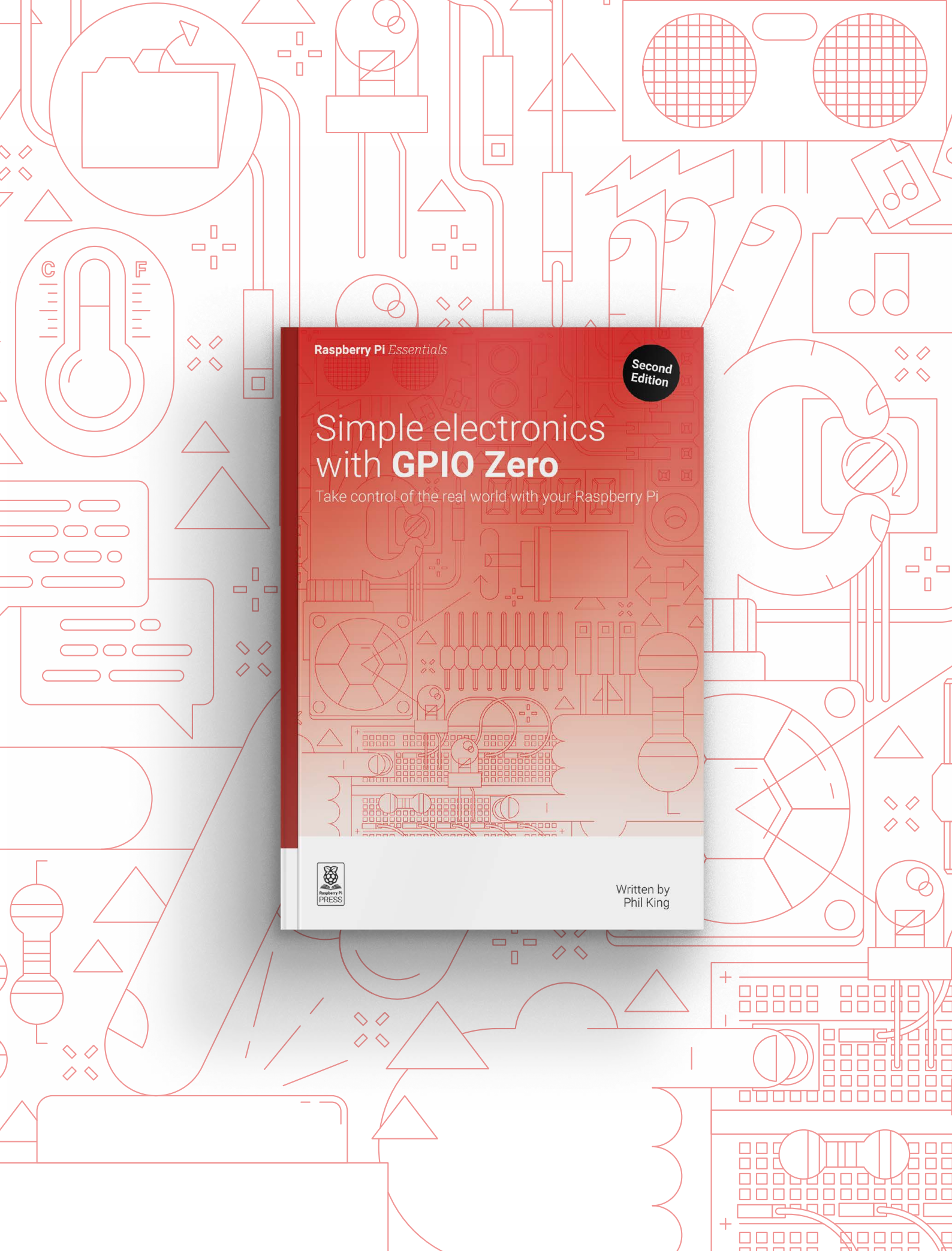
PolyJet is one of the more unusual 3D printing technologies. It's a bit like a mashup of an inkjet printer and a resin printer. A print head moves across the surface, squirting resin and then curing it with UV light.

The main reason a hobbyist might want PolyJet printing is that it has the best colour capabilities of any 3D printing technology. You can get a huge range of colours, including gradients, in a single print – far more than is possible with any other method you're likely to get access to.

Multi Jet Fusion

Multi Jet Fusion is similar to SLS in that the part is built up from powdered nylon layer-by-layer. However, it's done in a slightly different way. All the powder is heated to just under melting point, then a fusing agent is deposited in the areas that should be joined and a detailing agent on the edges.

The final parts are similar to SLS parts and typically done with nylon.


Raspberry Pi Essentials
Second Edition
Simple electronics with GPIO Zero
Take control of the real world with your Raspberry Pi
Written by
Phil King

COMPUTING AT THE EDGE

RASPBERRY PI IN INDUSTRY

Raspberry Pi isn't purely for hobbyists and education – it's routinely used by business and enterprise

By **David Crookes**

Although Raspberry Pi was originally designed to teach coding and computer science, it has since taken on a life of its own. Innovative creators have produced a wealth of amazing projects (as we see in each issue of this magazine), but businesses have also seen the potential and benefits of using Raspberry Pi technology in their products.

Businesses have seen the benefits of using Raspberry Pi

There are loads of devices and projects in the real world doing real things and many of them are making a big difference to productivity, innovation, and people's lives. As well as great support, flexibility, and an ability to interface with sensors and industrial protocols, Raspberry Pi devices are providing cost-effective solutions for bespoke needs. Let's see how it's making an impact.

DELIVERING INFORMATION

Raspberry Pi is transforming how businesses deliver dynamic, real-time content

▲ The Yodeck player has built-in passive cooling. Digital signage is perfect for the changing menus and deals of fast food restaurants

Yodeck

Digital signage

yodeck.com

Full story: rpimag.co/yodeck

Whether you're ordering from a digital menu above the counter in a pizza takeaway, checking information at a hotel, or viewing product videos in a store, there's a chance you may be looking at a screen driven by a Raspberry Pi computer.

Digital signage company Yodeck works with the likes of Domino's Pizza, TUI, and Richard Mille to display information using a Python-based application running on Raspberry Pi as a platform. Content can be managed remotely using an online dashboard or locally from an SD card.

Screenly

Innovative ads

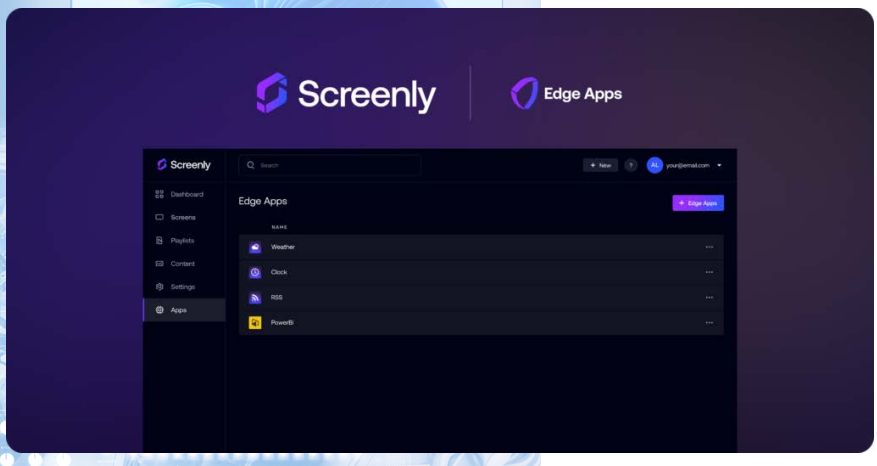
screenly.io

Full story: rpimag.co/screenly

Screenly also provides support for digital signs and it allows customers to either buy or create a signage player based around a Raspberry Pi 4 or later. With Screenly's Edge Apps, setup and customisation is made easier and clients are able to display all kinds of content, from image, video and audio files to live web footage, clocks, RSS readers, the weather, messages and more.

Having been around for more than ten years, Screenly now powers more than 10,000 screens in more than 75 countries, and clients include NASA and Amazon. But there are also many smaller companies taking advantage thanks to the low barrier to entry, which is why it remains a popular choice.

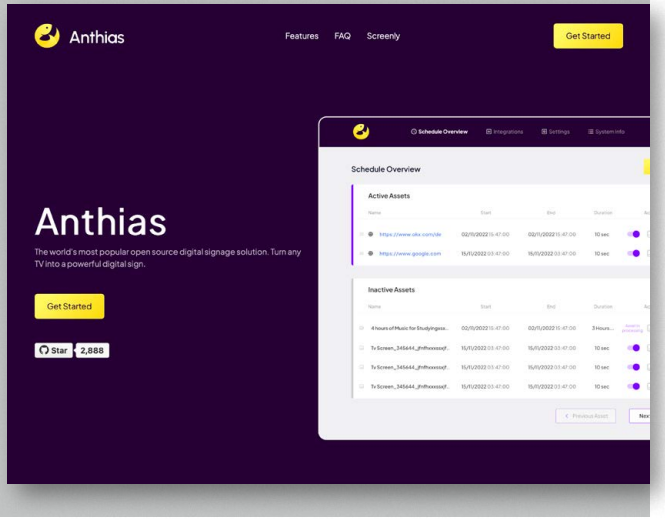
◀ Screenly is capable of displaying content at up to 4K resolution



Use a free signage OS

Want to use an open-source signage solution without paying a bean? Screenly's Anthias (**anthias.screenly.io**) – formerly known as Screenly OSE – runs on Raspberry Pi devices and it's great for single screens.

Perfect for use at events as well as in schools, offices or small businesses, Anthias lets you upload images, videos, and web pages. You can then use the Schedule Overview to see your active and inactive assets, making it simple to toggle between what you want and don't want.



MANUFACTURING

Raspberry Pi devices have been transforming the factory floor

Sony UK Technology Centre

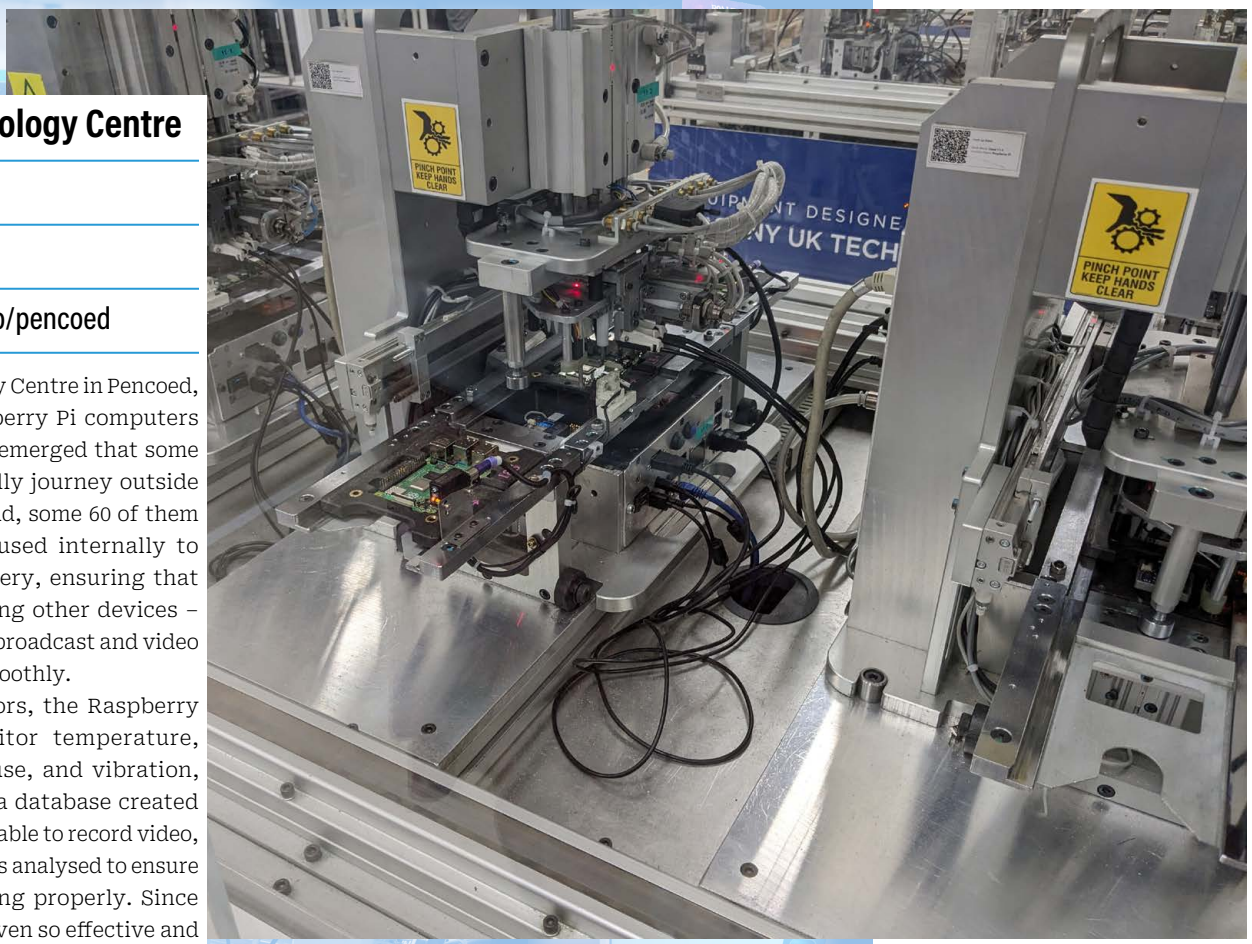
Pi eye

sonypencoed.co.uk

Full story: rpimag.co/pencoed

Sony's UK Technology Centre in Pencoed, Wales, makes Raspberry Pi computers but, in 2019, reports emerged that some of them don't actually journey outside of the factory. Instead, some 60 of them were shown to be used internally to monitor the machinery, ensuring that the process of making other devices – such as professional broadcast and video equipment – runs smoothly.

Fitted with sensors, the Raspberry Pi computers monitor temperature, proximity, energy use, and vibration, with data stored in a database created by Sony. They're also able to record video, the footage of which is analysed to ensure machines are working properly. Since the initiative has proven so effective and inexpensive, it has been extended to other Sony factories, in Japan and Malaysia.



▲ Ah, another wonderful Raspberry Pi device rolls off the production line

Brompton

Keeping the wheels turning

brompton.com

Full story: rpimag.co/brompton

When Brompton began selling its folding bikes, each one was handmade to order. As time has gone by and demand for the company's range of iconic bicycles has increased, the firm has turned to modern manufacturing processes.

As part of that system, for the past twelve years Brompton has been using Raspberry Pi devices to scan the serial number of each bike as it progresses to each production station. Today, there are more than 100 Raspberry Pi computers in use and, as well as checking out the production line, they keep a check on the factory's air quality.

▼ Brompton created its automated system using in-house talent

Giving industry the edge

Seeed Studio's Raspberry Pi Compute Module 4-based board, the EdgeLogix-RPi-1000 is an all-in-one industrial controller that boasts many I/O ports and a touchscreen interface. Created for use in factories and warehouses, it connects to equipment, sensors, and cameras and gathers data that can be used to control and automate processes. It has even been used to help filter dirty and polluted water in Africa, making it drinkable (**rpimag.co/edgelogix**).

◀ This interface can work with lots of data

RESEARCH AND MEDICINE

Medical researchers and companies are breathing new life into healthcare

Exoskeleton walking aid

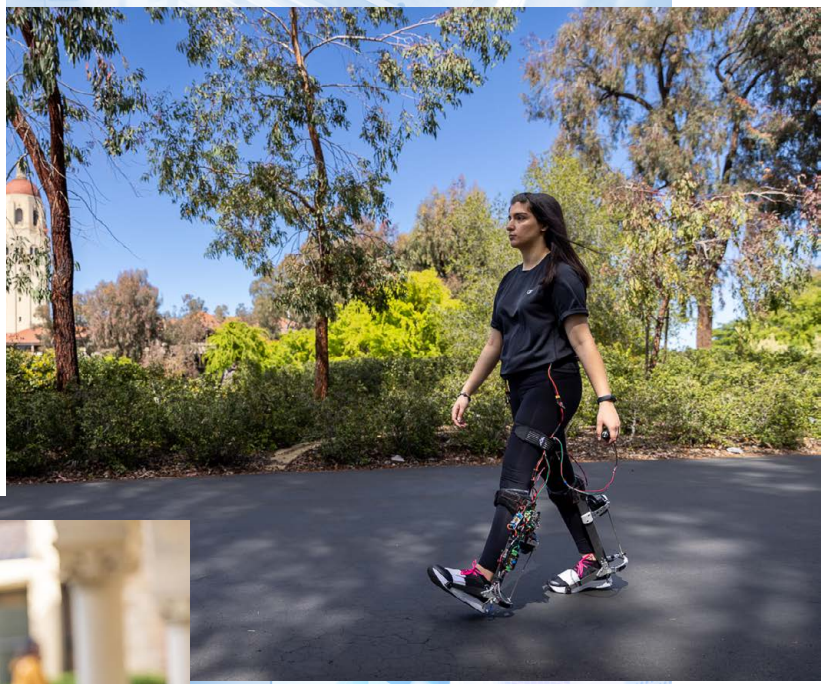
Path to success

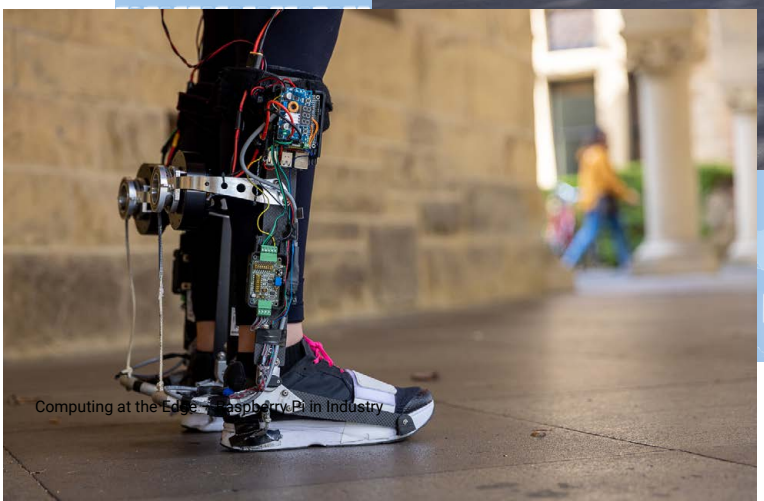
rpimag.co/biomechatronics

Full story: rpimag.co/exoskeleton

The medical technology industry has been making great strides thanks to Raspberry Pi and, as if to prove that, we couldn't really pick a better example than Stanford University's robotic exoskeleton walking aid. Worn like a boot, it's still very much in the prototype stages but, in using sensors, a motor, and motor driver connected to a Raspberry Pi 4 computer, it can speed up the wearer's walking and help with mobility impairments.

▼ The exoskeleton walking aid is personalised for each wearer





▲ Using IoT technologies in medical equipment is aiding healthcare

Bio Business

Cloud care

biobusiness-eg.com

Full story: rpimag.co/biobusiness

Bio Business is a research and development company which produces medical products, both under its own name and those of Philips, GE, and Siemens. It found that Raspberry Pi Compute Module 4 and RP2040 microcontrollers enabled it to incorporate real-time cloud connectivity while providing temperature, humidity, and air quality readings. This allowed medical equipment to be checked remotely. An RP2040 is now used inside a portable CPAP (continuous positive airway pressure) device monitor, and Raspberry Pi is also at the heart of an oxygen concentrator which lets users control their own flow.

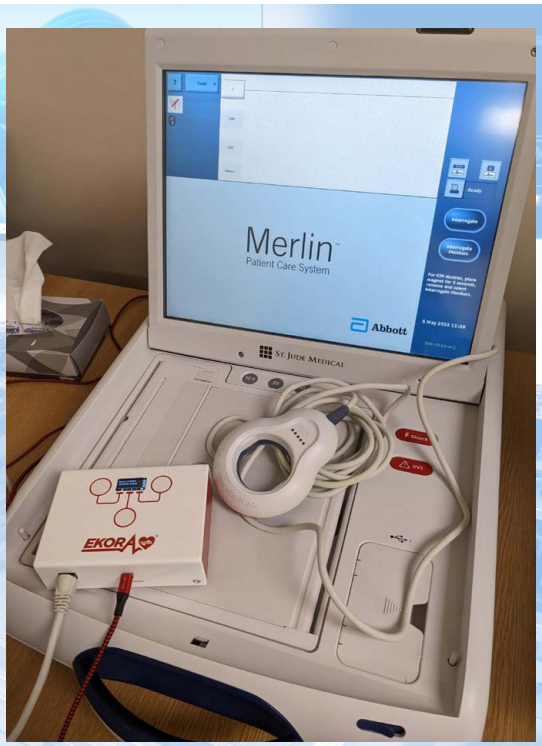
EKORA cardiology device monitoring

Heartwarming journey

ekora.io

Full story: rpimag.co/ekora

Developed by cardiologists Dr Alan Robertson and Dr Dougie Elder, EKORA is a secure device widely used by healthcare professionals. With a Raspberry Pi Zero W and custom PCB configured to mimic a USB flash drive using USB On-The-Go, data from pacemakers, implantable cardioverter-defibrillators, and cardiac resynchronisation therapy devices can be safely collected, stored and encrypted before being transmitted securely to EKORA's server. As a paperless solution, it allows for remote and in-clinic checks, makes data management more efficient, and hugely speeds up access to patient records. And there's no dodgy USB stick in sight.



▶ EKORA is designed to be quick and easy to use

LISTEN UP

Businesses like the sound of using a Raspberry Pi in their audio devices and musical instruments

Korg synthesizers

Play it again

korg.com

Full story: rpimag.co/korg

Raspberry Pi can be found inside some music keyboards, including synths created by Korg. Compute Module 3 is incorporated within Korg's Wavestate, Opsix, and Modwave models while Compute Module 4 was more recently included in the Korg multi/poly. It has allowed the company to reduce costs and make its products more widely accessible. What's more, it's gone down very well among its intended audience.

▼ From the Atari ST to Raspberry Pi, computers have long been used to help produce music

Yoto Player

Story spinner

uk.yotoplay.com

Full story: rpimag.co/yotoplayer

Audiobooks are great for kids, widening vocabulary, sparking imagination, and boosting reading skills. Children can enjoy them in a host of ways, via streaming music services such as Spotify, for example, or through a Toniebox which gets kids to place a character model onto a speaker device in order to listen to an associated story.

The Yoto Player works in much the same way as a Toniebox, only this audio device uses collectible cards. Insert one into the RFID slot and a story will start – played via a Raspberry Pi Zero W. At the same time, a 16×16 LED display shows simple graphics that illustrate basic concepts. Since 2017, when two fathers came up with the idea, Yoto has gone from strength to strength. There are loads of cards featuring stories by Julia Donaldson, Roald Dahl, and more.

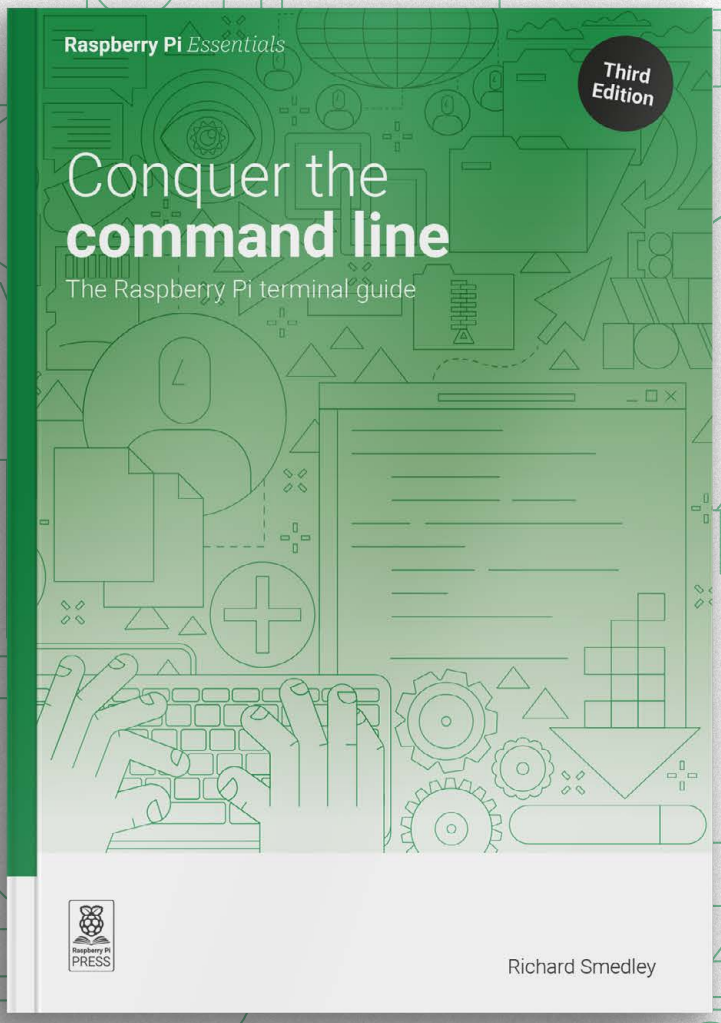
▲ Yoto has been a huge success, racking up more than a million sales

Insert a card into the slot and a story will start

Did you hear the one about…

…Lucem, the boutique guitar brand? In 2019, it created a concept electric guitar with BioTek 2 software developer Tracktion Corporation. Called Spirit Animal, it incorporates a Raspberry Pi synthesiser that can be operated by a built-in screen.

▲ It is possible to access Raspberry Pi's Ethernet port and wireless tech for updates


Raspberry Pi Essentials
Third Edition
Conquer the
command line
The Raspberry Pi terminal guide
Raspberry Pi PRESS
Richard Smedley

CrowPi 3

An electronics playground with added AI lessons for Raspberry Pi, Pico, and more. **Rob Zwetsloot** gets stuck in

Elecrow **rpimag.co/crowpi3** £168 / $229

SPECS

DIMENSIONS
285mm × 185mm × 38mm

SCREEN
4.3-inch 800×480 IPS screen

COMPATIBILITY
Raspberry Pi 5, Raspberry Pi Pico (all models), Arduino Nano, micro:bit

▶ A fairly packed electronic lab for people learning to code and make

Educational and electronics starter kits for Raspberry Pi have been around since, well, Raspberry Pi has existed. We've covered a large variety over the years – from small kits that cover specific use cases, to a newer breed of portable electronics labs. These latter types are always fascinating, cramming as many different functions as possible into a briefcase-shaped computer that looks a little like a prop from a 1990s hacker movie. Unlike its laptop-esque predecessors, CrowPi 2 and L, the CrowPi 3 returns to this lab form factor with more built-in components than you can shake a Sense HAT at.

The really clever thing is, once you install a Raspberry Pi 5 and load up the included OS, you are presented with an interface to start learning how to use these components – and this is where the new flagship feature comes in: working with AI.

Educational intelligence

These AI-based lessons allow you to make use of LLMs (large language models), voice commands with the built-in microphone, image recognition using computer vision

◀ A successful Kickstarter campaign for CrowPi 3 just finished

> *It all works well, with very clear and useful labelling on all the installed components*

▶ There are a ton of additional components that come in the box

on the built-in camera, and have it connect all of this up to the components on the board. Some of the example lessons will enable you to control some of the included LEDs with your voice as well as tracking a ping-pong ball or similar in your hand across the included screen.

These pair well with the multitude of lessons on the various components and how to use them with, for example, Python for Raspberry Pi. The AI examples can then be modified and grown using these lessons, making it a great way to extend the uses of this playground. Elecrow says there are over 180 individual lessons at the moment, and the number seems to be growing every time we talk to the firm as well.

Hands-on learning

Setting up the whole system is extremely easy – you basically just need to plug in a Raspberry Pi 5 – and you'll be ready to go in about ten minutes. We tested the basic kit, which doesn't come with any batteries; however, you can power it with just the provided PSU, and easily add the correct batteries later to make it portable. All the physical components and doodads are supported by a decent-sized bag of extra components for use in the breadboard, motor connectors, etc. and really add to the tactile feel of making something on the system.

Teaching 'Hello world!' to people is all well and good, but making your Python code control some lights or beep faster if your hand is closer to an ultrasonic sensor gives much better feedback and reward. And it all works well, with very clear and useful labelling on all the installed components so you can add or remove them from your code as you please, even beyond the pre-installed lessons.

It's a very cool piece of kit which should keep many curious folks busy for hours and days, and impart some genuinely useful making and coding skills as they go.

Verdict

A very complete learning kit for people wanting to get into coding and making, and also find out what all the fuss is about with the current AI trends in computing.

10/10

Tripod Mount

The easy way to mount a Raspberry Pi Camera Module. By **Lucy Hattersley**

The Pi Hut **rpimag.co/tripodmount** £3.50

▲ Tripod Mount is a backing plate that adds a ¼-inch tripod mount screw to a Raspberry Pi Camera Module

SPECS

COMPATIBILITY:
Official Raspberry Pi Camera Module 1, 2, 3, and AI Camera

FEATURES:
Tripod mounting plate for Raspberry Pi Camera Modules; slot for flex cable; female tripod fixing built-in; fixings included (including spares)

MATERIAL:
Acrylonitrile butadiene styrene (black), 5 × screws

▶ A Tripod Swivel Ball is sold separately and enables you to direct Camera Module to your subject matter

Verdict

An simple solution that is great value.

10/10

Sometimes it's the simple things that surprise and delight. For a while we've been putting together various camera-based projects, especially with regards to an AI HAT+ and AI Camera Module.

These projects need a quick and easy way to mount a camera on a tripod and point it at something. We've 3D-printed models for camera housings and used Blu Tack for homemade selfie sticks. Eventually, we asked The Pi Hut if they had something we could use and they supplied us with a Tripod Mount and a range of tripods to test out: Small (£6, **rpimag.co/smalltripod**), Medium (£9, **rpimag.co/mediumtripod**), and Large (£12, **rpimag.co/largetripod**).

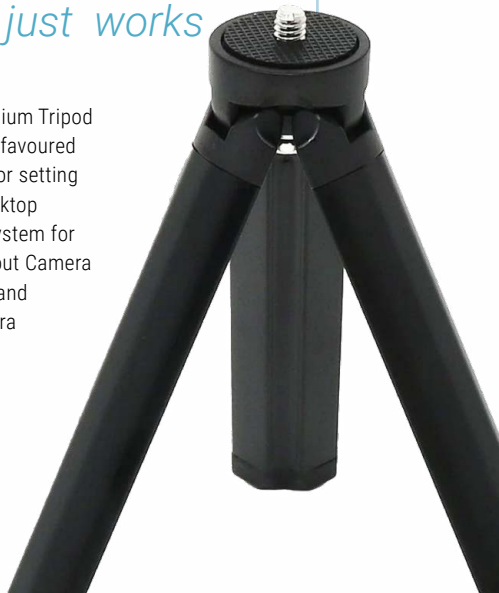
Tripod Mount solves the problem of using a Camera Module 3 or AI Camera Module with a tripod. It's a plastic mounting plate with screw mounts and a ¼-inch screw. The Camera Module cable flex flips through the back of the mounting plate and connects to Raspberry Pi.

If you want, you can also use it with a heavy-duty tripod swivel ball (£2, **rpimag.co/tripodswivelball**).

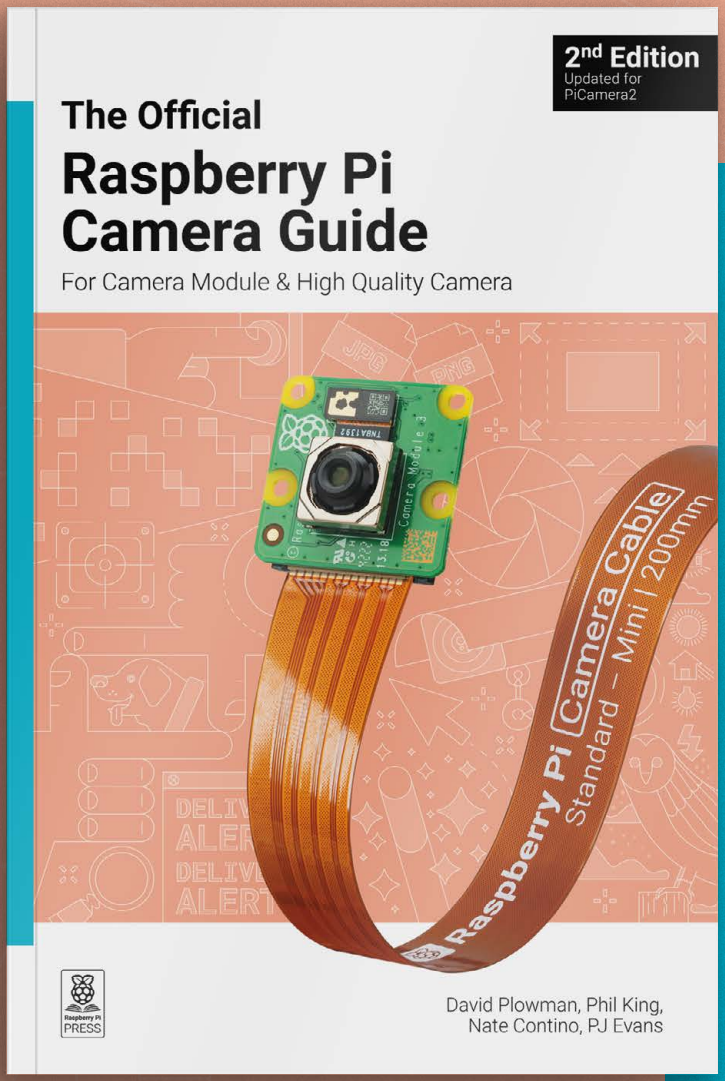
It's very easy to use. You connect Camera Module, attach the swivel ball, and hook it up to the tripod. Then point it at things and crack on with the more difficult task of coding and building your camera-based project.

Sometimes the best solution is the one that just works, as we've found when building a camera-based project. When working on our recent book: *The Official Raspberry Pi Camera Guide* (£15, **rpimag.co/cameraguide**), we found this tripod mount setup invaluable.

> *Sometimes the best solution is the one that just works*



▶ The Medium Tripod was our favoured choice for setting up a desktop tripod system for testing out Camera Module and AI Camera



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ONLY THE **BEST**

Cooling solutions

By **Phil King**

With the weather hotting up in the UK, it's a good time to look at how to keep your Raspberry Pi 5 cool. While this shouldn't be an issue during normal usage, a heavy continuous load will cause things to heat up. To prevent overheating, all Raspberry Pi computers start to throttle the SoC at 82°C. Between 82°C and 85°C, Raspberry Pi reduces the clock frequency by 100MHz per degree over 82°C. If the CPU temperature reaches 85°C, Raspberry Pi greatly throttles the Arm CPU frequency, along with the GPU. Naturally, this reduces system performance, so cooling solutions aim to keep the temperature below this point.

We've gathered some of the best cooling cases and devices around to try them out. Two main cooling methods are used: passive and active. Passive involves dissipating heat from Raspberry Pi's SoC (and other chips) via sticky thermal pads linked to a metal case. Active cooling is typically achieved using a PWM-controlled fan connected to the port marked 'FAN' on Raspberry Pi 5. Some cases use both methods.

While our tests weren't conducted under strict laboratory conditions, they should give an indication to how well each case performs. See the table at the end to compare results.

Official Raspberry Pi 5 Case with Fan

Raspberry Pi | £9 / $12 | raspberrypi.com

Coming in red/white or black, the official Raspberry Pi 5 case features the same snap-together design as the ones for other models, with improvements to aid ventilation and cooling. It's very easy to assemble the plastic pieces.

While some passive cooling is provided by a metal heatsink to stick onto the SoC, the main cooling method is a fan. It's mounted in a clear insert that can be removed if needed, such as to mount a HAT – although it's probably better to use a GPIO booster header. The case lid fits on top with a gap to aid ventilation.

Although cooling performance wasn't as good as the other cases in this roundup, resulting in some minor throttling when overclocked, you could always take out the fan insert and use an Active Cooler.

▲ A three-part plastic case with built-in fan

Verdict

Easy to assemble and keeps Raspberry Pi 5 cool unless overclocked.

Active Cooler

Raspberry Pi | £5 / $6 | raspberrypi.com

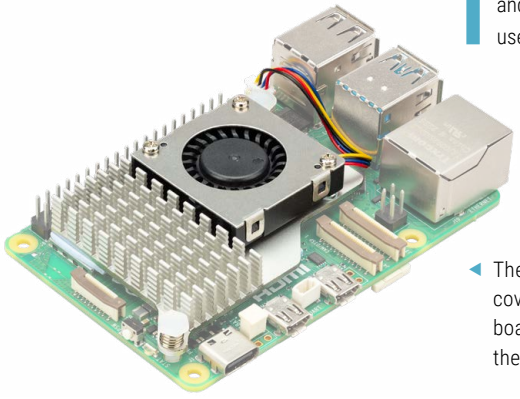
The Active Cooler combines a fan with a large, single-piece aluminium heatsink that covers most of the top of Raspberry Pi 5, but leaves all the ports and GPIO header exposed. So you can easily mount a HAT over the top of it. Pre-applied thermal pads help to dissipate heat from the board. Spring-loaded clips are used to mount the Active Cooler.

If you don't want to buy a new case for your Raspberry Pi 5, you can use the Active Cooler with a standard one, or the official case with the fan insert removed. There's also the option of adding an Active Cooler cover – they come in five translucent shades.

For our tests, we used the Active Cooler on a bare Raspberry Pi 5 board and found that it kept it pretty cool – well below the threshold for thermal throttling, even when overclocked.

Verdict

It combines passive and active cooling and could be used with a case.



◀ The Active Cooler covers most of the board while leaving the ports free

Aluminium Armour Dual-Fan Heatsink Case

The Pi Hut £14 / $19 | thepihut.com

Why have one fan when you can have two? That's the philosophy behind this case that combines active and passive cooling. The latter is provided by two solid metal case pieces that sandwich Raspberry Pi 5, leaving a gap around the edges to aid air flow. Assorted thermal pads are supplied to aid heat dissipation from the main chips.

It's fairly easy to assemble using supplied screws – be careful not to overtighten the ones for the fans in the top. While there are slots for the CAM/DISP and PCIe ports, you'll need to connect the cables before assembly.

In our tests, we found it provided impressive cooling from the combination of the heatsink case parts and dual fans, which are near silent. The metal case top does get hot to the touch, though, so don't do it!

Verdict

Two fans are better than one, as shown by its cooling performance.

◀ With two fans and a two-part metal heatsink case, it's very effective

Argon NEO 5

Argon 40 | £15 / $19 | argon40.com

▲ The metal case acts as a heatsink while a fan aids cooling

Coming in three parts – two aluminium sections and a plastic base – and a black/red colour scheme, the NEO 5 looks good and feels really solid. The middle section is especially stylish, featuring a fan next to curved fins to aid cooling. A special NVMe version of the case is also available.

Assembly is made easier by a small booklet showing you how to snap-fit Raspberry Pi 5 onto the bottom of the middle section, with the fan cable routed around the edge. You then screw in the base and add the metal cover. You'll need to remove the latter to access some of the ports, and to mount a HAT using a booster header to lift it over the fan.

Most importantly, cooling performance is excellent, especially at the standard CPU clock speed, although it also kept it well under the throttling threshold during overclocking.

Verdict

A stylish three-part design that delivers excellent cooling.

ICE Tower CPU Cooler

52Pi / The Pi Hut | £16 / $16 | 52pi.com / thepihut.com

If you're looking for a cooling solution that looks cool as well, this could fit the bill. Its aesthetic is enhanced by RGB LEDs that make the fan glow in various colours. We're not sure it's really a case, although it does have a plastic base that's connected via screws and bolts to two metal mounting brackets and the main fan/heatsink section on top. Assembly is a little fiddly.

The ICE Tower does, indeed, tower over the board, so there's certainly no room for a HAT. The ports and GPIO header are all easily accessible, though. Positioned vertically, the fan blows air onto the aluminium fins of that large heatsink, whose copper base is connected to Raspberry Pi 5's SoC via a thermal pad. This results in effective cooling, including when overclocked.

◀ Towering above Raspberry Pi 5, it delivers efficient cooling

Verdict

No room for a HAT, but it looks cool and will keep your Raspberry Pi 5 cool.

Galactic Case

DeSalvo | £60 / $80 | desalvoinc.com

▲ It's CNC machined from aerospace aluminium

This is one amazing-looking case, featuring aesthetically pleasing wavy fins on the top to aid passive cooling. Weighing in at 298g (without Raspberry Pi), the solid case is fully CNC machined from 6061-T651 aerospace aluminium. If you want even greater luxury, a stunning copper version of the case is available for £226 / $300.

While the Galactic's design prevents access to Raspberry Pi 5's internal connectors and CAM/DISP ports, there is a slot for the PCIe connector. There's also a slot to thread a GPIO 40-pin cable through to the header, although it's a very tight fit.

A sticky thermal pad connects Raspberry Pi 5's PMIC circuitry to a riser in the case, while thermal grease is used for the SoC. Despite the lack of a fan, the cooling performance is outstanding, peaking just above 40° in our standard stress test; 51° during overclocking.

Verdict

It looks stunning and also provides the most effective cooling of the group.

Pironman 5

SunFounder | £60 / $80 | sunfounder.com

Pironman 5 turns your Raspberry Pi 5 into a stunning desktop mini PC with an NVMe M.2 slot for SSD storage – or two slots in the Max version (which also has a stylish black colour scheme). On the cooling front, it's equipped with RGB-lit dual fans set into one case wall, plus a third fan on the tower cooler heatsink that sits on the SoC.

An adapter board extends Raspberry Pi 5's USB-C power port and converts its micro-HDMI outputs to full-size HDMI ones on the case exterior. An IO expander board extends the GPIO pins, powers the two RGB fans, and connects a mini OLED which shows key stats (or you can view them on a web dashboard).

As expected, cooling performance is excellent. With the two RGB fans on the default 'Always On' setting (rather than triggering at a specific temperature), the temperature during our stress test stayed below 60°C even when overclocked.

Verdict

A feature-packed case with quality components and three fans for cooling.

◀ It looks fabulous and provides outstanding cooling

COOLING COMPARED

For each cooling case/solution in the group, we ran a five-minute stress test on all four CPU cores, at the standard 2.4GHz clock speed and then overclocked to 2.8GHz. There's no advantage to cooling below the minimum throttle point: cooling Raspberry Pi to 50°C is not better than cooling it to 70°C. Our engineers tell us: "70°C is a reasonable target. It leaves some headroom for bursts in performance".

* Thermal throttling triggered
** With default 'Always On' fan setting

Case	Max temp °C (2.4GHz)	Max temp °C (2.8GHz)
Official Case (with fan)	74.7	84.5*
Active Cooler (no case)	63.1	70.8
Aluminium Armour Dual Fan	57.6	69.7
Argon NEO 5	55.4	70.8
ICE Tower	61.5	71.9
Galactic	40.6	51.0
Pironman 5**	50.5	58.7

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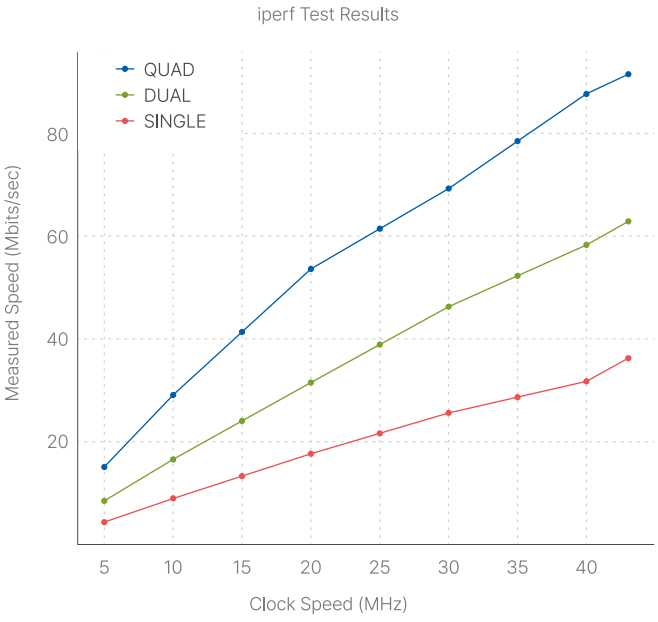
- **Embedded Servers & Cloud Devices**

Performance Test Results

- iPerf3 Performance
  Up to 90 Mbps on RP2040/RP2350 in 43MHz QUAD mode
- Optimized speed across different QSPI modes



WIZ630io 

W6300-EVB-Pico
(W6300 + RP2040) 

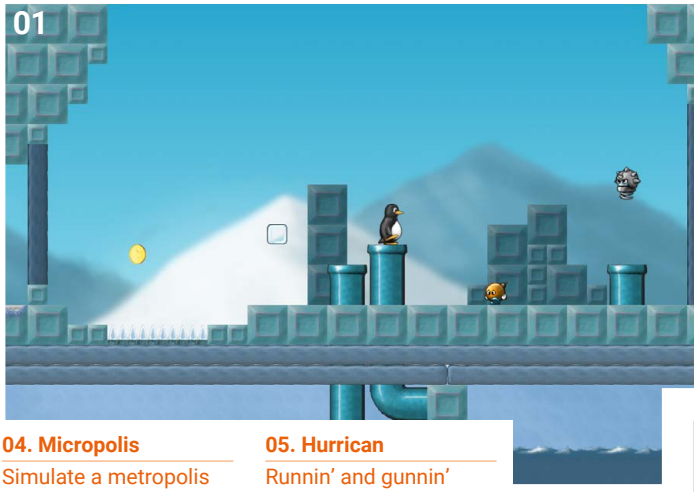
W6300-EVB-Pico2
(W6300 + RP2350) 

10 amazing:

Raspberry Pi games

Get gaming on Raspberry Pi with these titles that don't require emulation

RetroPie is one of our favourite bits of software for Raspberry Pi, turning it into a fully-functional retro gaming machine. Did you know that there are plenty of games that run on Raspberry Pi without needing extra emulators, though? Here are some of the best ones...



01. SuperTux

Platforming penguin

supertux.org

Free

Tux is the mascot of Linux, of which Raspberry Pi OS is a version, and in this game he shows that plumbers aren't the only ones that can have all the jumping fun.

02. SuperTuxKart

Open-source racing

supertuxkart.net

Free

Tux and his various open-source pals take to the track to find out who is the fastest in this high-octane story-driven race-'em-up.

03. Pingus

What a lemming

rpimag.co/pingus

Free

Pingus is a fun puzzle game that involves using your penguins in inventive ways, by assigning various abilities, so that at least some of them may escape.

04. Micropolis

Simulate a metropolis

rpimag.co/micropolis

Free

City builder sims are a classic of the medium, and you can play this open-source throwback to some of the very first on your Raspberry Pi.

05. Hurrican

Runnin' and gunnin'

rpimag.co/hurrican

Free

Based on the classic Turrican games from the 1990s, Hurrican is a fan-made spiritual successor that has been around for nearly 20 years.

06. DOOM

Big Famous Game

rpimag.co/doominstall

Free

The source code to DOOM is free, and using the Chocolate Doom port and the old Shareware WADs, you can play the first part of Doom on Raspberry Pi. Or play it all with a purchase.

07. Ben Was Assimilated

Hack-and-move

rpimag.co/benassim

Pay what you want

Enemies move as you do in this turn-based hack-and-slash game which 'prominently features' the Derbyshire dialect – it's sound as a pound!

08. Slither

Snake? Snake?! Snake!

rpimag.co/slither

Free

As a snake, you eat gems, get longer, and move faster. Don't eat your own tail, though! This kind of game has been around for nearly 40 years and is still very addictive.

09. BBQ DAD

Grill 'em up

rpimag.co/bbqdad

Pay what you want

Created by the magazine's own Features Ed Rob, this simple game is about managing your weekly BBQ for your family and guests. We're a bit biased, but think it's fun.

10. Minecraft: Pi Edition: Reborn

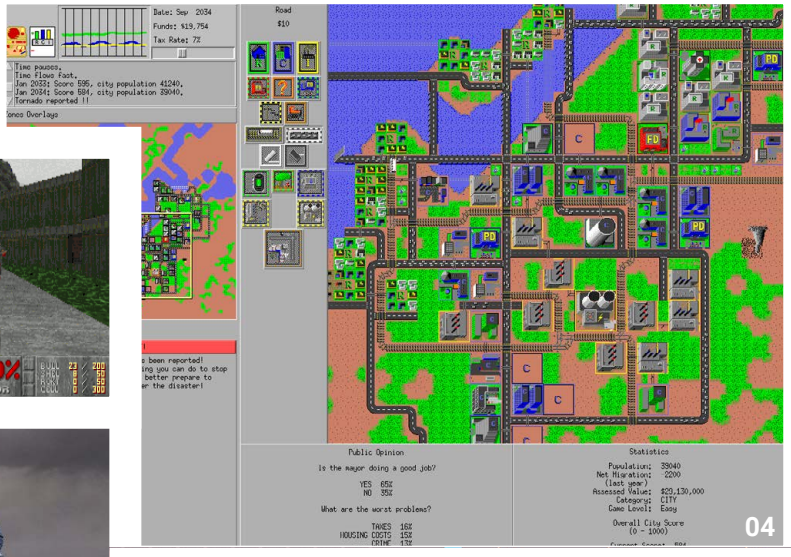
Block game revived

rpimag.co/mcpi

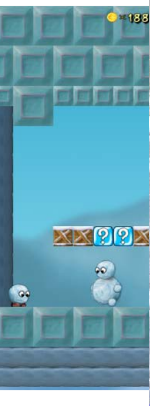
Free

Minecraft Pi is an official version of Minecraft for older versions of Raspberry Pi OS, and this project aims to mod and update it for modern hardware.


02


Public Opinion
Statistics
04


06
100%
0%

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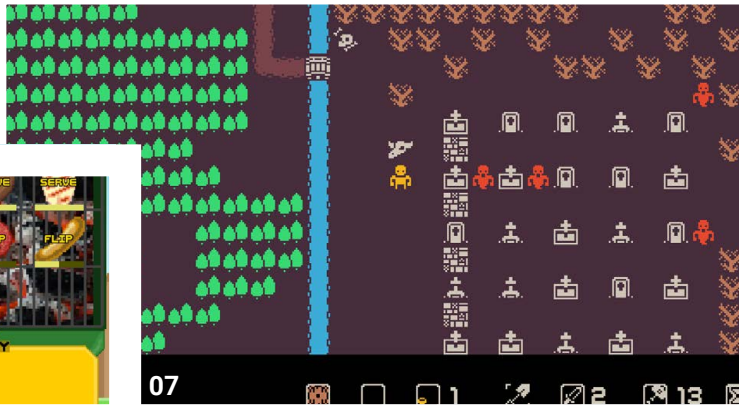
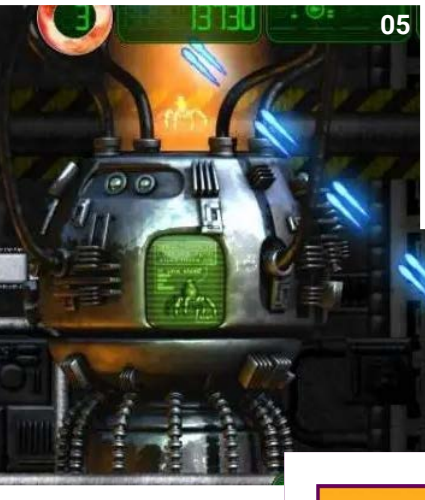
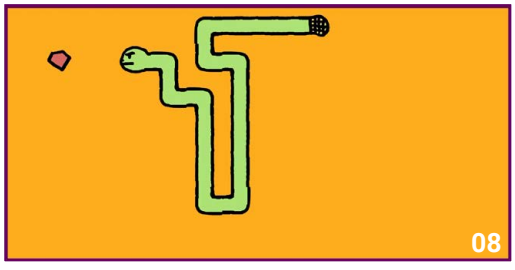

07


09
FLIP
SERVE
Thanks!
INVENTORY


05


MINECRAFT
PI EDITION: REBORN
v0.1.1 alpha / Reborn v3.0.0
Python API!
Start Game
Join Game
Options
Quit
10


08

Andrew Lewis

Our unusual tools section has a not-so-unusual writer: research scientist and crafter, Andrew Lewis

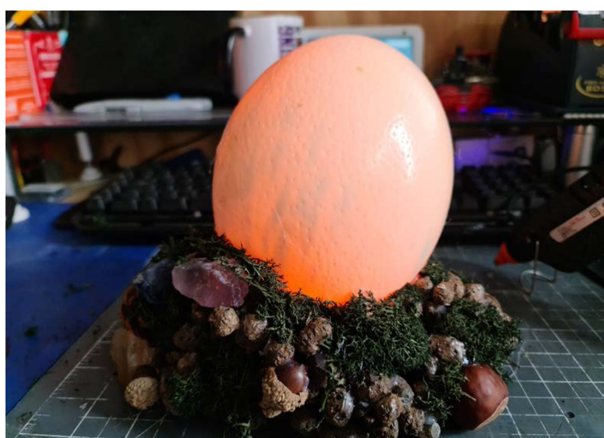
- **Name** Andrew Lewis
- **Occupation** Craft seller
- **Community role** Guide writer
- **URL** lewis-workshop.com

Long-time writer for *HackSpace Magazine*, and now a regular here in the pages of *Raspberry Pi Official Magazine*, Andrew Lewis has been programming and making for his whole life.

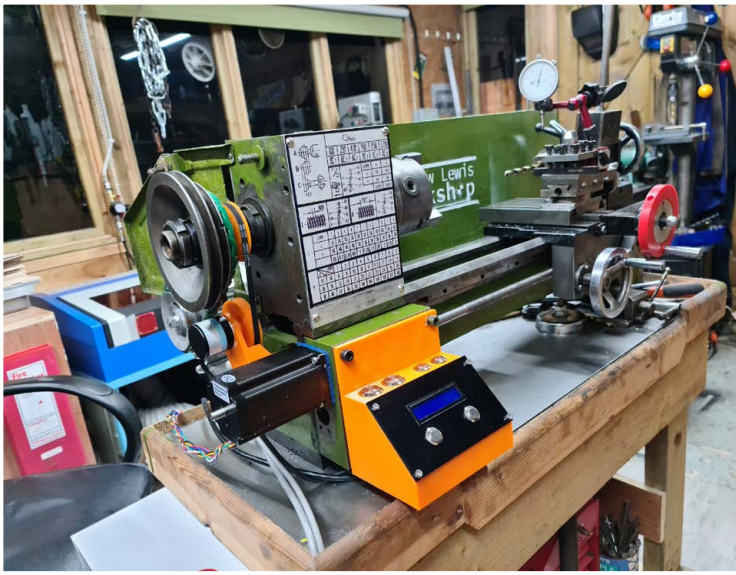
"I started programming computers when I was about four years old, on a ZX81 that my parents brought for my older brother," Andrew says. "I was always fascinated with how things worked, and by the age of nine or ten I had a healthy collection of Forrest Mims project books and a pile of things I'd taken apart for spares and never quite put back together. I was largely bored by the lack of practical computers or electronics during my school years, and I left at 18 intending to go straight into work. Through pure chance, I wandered into a university open day in the 1990s and got chatting to someone in the foyer of the building. I told them about some of the upgrades I'd done to my home computers, piggybacking memory modules and using a video camera to trigger MIDI events and make an invisible drum kit and an air harp, building my own light pen and document scanner… I was just excited to be talking to someone who understood what I was going on about. It turned out they were the head of the computer science course… by the end of the day, I was enrolled with full funding [and] skipped half of my first year."

When did you learn about Raspberry Pi?

I first heard of the Raspberry Pi in early 2012, while I was working on my PhD. We could see the advantages of the board right away, and we were chomping at the bit to get our hands on some, but had to wait



A glowing dragon egg, made with various cool and organic materials



◀ These special reading glasses read out what the reader is looking at

▼ The gearbox for this lathe is powered by a Pico

I sometimes feel a need to ignore my reservations and make a whimsical project

about six months before we finally got around to playing with them. We spent quite a while experimenting with them for heritage applications, but I'd finished my PhD before we managed to implement any of the coolest ideas we had for using them.

What have you made with Raspberry Pi?

Where do I even start? I made a few projects for my dad, who's had problems with his eyesight and can't really see well enough to read. I built him a pair of 'reading glasses' that use glasses with a camera built in to scan text, transform it, run it through OCR, and speak the text into earphones when you press a button on the controller box. I also made him a digital calliper that speaks the measurements out loud using a Raspberry Pi and an amplifier in a box. I made a Pico-based word game for my daughter that uses RFID picture and letter cards to spell words on a game board, and a 'fairy lantern' for her bedroom that uses a Pico to project a Pepper's ghost illusion inside the lantern. I replaced the internals of my old Atari ST with a Raspberry Pi, and even built a full-sized arcade machine. I made a night-vision baby-cam, a chicken camera, a 3D scanner, controllers for my 3D printers, plant monitors, my daughter's computer, an electric gearbox for my lathe, and so many other things.

What's your favourite thing you've made for the magazine?

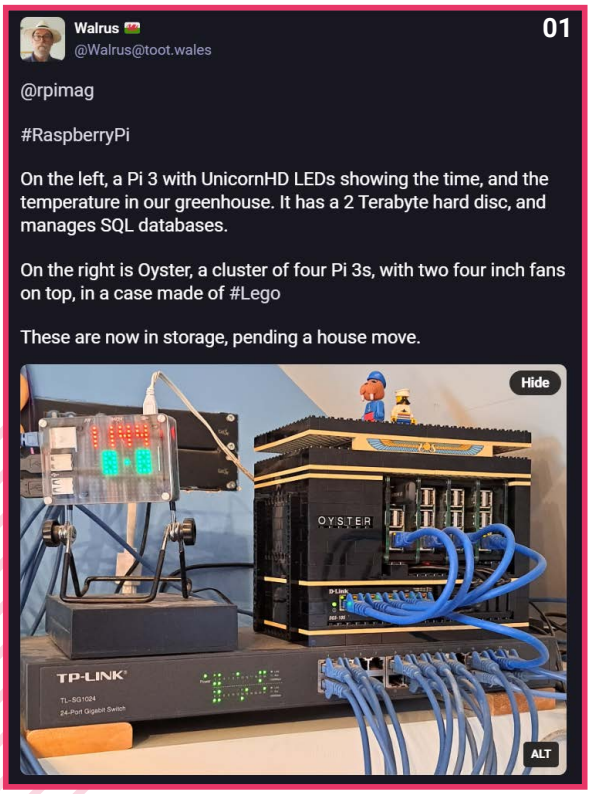
Although I'm a very practical person when it comes to making, I sometimes feel a need to ignore my normal reservations and make a whimsical project. Having children is great for this, because I can do cool but impractical projects under the guise of it being 'for the kids'. I think my favourite project is probably the dragon's egg night-light I made for my daughter. It's a simple project that uses a flickering 'fire effect' bulb matrix, some batteries, and a few odd things like an ostrich egg, semi-precious stones, lichen, and agricultural clay beads. It's simple, largely purposeless, and makes my daughter happy.

Maker Monday

Amazing projects direct from social media!

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

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



01. We love the design of this LEGO case, and the functionality of the build is off the charts too

02. For those not in the know, the original GBA did not have a backlight without mods

03. Ah, a very cool way to make sure your lawn is healthy

04. This is a cool project, but we insist you do read this magazine!

05. Akkie here with a custom Pico display stand

06. More robots at events from Dr Footleg

07. Mind-your-head sensor is finished, saving noggins and hats everywhere

08. A fun little data project, visualising info with LEDs

09. Pico can be used for HID, so building your own custom keyboard is possible

10. Wonder if this will work with a Pico Jumbo?

11. We're gonna need a bigger LEGO set

Ulli Sundermann 03
@ullisun58

I've been working on my green detection SW for my lawn mower #rpiLawnMow the fields in the image are represented as binary numbers and occur only once this makes it easy to map the query and decision logic in Python source Code you will find here github.com/ullisun/RopiLa... soon

Nick Bild 04
@NickBild79

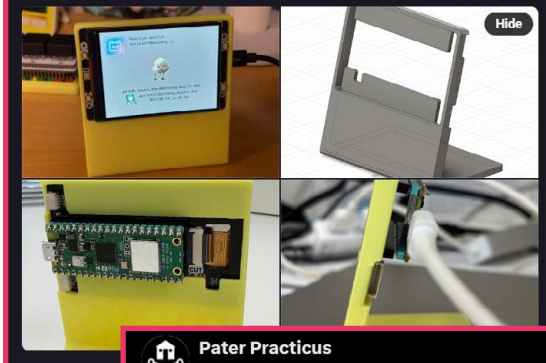
I thought you'd never ask. I taught a @Raspberry_Pi Zero 2 W to read so that I don't have to:

あっきぃ / C106(日)東7S-33b 05
@akkiesoft@social.mikutter.hachune.net

@rpimag Hello!
I made a stand for Pimoroni Pico Display Pack 2.8".

I also used this display to create a notification monitor for Misskey (SNS software that communicates using the same Activity Pub protocol as Mastodon).
I'm connecting to Misskey using a websocket to receive real-time notifications and display custom emojis called reactions!

3D data: thingiverse.com/thing:7067419
Code: github.com/Akkiesoft/misskey_r...
Video: youtu.be/260o7uGFQwg

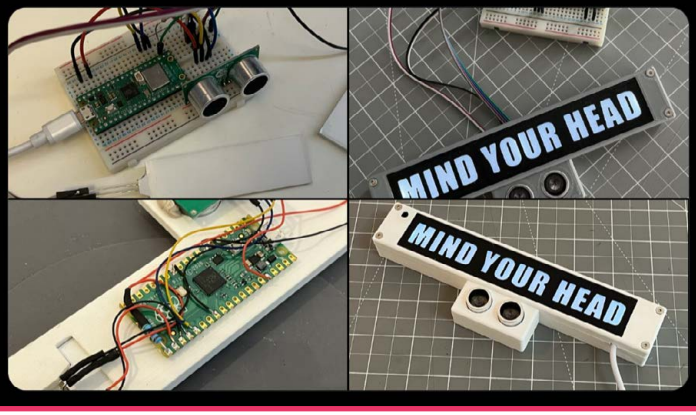


Dr Footleg (he/him) 06
@drfootleg@fosstodon.org

@rpimag Spent a very busy and rewarding Saturday letting kids drive robots and see a 3D printer running at #LivMF25
Also the Circuit Python Lightsabre, Neotrellis battleships and Game of Life animations on different displays. Well worth the 5 hours of driving each way to support this excellent event. #MakerMonday

Pater Practicus 07
@PaterPracticus

My ultrasonically triggered 'mind your head' warning sign is now finished, as is Part 2 of my 'how-to' video with details of the 3D printed screen and case with space for all the gubbins inside: youtu.be/WYHUWdoq3kw #MakerMonday



Simon Prickett | simonprickett.dev
@simon_prickett

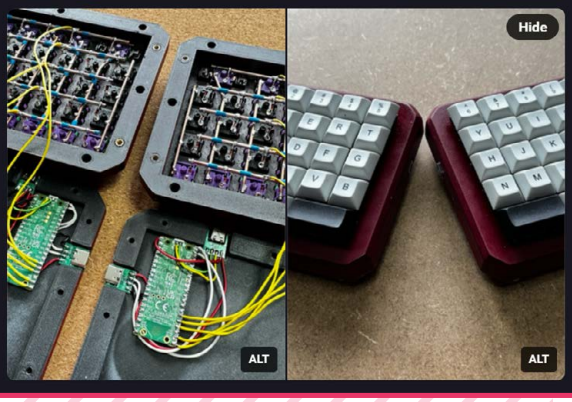
08

Showing Cheerlights history via Grafana alerts over mqtt with MicroPython and a Pimoroni stellar unicorn.

Andy Warburton
@andy_warb@mastodon.social

09

@rpimag recently finished working on a spit mechanical keyboard with a Pico in each side. I'm just about to start assembling a 30% staggered split version that has the Pico's on display on top of the keyboard!



briancorteil › #MakerMonday 5d

10

Finally finished the hardware of my giant Unicorn hat, and showed it off at Liverpool MakeFest, made from 64 original @pimoroni Unicorn hats. The spacers are M40 and 100mm long :-)

Kevin McAleer Robot Maker
@kevsmac

11

Happy #MakerMonday, This weekend I added an RP2040-based Tiny FX W board (from @pimoroni) to a Lego Jaws set.

This brings sound, lighting and sensing to any lego set.

Write up here:

Crowdfund this

Great crowdfunding projects this month

Ubo Pod

A hackable personal AI assistant powered by Raspberry Pi, this classy-looking box is designed to help you with development and also with stuff around the house. It supports a whole range of AI services and can even act as a universal remote. Very smart.

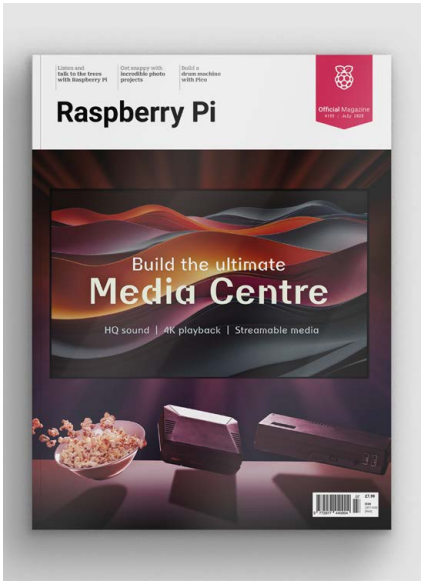
▶ **rpimag.co/ubopod**

ALPON X5 AI

A new edge computing box with Wi-Fi and 4G LTE designed for industry, it has onboard AI acceleration of about 25 TOPS. It includes a fanless design and low-power operation and is designed to help people put real-world AI projects out in the field, straight out of the box.

▶ **rpimag.co/alponx5**

Your Letters



▶ It's OK: the missing magazines have now been found!

Missing magazines

Where's my magazine got to? It would normally be with me [in the USA] a week or so after it's available to download, but it's still not here. Are you sending it by sailing ship, to reduce your carbon emissions or something?

Aaron via email

We'd love to claim some environmental credits by shipping magazines around the world on 18th century tea clippers, but the sad truth is that for a time, a pallet of magazines was... mislaid. Not stolen, or damaged, just mislaid, languishing in a warehouse somewhere by accident. We know this because, fortunately, the magazines have since been found and, by the time we've finished spell-checking this reply, they'll be with our readers in the USA and Canada. To everyone affected, thank you for your patience; it turns out that logistics is hard.

Photography in focus

Your look at photographic projects really rekindled some of the enthusiasm I felt when I first got my hands on a Raspberry Pi Camera Module. It was the first one, so the images I got from it were nowhere near as good as you'd get with one from today, and I absolutely loved it. I did a time-lapse of the sunrise outside my house, and then when I got confident with the code, I changed the parameters and did a time-lapse of my garden growing. Simple stuff, but fun. And now I've got an excuse to spend some money on a better Camera Module and do it all over again. Cheers!

William via email

If you liked last issue's feature, you're going to love *The Official Raspberry Pi Camera Guide 2nd Edition* – it's available now (**rpimag.co/cameraguide**) and it's packed full of project ideas for the photographer in need of something to do. We're extremely proud of it – we've even set up one for a friend so she can keep an eye on her hamster while she's at work. Of course, hamsters sleep in the day, so she hardly ever sees anything, but it was fun to do.

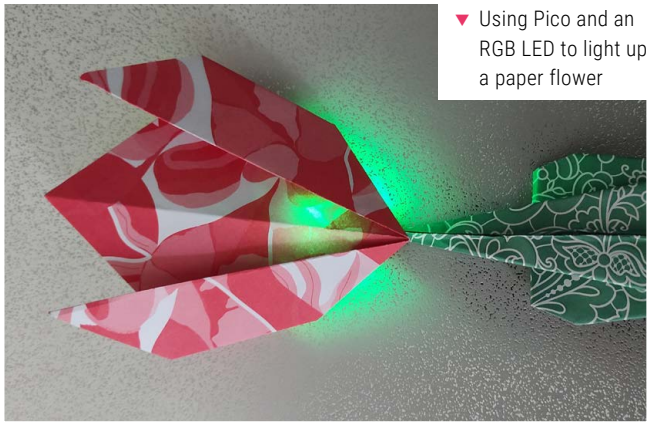
▶ What will you do with your Raspberry Pi Camera Module?

Folding circuits

I'm loving the mix of traditional craft skills and Raspberry Pi in the new magazine. Last issue's origami and Raspberry Pi Pico was excellent, as I don't have the time or inclination to build a complicated robot only to let it down with my mediocre coding skills.

Josh via email

The beauty of origami is that it's affordable – paper is cheap, as long as you're not buying tons of it and leaving it lying around in a warehouse, so you can mess up as many times as you like, each time getting better and better at an ancient skill. Top it off with an RGB LED cycling through a range of colours and you've got something that combines old and new, high-tech with low-tech, traditional and modern.



▼ Using Pico and an RGB LED to light up a paper flower

Contact us!

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

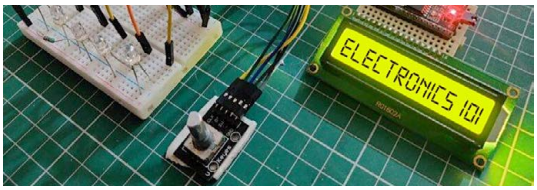
Community Events Calendar

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

01. Melbourne Raspberry Pi Makers Group Meeting

Sunday 3 August
Docklands Makerspace and Library, Melbourne, Australia
rpimag.co/mrpmgm156

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



02. Electronics 101

Saturday 9 August
Bellingham Makerspace, Bellingham, WA, USA
rpimag.co/elec101156

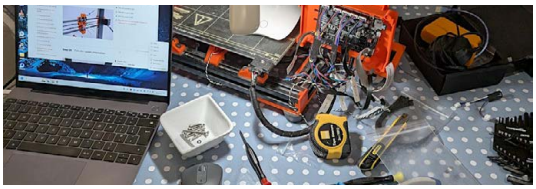
This 1½ hour class will provide the basic building blocks for understanding electronics. After this class, you will have the confidence to add circuitry to your maker project. It will also aid you in browsing the internet for more knowledge, and/or aid you in understanding the next higher level leading to a hobby or career. Main subjects are: basic electricity, electromagnetism, electronic components, and circuit design up to and including basic computer circuitry.

03. Riverside Raspberry Pi Meetup

Monday 11 August
3600 Lime St, Riverside, CA, USA
rpimag.co/rrpm156

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

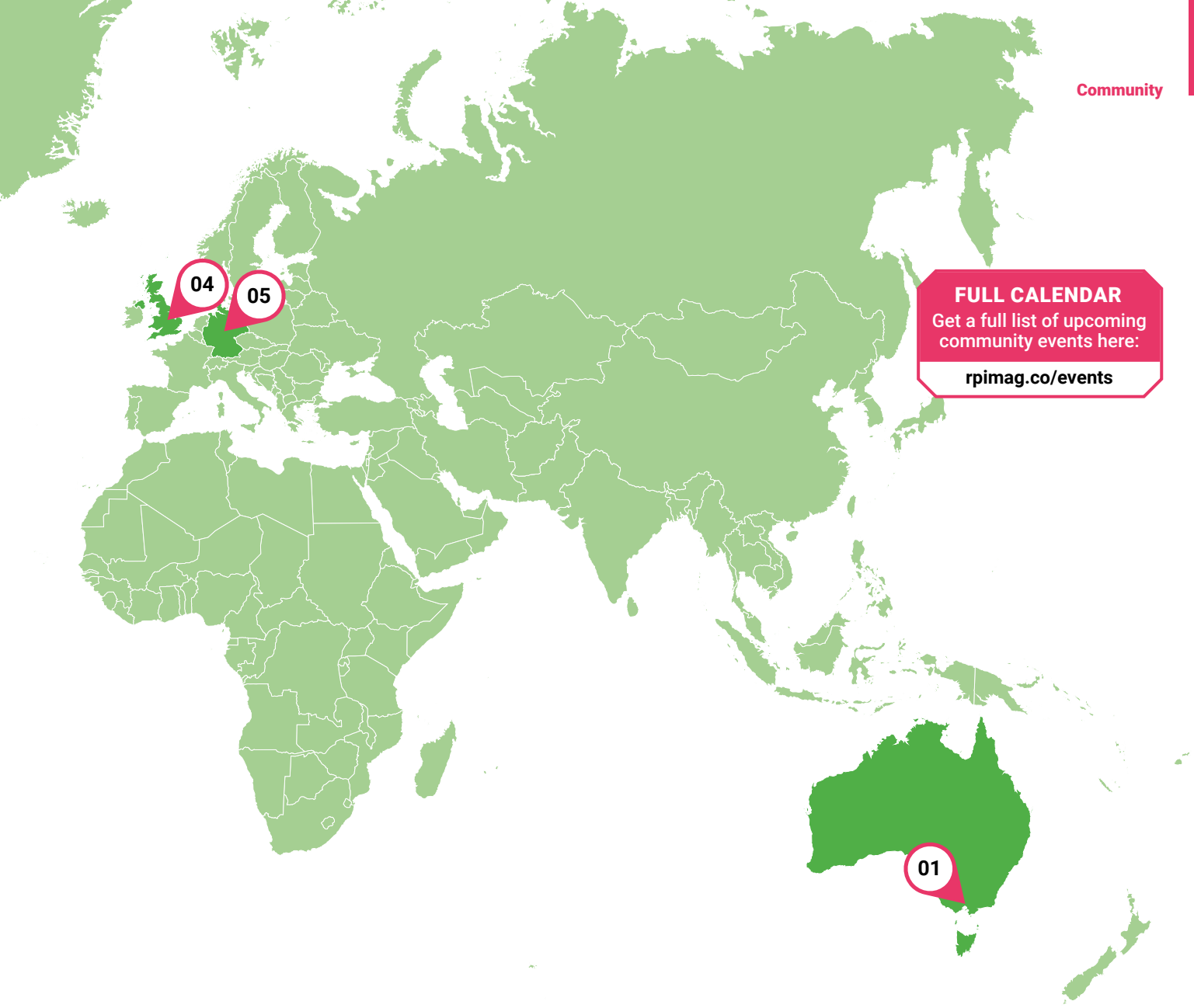
While the group is focused on Raspberry Pi specifically, they also cover topics about all kinds of maker technology, as well as having discussions about various programming languages and about electronics in general.



04. Make and Hack: Medway Makers Meetup

Sunday 17 August
Medway Makers, Gravesend, UK
rpimag.co/medway156

Are you passionate about technology, crafting, and innovation? Do you get a thrill from the whir of servos, the glow of LEDs, and the satisfaction of code running flawlessly? Then Medway has just the thing for you! Medway Makers are thrilled to announce their next meetup, and you're cordially invited to join a community of like-minded enthusiasts who share your passion for creating and exploring the limitless possibilities of technology!



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

05. Maker Faire Hannover

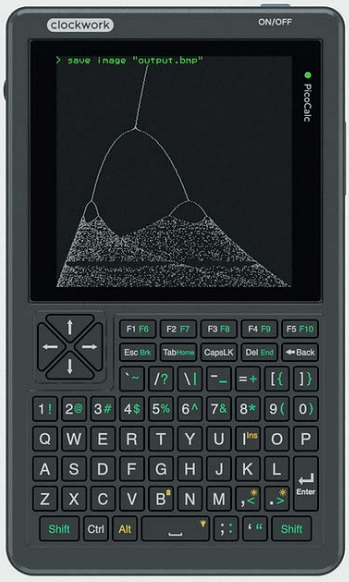
Official Raspberry Pi Event

- **Saturday 23 August and Sunday 24 August**
- **Hannover, Germany**
- **rpimag.co/mfh2025**

The team at Raspberry Pi are proud to partner with Raspberry Pi Approved Reseller BerryBase to be at Maker Faire Hannover for a third year in a row. Come and meet members of the Raspberry Pi team, learn about latest products, and share what you've made with Raspberry Pi technology.

Win 1 of 5 PicoCalc Kits

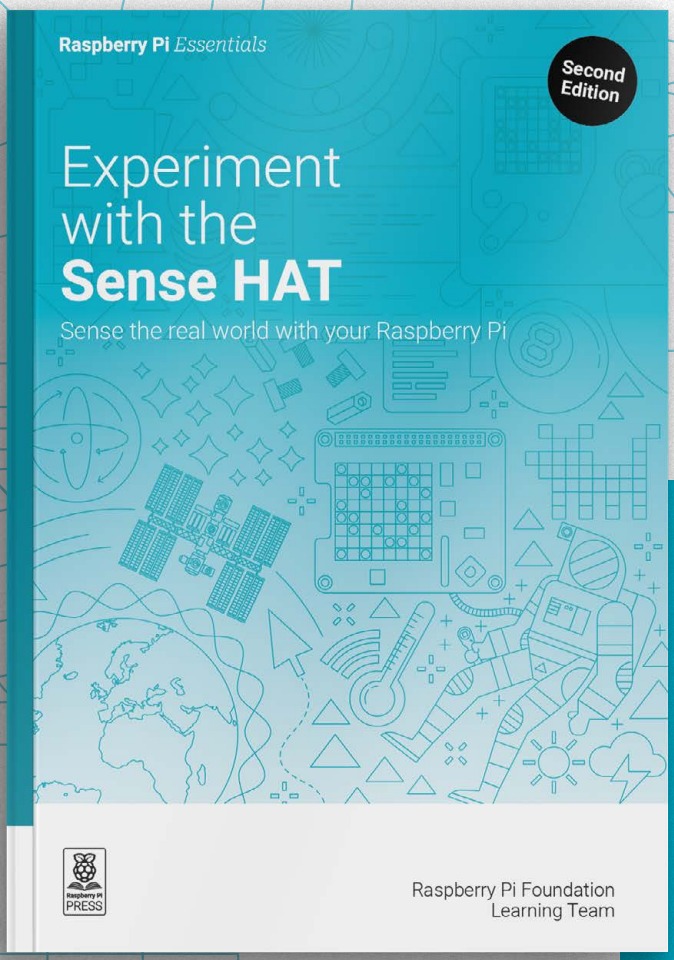
Based around Raspberry Pi Pico, ClockWork Pi's handheld looks like a retro scientific calculator, but inside is a ClockworkPi v2.0 mainboard. This offers you an efficient and cost-effective microcontroller unit development solution.



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

Terms & Conditions

Competition opens on **30 July 2025** and closes on **28 August 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.



The Sense HAT is an incredibly versatile and flexible bit of kit with plenty of obvious uses, along with a huge number of less obvious ones, that you'll love to make and share. Updated for the latest Raspberry Pi devices and hardware, this book has everything you need to get started.

- ***Getting started with Sense HAT***
- ***Learn by building:***
  - *A digital twist on the Magic 8 Ball*
  - *Your own interactive pixel pet*
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BUY ONLINE: **rpimag.co/sensehatbook**

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Official Magazine
#157

CIRCUIT TRAINING

GET GOING WITH CIRCUITS AND ELECTRONICS

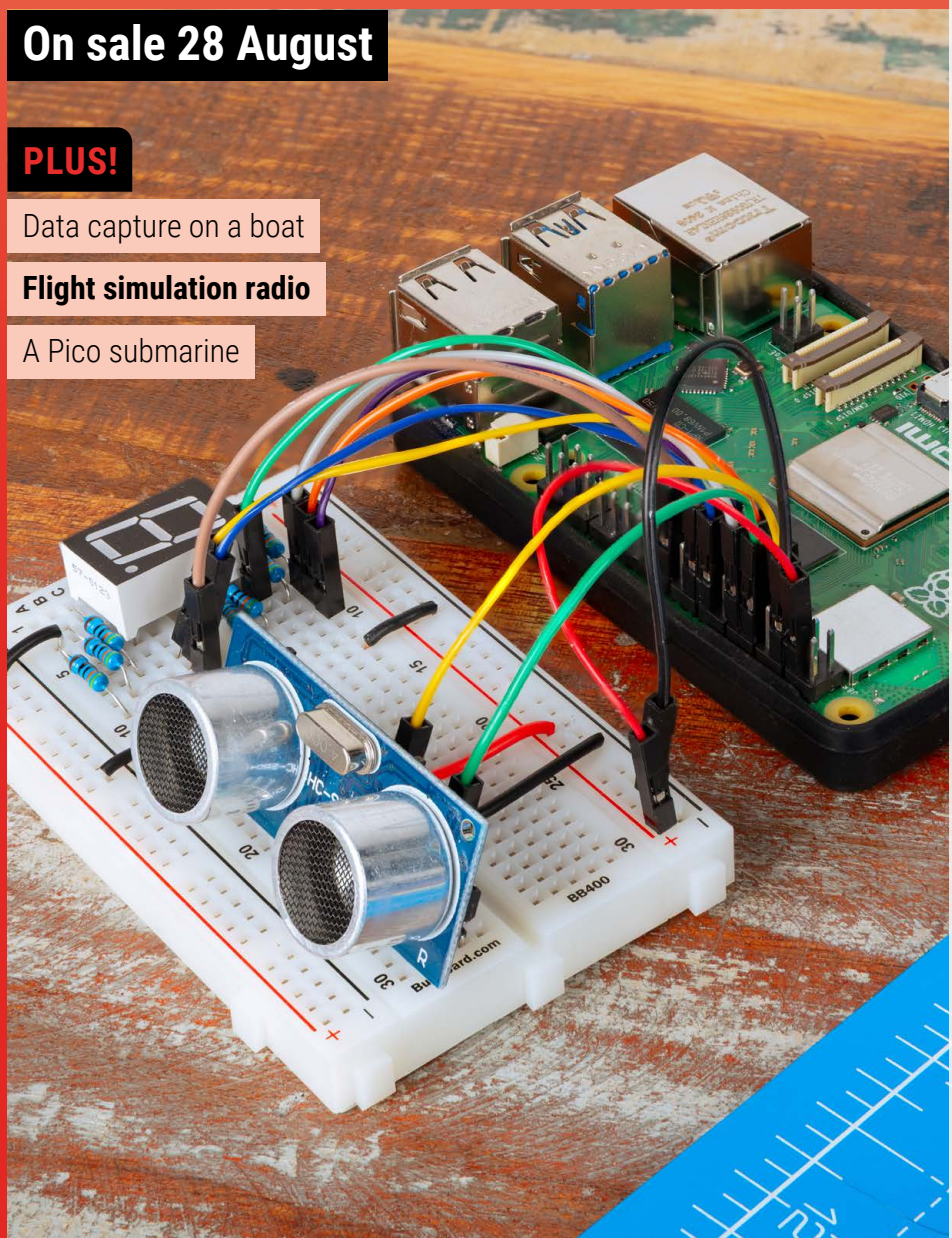
On sale 28 August

PLUS!

Data capture on a boat

Flight simulation radio

A Pico submarine



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Raspberry Pi Desktop

The evolution of the desktop.

By **Lucy Hattersley**

My first Raspberry Pi was a Model B from 2012. I spent the first few months looking at it, a little lost and confused. It seemed equally bemused.

You can still buy a Raspberry Pi 1 Model B+ today (**rpimag.co/pi1**). This was the final revision of the original board, with a few extra USB ports and the 40-pin GPIO connection we have loved ever since.

Right from the start, the question was "what do I do with this incredible thing?" The answer hasn't always been easy. At the same time as I got that first Raspberry Pi, I was doing MITx courses in computer science and computational thinking.

So, in the first instance, my Raspberry Pi was a coding machine. A safe development platform that I could use to run code, hack together scripts, and break things without damaging my 'grown-up' computer, which I needed for work.

Then Raspberry Pi 2 came along. This had a 900MHz quad-core and 1GB RAM, which made running a GUI a more realistic prospect. I mostly used it to build robots.

It wasn't really until Raspberry Pi 3 Model B+ came along with its 1.4GHz CPU that I seriously fired up a word processor in Raspbian (as Raspberry Pi OS was known at the time) and thought: "I can work with this thing!"

> *To put the power of computing and digital making into the hands of people all over the world*

In May 2020, when Raspberry Pi 4 came along with 8GB RAM, a 1.5GHz ARM CPU (now 1.8GHz), and dual 4K monitor support, everything got real.

The MagPi issue 93 (**rpimag.co/93**) featured a 'How to Work from Home' article. It covered LibreOffice, video chat, email, and app work. This month, we're looking at the evolution of everything we've seen from then till now. Raspberry Pi 5 and Raspberry Pi 500 are full desktop computers, capable of performing the same tasks as a traditional Windows or Apple-based machine, but with a lighter, faster, and more energy-efficient hardware space. Thin computing seriously threatens the desktop market in the corporate space.

I know lots of reasons why you should use a Raspberry Pi over an old-fashioned desktop computer. Mostly they boil down to "Linux is better than Windows. Natch!"

Perhaps a more compelling reason lies at the heart of the Raspberry Pi project. The mission: "To put the power of computing and digital making into the hands of people all over the world." It's easy to forget that the mission also includes your own hands.

We democratise computing. By that, I mean we make computing and digital making available to anybody regardless of income, location, social background, or education level. We – and I'm using the royal we here – design and sell affordable, high-performance single-board computers and accessories that are superbly engineered (not by me, I hasten to add).

I have on my desk an Argon ONE UP laptop computer. Inside is a Compute Module 5. I'm looking at my traditional laptop and thinking: "What is the point of you? What are you for?" You were the future once.

Lucy Hattersley – Features Editor
Lucy is working in the British Library to the sound of microfiche machines clacking. Sometimes old is best.

rpimag.co

HiPi.io

HIGHPI PRO

The new case from the HiPi.io team

- Rapid tool-free assembly and disassembly
- Large internal volume for HATs
- Compatible with Pi 2/3/4
- Multiple lid options
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Available at these great Pi stores:

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Contact your favorite Pi store if it's not listed here

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Manage your servers or PCs remotely!

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PiKVM V4 Plus

The most feature-rich edition

- More connectivity
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A cost-effective solution for data-centers, IT departments or remote machines!

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HiPi.io

No reseller in your country?
Check shop.hipi.io (import fees might apply).

List of official resellers by country: