Priority Boarding

GET YOUR **RASPBERRY PI 500** *FIRST!*

The MagPi + HackSpace

Issue 149 | January 2025 | magpi.cc

Raspberry Pi PRESS

£7.99

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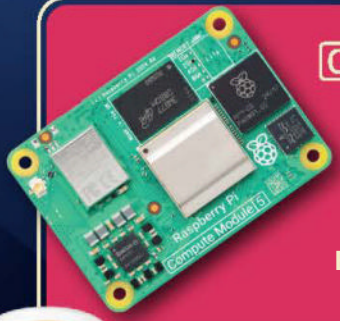
Introducing

Raspberry Pi 500 + Monitor

New!
Pico 2 W



Compute Module 5

Tech specs & info

—

Industry case studies

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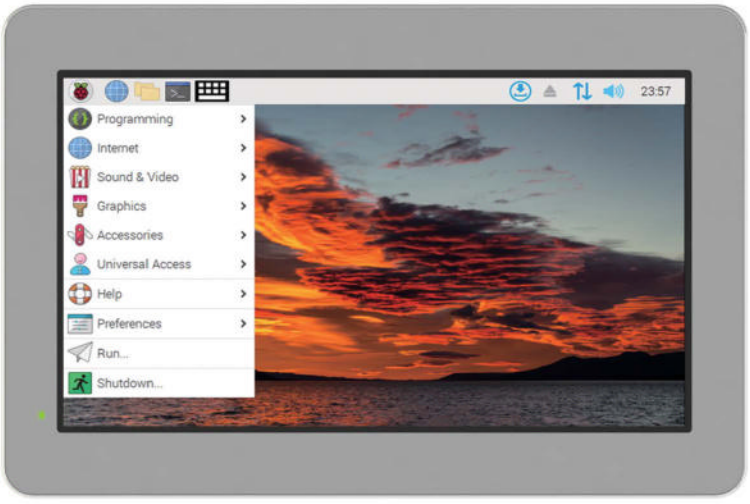
Engineering interviews

COMPLETE Raspberry Pi STARTER GUIDE

MIDI FOOT PEDAL • FREECAD 1.0 • TOUCH DISPLAY 2 TUTORIAL

Industrial Raspberry Pi
ComfilePi



UL LISTED

Powered by Raspberry Pi

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

Use the rear-panel 40-pin GPIO header to expand its features and capabilities with additional I/O boards. The ComfilePi is UL Listed and employs Raspberry Pi Compute Module.

Visit www.comfiletech.com

COMFILE TECHNOLOGY

WELCOME
to The MagPi 149

One of the joys of editing *The MagPi* is seeing behind the curtain and watching all the amazing products come to life.

I've had a Raspberry Pi 500 for a while now, and it's been a joy to watch it get launched to market. Raspberry Pi 500 takes all the power of Raspberry Pi 5 and turns it into a keyboard-style computer of the type most of us grew up with. Meanwhile, the brand new official Raspberry Pi Monitor is a companion screen that turns Raspberry Pi into a full desktop computer kit.

In some ways, the bigger news is Compute Module 5, which is also out this month. This completely different product takes Raspberry Pi 5's form factor and puts it into a stripped-back modular format that is perfect for industrial applications. Andrew's interview with Dominic Plunkett, the senior principal Raspberry Pi hardware engineer, offers some keen insights into how this modular product gets to work.

Whether you're in the enthusiast or the engineering camp (or like us, a bit of both), there's a lot that is inspiring this month. Welcome to the new year!

Lucy Hattersley Editor

EDITOR

Lucy Hattersley

Lucy is going to use a Raspberry Pi 500 and Monitor to hack the Compute Module 5 with a Breakout Board. You can't have too much Raspberry Pi, right?

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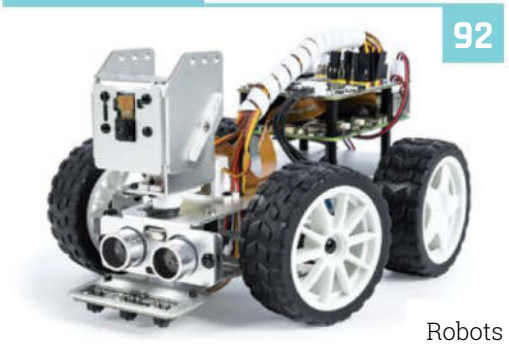
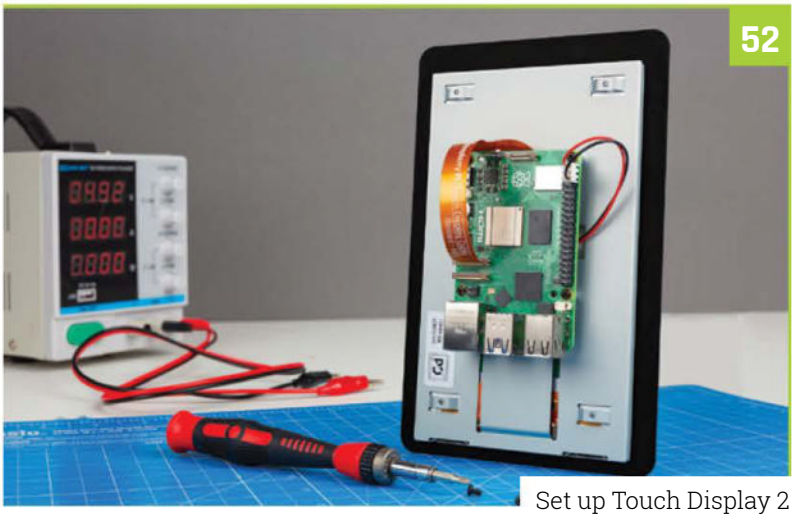


Robots



Set up Touch Display 2

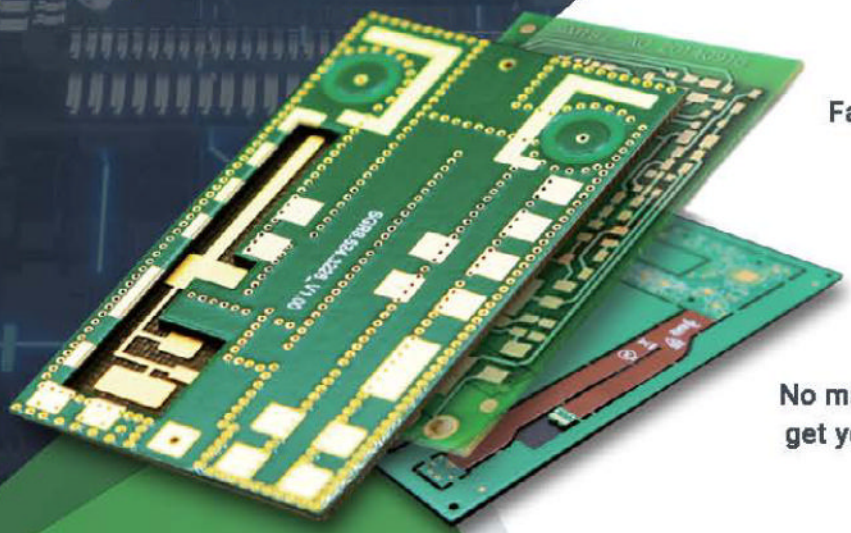
The Pet Piano

Needful things – telescopic gauge

EMPOWERING AI INNOVATION, ONE PCB AT A TIME

PCBWay

In the rapidly advancing world of AI, precision and reliability are essential. PCBWay provides high-quality PCB prototyping, assembly, CNC machining, and 3D printing services to bring your AI-driven projects to life. From robotics to smart devices, we offer a complete solution to power your next AI breakthrough.



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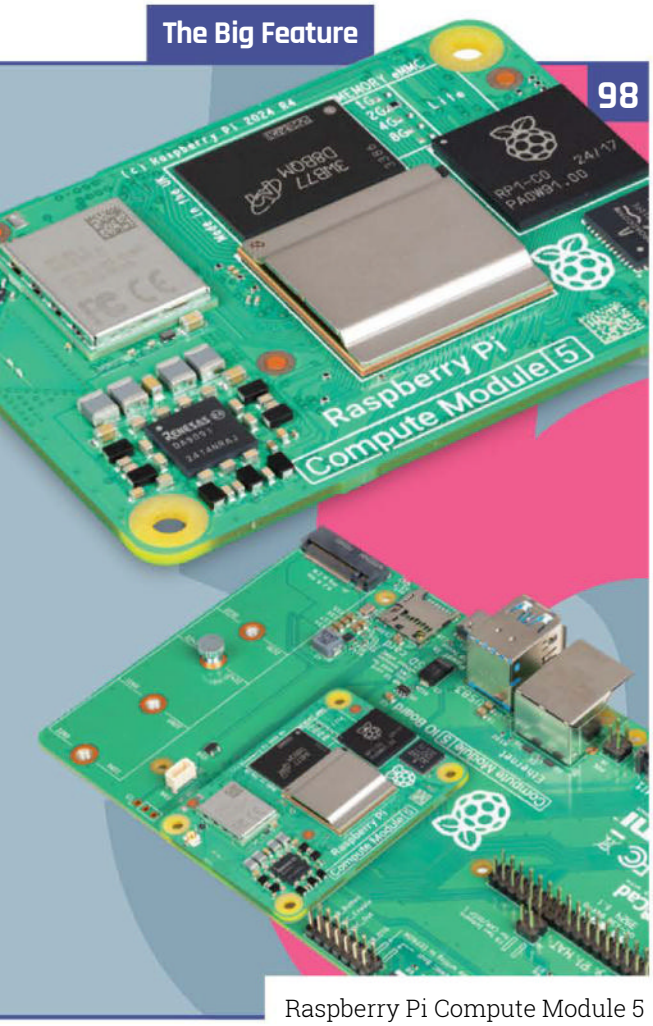
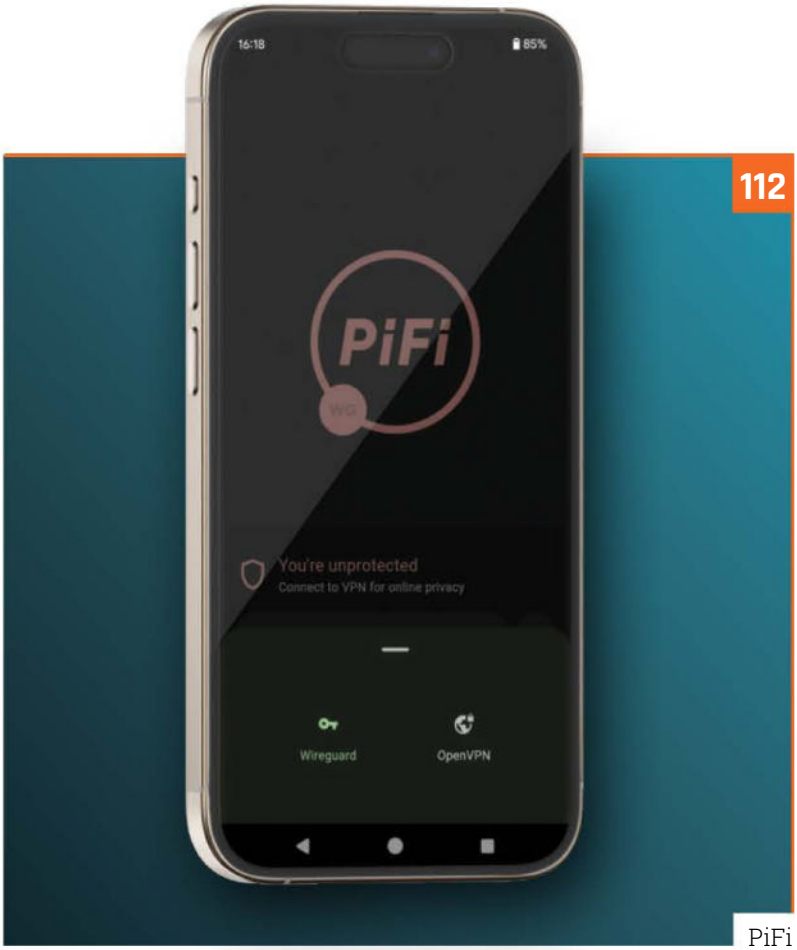
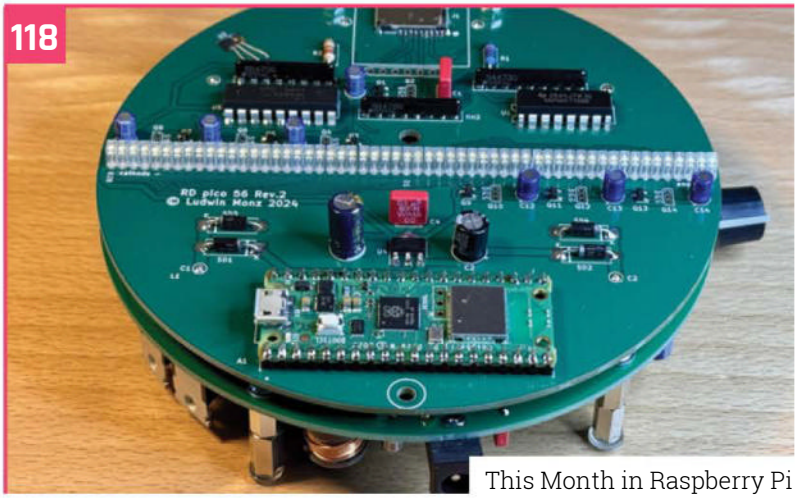
The Big Feature



Raspberry Pi Compute Module 5



PiFi



This Month in Raspberry Pi

Reviews

Community

WIN 1 OF 5 RASPBERRY PI **MONITOR**

All the best combined in one connector

The new SPC 4 series PCB connectors

The everyday challenges our customers face are what drive us to continuously improve our products. The new SPC 4 series PCB connectors are the best proof that passionate engineering is indeed an art

For additional information, visit **https://phoe.co/uk-spc4**

PHOENIX CONTACT

Raspberry Pi 500 PRIORITY BOARDING

We've reserved Raspberry Pi 500 computers ***for The MagPi subscribers***

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How it works!

If you have a print subscription to *The MagPi* (**magpi.cc/subscribe**) we will have your email on file. We'll send each of our subscribers a unique code in mid-December 2024. Click the link in the email. It will take you to a site where you can order and pay for your Raspberry Pi 500.

Customers in the US and Canada will be directed to PiShop to purchase a US keyboard computer; while customers in the UK, Europe and the rest of the world will be redirected to The Pi Hut where both US and UK keyboard computers are available.

Get started

New subscribers to *The MagPi* will get a Priority Boarding code when they sign up. So don't delay. Take out a subscription today (**magpi.cc/subscribe**).

You'll be able to buy your Raspberry Pi 500 first and get incredible Raspberry Pi tutorials, projects, and product reviews each month.

Click here for more information:

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Raspberry Pi 500 and Raspberry Pi Monitor

In December 2025, Raspberry Pi introduces its complete desktop solution.

By **Lucy Hattersley, Helen Lynn,** and **Eben Upton**

Raspberry Pi has introduced its latest desktop computer setup: Raspberry Pi 500 and Raspberry Pi Monitor.

Raspberry Pi 500 is easy to understand although packed with hidden details. It takes the power of Raspberry Pi 5 and places it into a high-quality keyboard. Featuring a quad-core 64-bit processor, wireless networking, dual display output, and 4K video playback, it's described by Raspberry Pi CEO Eben Upton as "a capable desktop PC that's ideal for home computing." It is available as a standalone device for $90 or as part of a Desktop Kit (including a mouse, power supply, micro HDMI to HDMI cable, and Raspberry Pi SD card preloaded with Raspberry Pi OS).

Raspberry Pi 500 monitor?

Raspberry Pi Monitor is a thoughtful hardware addition to the Raspberry Pi stable. It's been in development for a while and has made a couple of covert appearances at Raspberry Pi booths at trade shows, but its release just in time for Christmas 2024 remains delightful.

It's "designed to coordinate perfectly with your Raspberry Pi 500 (or cased Raspberry Pi 5)," explains Eben. Raspberry Pi Monitor incorporates a 15.6″ full HD panel with 1920×1080 screen resolution and a pair of 1.2W speakers in a slender enclosure with a fold-away integrated stand. It's all yours for the remarkably low price of $100.

Paired with Raspberry Pi 500 or Raspberry Pi 5, it will work well as a standalone desktop computing setup. Any performance difference between Raspberry Pi and mainstream computers has vanished. It will also sit beside another computer as a development sidekick and we think it's the ideal platform for honing your coding and engineering skills.

> "To build a complete system, you need a display device"

Raspberry Pi Monitor is available now in red and white, but if you'd prefer to wait for a black version, those will be available in early 2025.

The vision thing

"To build a complete system, you need a display device," says Eben. "Which is why we're also launching the Raspberry Pi Monitor."

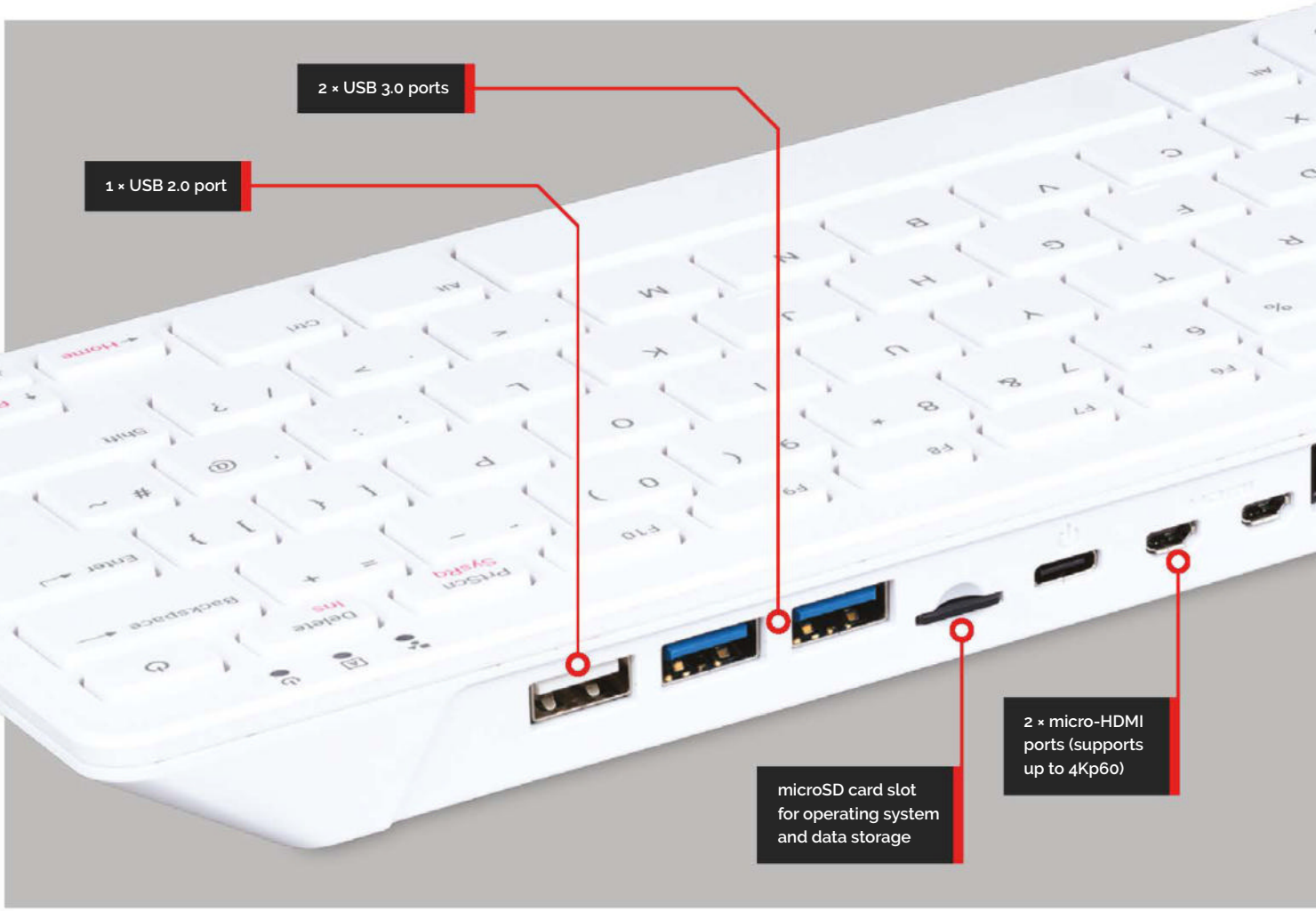
Power to Raspberry Pi Monitor is provided via a USB-C connector. Cost-conscious users can power the monitor directly from their Raspberry Pi via the included USB-A to USB-C cable; in this mode, display brightness is limited to 60% of maximum (which is "still quite bright," Eben tells us) and the volume is set to 50% of maximum ("still quite loud!").

Using a dedicated USB-C supply capable of delivering 5V/3A, like the Raspberry Pi 15W USB-C Power Supply, enables the full brightness and volume ranges (see **magpi.cc/power**).

Raspberry Pi 400 price cut

While we're incredibly excited about Raspberry Pi 500, "we need to remember that cost remains a barrier to access for many people, young and old," says Eben. "So, we're also taking this opportunity to cut the price of Raspberry Pi 400 from $70 to $60, and the Raspberry Pi 400 kit from $100 to $80. We're also bundling a Raspberry Pi-branded SD card with Raspberry Pi 400."

Raspberry Pi Monitor and Raspberry Pi 500 combine to make an ideal desktop computing environment



Raspberry Pi 500

PRIORITY BOARDING

We've reserved US and UK Raspberry Pi 500 computers ***for The MagPi subscribers***

GET YOUR RASPBERRY PI 500 ***FIRST!***

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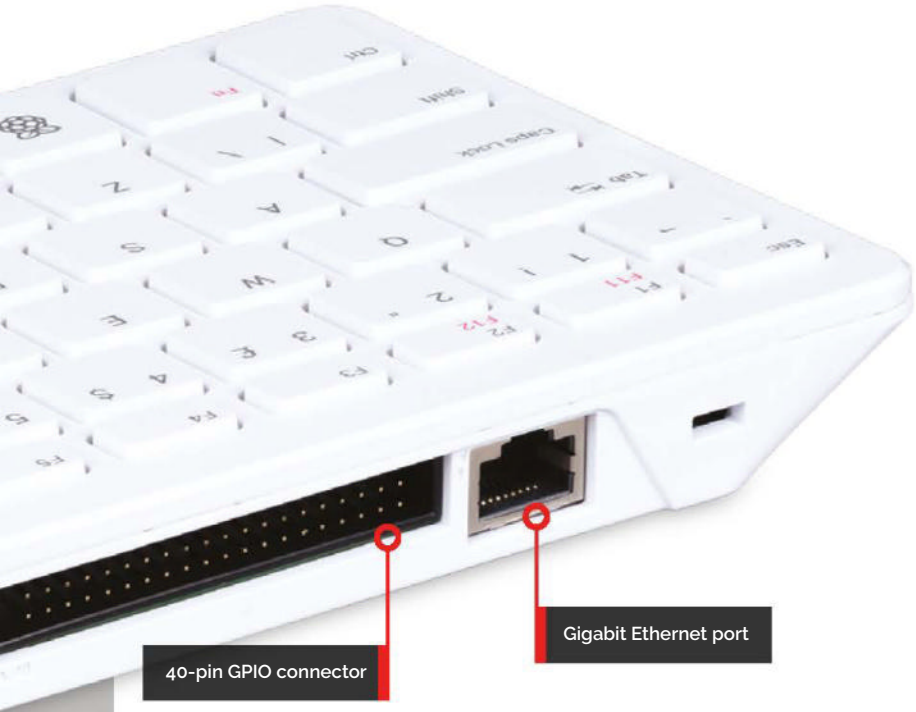

▲ Raspberry Pi 500 places the power of Raspberry Pi 5 with 8GB RAM into a high-quality keyboard computer

Raspberry Pi 500 summary

Featuring a quad-core 64-bit processor, wireless networking, dual display output, and 4K video playback, Raspberry Pi 500 puts the power of Raspberry Pi 5 into a high-quality compact keyboard. It's a capable desktop PC in a form factor that's ideal for home computing.

Raspberry Pi 500 is supplied with a 32GB Raspberry Pi SD Card preloaded with Raspberry Pi OS Bookworm, so users can get up and running quickly. It is available on its own, or as the Raspberry Pi 500 Desktop Kit.

In addition to a Raspberry Pi 500, the Desktop Kit contains a Raspberry Pi Mouse, 27W USB-C Power Supply, 2m micro-HDMI to HDMI cable, and *Raspberry Pi Beginner's Guide* to help users get the most out of their new computer.

Raspberry Pi 500 will be available in UK and US keyboard variants at launch. German, Spanish, French, Italian, Nordic will follow.

Specification:

- Quad-core 64-bit Arm Cortex-A76 processor
- 8GB LPDDR4X SDRAM
- 2 × micro HDMI ports (supports up to 4Kp60)
- 2 × USB 3.0 ports
- 1 × USB 2.0 port
- Gigabit Ethernet port
- microSD card slot for operating system and data storage
- Horizontal 40-pin GPIO header
- 802.11b/g/n/ac Wi-Fi
- Bluetooth 5.0
- 5V DC via USB-C connector
- Compact keyboard

Pricing:

- Raspberry Pi 500: $90 US
- Raspberry Pi 500 Desktop Kit: $120 US

Raspberry Pi Monitor displaying the Raspberry Pi OS interface

Raspberry Pi Monitor summary

Raspberry Pi Monitor is a 15.6-inch full HD computer display. User-friendly, versatile and compact, it is the perfect desktop display companion for both Raspberry Pi computers and other devices.

It features a 15.6-inch full HD 1080p IPS display, integrated angle-adjustable stand, built-in audio via two front-facing speakers, audio out via a 3.5 mm jack, full-size HDMI input, VESA and screw mounting options, and volume and brightness control buttons. It is supplied with a 1 m USB-C power cable.

Raspberry Pi Monitor is available in red and white, or in black. Red and white variants will be available at launch, with black variants available in early 2025.

Specification:

- Screen size: 15.6 inches, 16:9 ratio
- Panel type: IPS LCD with anti-glare coating
- Display resolution: 1920 × 1080
- Colour depth: 16.2M
- Brightness (typical): 250 cd/m²

Connectivity:

- Standard HDMI port (1.4 compliant)
- 3.5 mm stereo headphone jack
- USB-C (power in)

Audio:

- 2 × 1.2 W integrated speakers
- Support for 44.1 kHz, 48 kHz, and 96 kHz sample rates

Pricing:

- $100

▼ The rear of Raspberry Pi Monitor: handle, controls, and a VESA mount

> The perfect desktop display companion for both Raspberry Pi computers and other devices


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RASPBERRY PI HANDBOOK
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Olga Fortune Teller
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Emulate a BBC Micro
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THE OFFICIAL RASPBERRY PI HANDBOOK 2025
200 pages of brilliant builds

Raspberry Pi Pico 2 W

New Raspberry Pi Pico with wireless on sale now at $7. By **Eben Upton**

Our epic year of product launches continues with Raspberry Pi Pico 2 W (magpi.cc/pico2w), the wireless-enabled variant of this summer's Pico 2. Built around our new RP2350 microcontroller (**magpi.cc/rp2350**), featuring the tried and tested wireless modem from the original Pico W, and priced at just $7, it's the perfect centrepiece for your connected Internet of Things projects.

RP2350: the connoisseur's microcontroller, redux

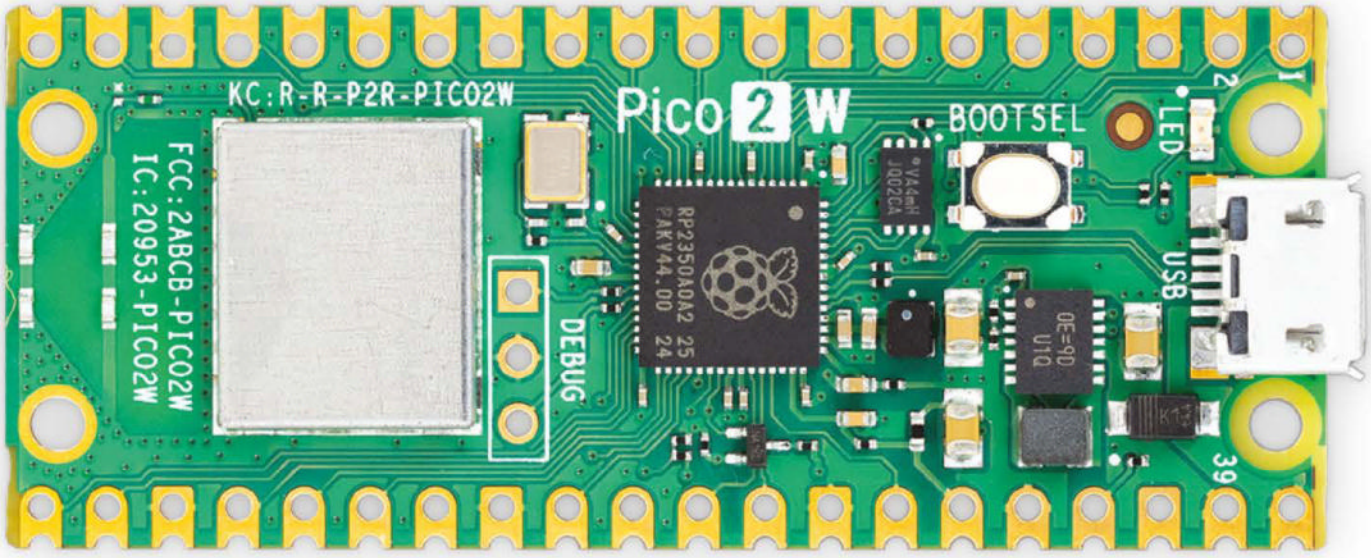
When we launched our debut microcontroller, RP2040 (**magpi.cc/rp2040**), way back in 2021, we couldn't have imagined the incredible range of products that would be built around it, or the uses that the community would put them to. Combining a symmetric pair of fast integer cores; a large, banked, on-chip memory; rich support for high-level languages; and our patented programmable I/O (PIO) subsystem, it quickly became the go-to device for enthusiasts and professional engineers seeking high-performance, deterministic interfacing at a low price point.

RP2350 builds on this legacy, offering faster cores, more memory, floating point support, on-chip OTP, optimised power consumption, and a rich security model built around Arm's TrustZone for Cortex-M. It debuted in August on Pico 2, on the DEF CON 32 badge (designed by our friends at Entropic Engineering, with firmware and a gonzo sidewalk badge presentation by the redoubtable Dmitry Grinberg, **magpi.cc/defcon32**), and on a wide variety of development boards and other products from our early-access partners.

Wireless things

Many of the projects and products that people build on top of our platforms — whether that's our Linux-capable Raspberry Pi computers, our

▼ The new board has the same compact Pico form factor



microcontroller boards, or our silicon products — answer to the general description 'Internet of Things'. They combine local compute, storage, and interfacing to the real world with connectivity back to the cloud.

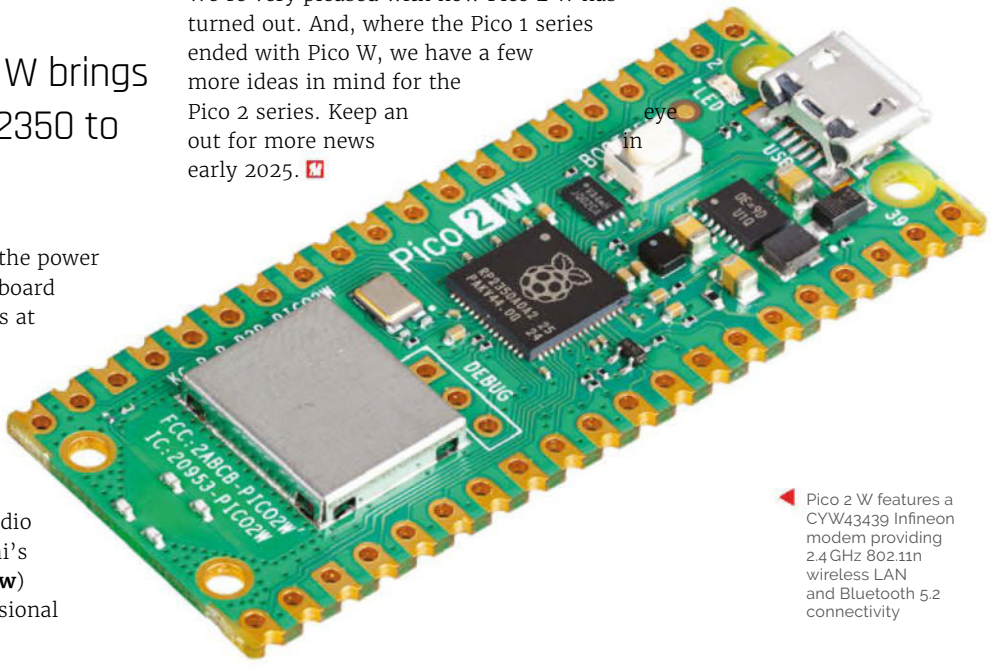
> Raspberry Pi Pico 2 W brings all the power of RP2350 to IoT projects

Raspberry Pi Pico 2 W brings all the power of RP2350 to IoT projects. The on-board CYW43439 modem from our friends at Infineon provides 2.4 GHz 802.11n wireless LAN and Bluetooth 5.2 connectivity, and is supported by C and MicroPython libraries. Enthusiasts benefit from the breadboard-friendly Pico form factor, while our upcoming RM2 radio module (already in use on Pimoroni's Pico Plus 2 W, **magpi.cc/picoplus2w**) provides a route to scale for professional products which have been prototyped on the platform.

More to come

We're very pleased with how Pico 2 W has turned out. And, where the Pico 1 series ended with Pico W, we have a few more ideas in mind for the Pico 2 series. Keep an eye out for more news in early 2025.

▲ The same form factor enables you to drop in Pico 2 W into your Pico projects and the wireless functionality is supported by C and MicroPython libraries



◀ Pico 2 W features a CYW43439 Infineon modem providing 2.4 GHz 802.11n wireless LAN and Bluetooth 5.2 connectivity

Raspberry Pi USB 3 Hub on sale now at $12

Probably the best USB hub on the market. By **Eben Upton**

Most Raspberry Pi single-board computers, with the exception of Raspberry Pi Zero and A+ form factors, incorporate an on-board USB hub to fan out a single USB connection from the core silicon, and provide multiple downstream USB Type-A ports. But no matter how many ports we provide, sometimes you just need more peripherals than we have ports. And with that in mind, we have launched the official Raspberry Pi USB 3 Hub (**magpi.cc/usbhub**), a high-quality four-way USB 3.0 hub for use with your Raspberry Pi or other, lesser, computer.

Key features include:

- A single upstream USB 3.0 Type-A connector on an 8cm captive cable
- Four downstream USB 3.0 Type-A ports
- Aggregate data transfer speeds up to 5Gbps
- USB-C socket for optional external 3A power supply (sold separately)

▲ An optional external USB-C power input supports high-power downstream peripherals

Race you to the bottom

Why design our own hub? Well, we'd become frustrated with the quality and price of the hubs available online. Either you pay a lot of money for a nicely designed and reliable product, which works well with a broad range of hosts and peripherals; or you cheap out and get something much less compatible, or unreliable, or ugly, or all three. Sometimes you spend a lot of money and still get a lousy product.

A single upstream USB 3 Type-A connector on 8 cm captive cable connects to Raspberry Pi and provides four downstream USB 3 Type-A ports

> A high-quality four-way USB 3.0 hub for use with your Raspberry Pi or other, lesser, computer

It felt like we were trapped in a race to the bottom, where bad quality drives out good, and marketplaces like Amazon end up dominated by the cheapest thing that can just about answer to the name 'hub'.

So, we worked with our partners at Infineon (**infineon.com**) to source a great piece of hub silicon, CYUSB3304, set Dominic Plunkett to work on the electronics and John Cowan-Hughes to work on the industrial design, and applied our manufacturing and distribution capabilities to make it available at the lowest possible price. The resulting product works perfectly with all models of Raspberry Pi computer, and it bears our logo because we're proud of it: we believe it's the best USB 3.0 hub on the market today.

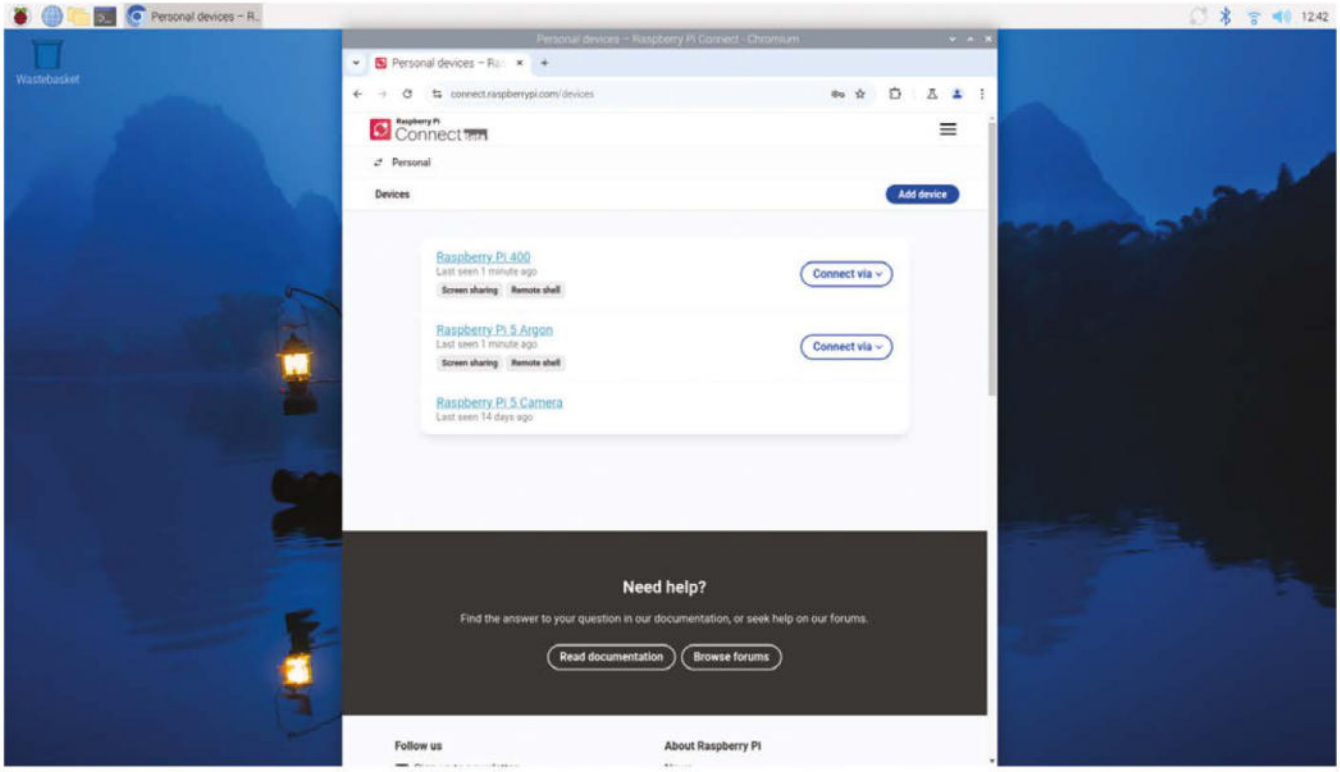
Grab a Raspberry Pi USB 3 Hub and have a play: we think you'll like it.

A high-quality hub that looks neat and converts one USB 3.0 Type-A port into four

Raspberry Pi Connect

New native panel plugin and connectivity testing.

By **Paul Mucur**



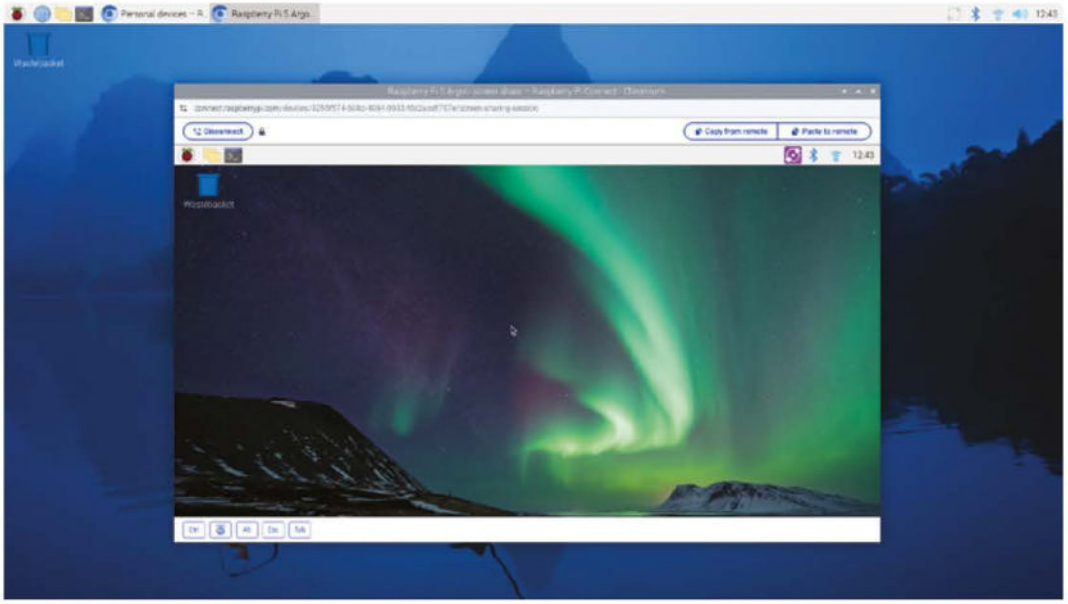
▲ The Raspberry Pi Connect web service enables you to remotely connect to and control connected Raspberry Pi computers

The latest version of Raspberry Pi OS (magpi.cc/rpioct24) includes an all-new, native panel plugin for Raspberry Pi Connect, our secure remote access solution that allows you to connect to your Raspberry Pi desktop and command line from a web browser.

Since the launch of our public beta with screen sharing (**magpi.cc/connectpost**) back in May 2024, and the addition of remote shell access and support for older Raspberry Pi devices in June (**magpi.cc/connectshell**), we've been working on improving support and performance on as many Raspberry Pi devices as possible – from Raspberry Pi Zero to Raspberry Pi 5 – both when using Raspberry Pi OS with desktop and our Lite version.

By default, Raspberry Pi Connect will be installed but disabled, only becoming active for your current user if you choose 'Turn On Raspberry Pi Connect' from the menu bar, or by running `rpi-connect on` from the terminal.

If this is your first time trying the service, using the menu bar will open your browser to sign up for a free Raspberry Pi Connect account; alternatively, you can run `rpi-connect signin` from the terminal



Remote access of a Raspberry Pi 5 desktop environment from a Raspberry Pi 400 computer

to print a unique URL that you can open on any device you like. Once signed up and signed in, you can then connect to your device either via screen sharing (if you're using Raspberry Pi desktop) or via remote shell from your web browser on any computer.

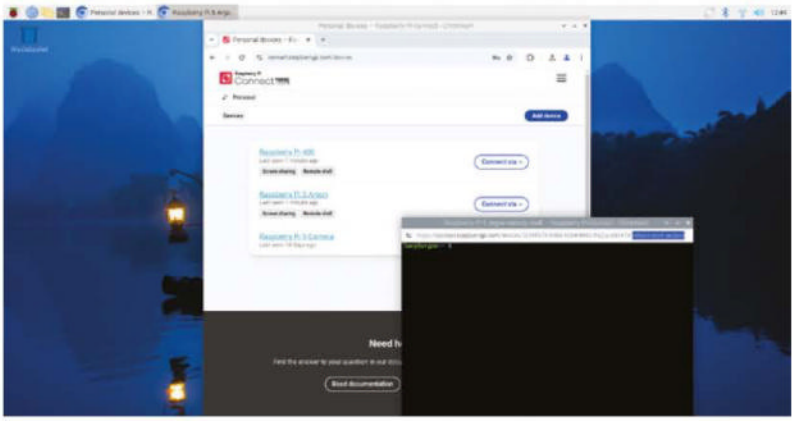
> We've heard from lots of users about the features they'd most like to see next

You can now stop and disable the service for your current user by choosing 'Turn Off Raspberry Pi Connect' or running `rpi-connect off` from the terminal.

With the latest release of 2.1.0 (available via software update), we now include a new `rpi-connect doctor` command that runs a series of connectivity tests to check the service can establish connections properly. We make every effort to ensure you can connect to your device without having to make any networking changes or open ports in your firewall – but if you're having issues, run the command like so:

```
$ rpi-connect doctor

✓ Communication with Raspberry Pi Connect API
✓ Authentication with Raspberry Pi Connect API
✓ Peer-to-peer connection candidate via STUN
✓ Peer-to-peer connection candidate via TURN
```



SSH (secure shell) can be used to remotely access a command-line environment

Full documentation for Raspberry Pi Connect can be found on our website (**magpi.cc/connectdocs**), or via `man rpi-connect` in the terminal when installed on your device.

Updates on updates

We've heard from lots of users about the features they'd most like to see next, and we've tried to prioritise the things that will bring the largest improvements in functionality to the largest number of users. Keep an eye on the Raspberry Pi blog (**raspberrypi.com/news**) to see our next updates.

Powering industrial innovation

Compute Module 5 meets Revolution Pi.

By **Ekkehard Krebs** and **Dave Lee**

A typical Revolution Pi system configuration, consisting of a RevPi Connect 5 and several expansion modules

Revolution Pi has been designing and manufacturing successful products with Raspberry Pi Compute Modules for years. In this article, Ekkehard Kreb, Revolution Pi's Head of Marketing talks about why they continue to choose Raspberry Pi technology, and discuss their experience designing with our brand-new Compute Module 5.

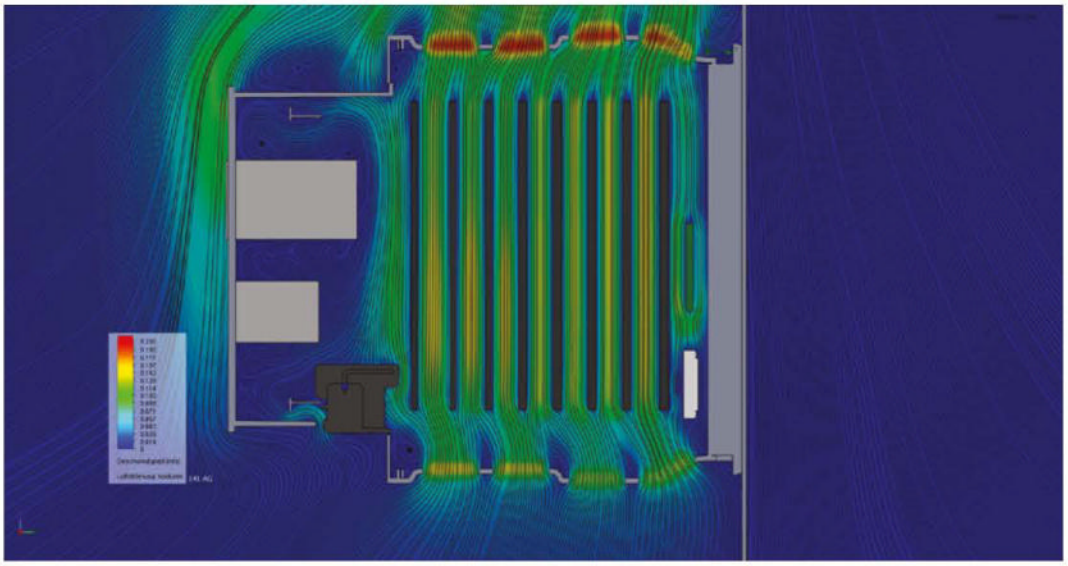
"Revolution Pi has been building flexible industrial devices with Raspberry Pi Compute Modules since the very beginning," says Ekkehard. "As a long-time partner, we have witnessed their impressive evolution from the first to the fifth generation over the past ten years."

Technical advancements that matter

Raspberry Pi Compute Module 5's enhancements directly address industrial requirements: it provides quad-core CPU performance up to 2.4GHz, a built-in USB 3.2 controller, and an improved PCIe controller. Raspberry Pi's continuous integration of more interfaces directly on the Compute Module advances its capabilities while freeing up valuable space on our carrier board. These well-integrated interfaces within the Raspberry Pi ecosystem enable more flexible hardware designs. "This allowed us to equip the RevPi Connect 5 (**magpi.cc/connect5**) with up to four multi-Gigabit Ethernet ports, letting industrial users connect multiple industrial fieldbuses and other networks with low latency."

Collaborative development process

Working with Raspberry Pi on this has been "exceptional," Ekkehard tells us. "They understand what industrial developers need. We received early samples to test with, which was critical. It allowed us to iterate and optimise our design solutions, especially when developing a custom heatsink." Managing the heat generated by the powerful new Compute Module in a DIN rail enclosure was an important part of the design process. Having real hardware to test with made all the difference.



Analysis of simulated airflow in the heatsink

Systematic thermal management

Maintaining Compute Module 5's operating temperature below 85°C under heavy load required a methodical development process. "We started with thermal simulation analysis to identify hotspots at full operating capacity," says Ekkehard. "This analysis formed the basis for our practical prototyping. Through iterative testing under extreme conditions, we optimised the heatsink design before conducting extensive testing with the final housing inside our climatic chamber. The entire process culminated in establishing precise manufacturing standards with rigorous quality control."

> "We're excited to continue pushing the boundaries of industrial automation"

Seamless software integration

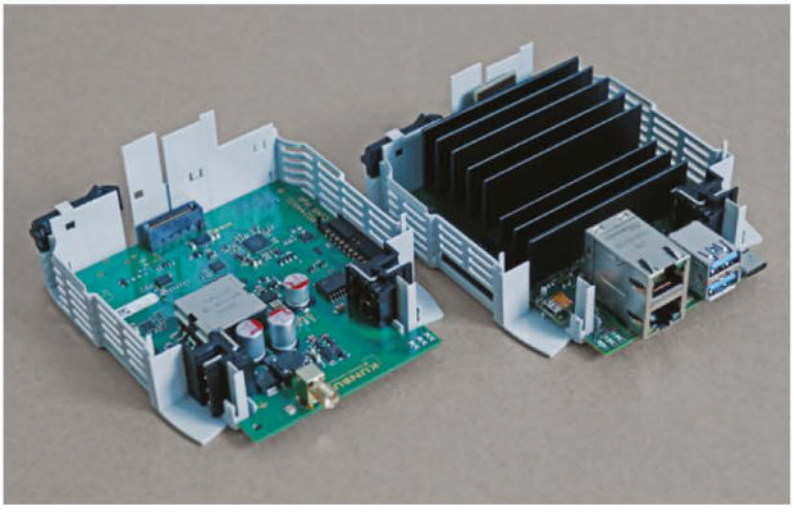
On the software side, working with Raspberry Pi's platform enables smooth integration. When we hit technical challenges, their engineering team was right there to support us. Their unified kernel approach across all products allowed us to focus on integrating new features like the CAN FD interfaces instead of wrestling with compatibility issues. "This standardisation benefits Revolution Pi users as well – they can use our industrialised Raspberry Pi OS-based image consistently across all Revolution Pi devices."

A typical Revolution Pi system configuration consists of a RevPi Connect 5 and several expansion modules.

A proven partnership

From the first Compute Module to now, Raspberry Pi has shown growing commitment to industrial computing. Compute Module 5, purpose-built for products like Revolution Pi, demonstrates what's possible when combining Raspberry Pi's innovation with our industrial-grade engineering. We're excited to continue pushing the boundaries of industrial automation and IIoT [Industrial Internet-of-Things] applications together.

The RevPi Connect 5 consists of two PCBs with a big bolted-on heatsink



Hackberry Pi Zero

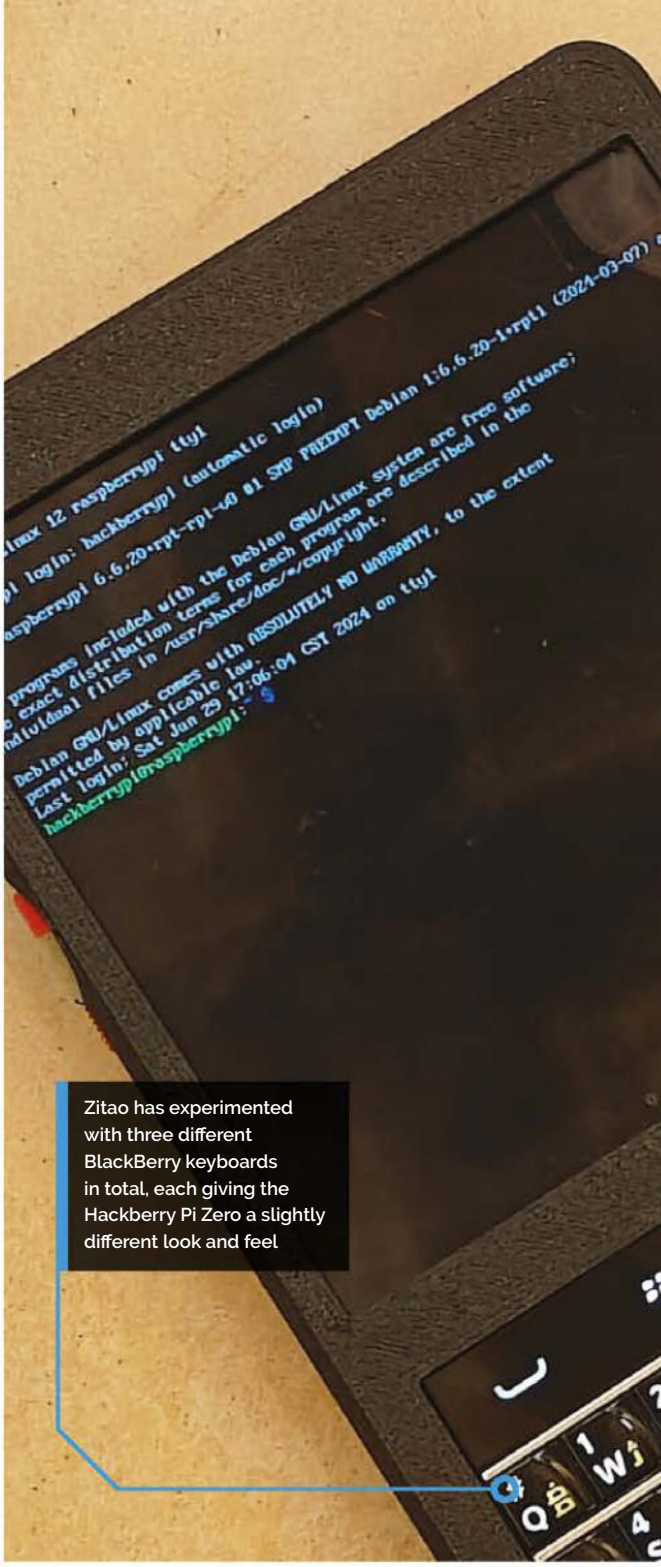
Zitao Dai's pocket-sized tinker tool contains parts from two popular retro smartphone brands. **David Crookes** challenges you to guess them both

MAKER

Zitao Dai

Zitao is currently studying for a master's degree in industrial design and mechanical engineering at the Dresden University of Technology in Germany. He's an electronics and 3D-printing enthusiast who loves to make different hobby projects.

magpi.cc/hackberry



Zitao has experimented with three different BlackBerry keyboards in total, each giving the Hackberry Pi Zero a slightly different look and feel

Although you can compute on the go using a smartphone or a tablet, sometimes you crave a small device which feels and works more like a traditional desktop or laptop computer. With the Hackberry Pi Zero – a cool handheld cyberdeck – you gain the ability to engage in a spot of hacking on the move or, at the very least, get to carry around a pocket device that can run Raspberry Pi OS or, for the gamers among us, the ever splendid RetroPie.

Created by Zitao Dai, this project uses three main components: a 4-inch 720×720 TFT display, an original keyboard from a BlackBerry smartphone, and a Raspberry Pi Zero 2 W computer. But while it would appear to be a simple enough build housed in a smart 3D printed case, a lot of thought and work has gone into its design and overall functionality. The result is a smart, desirable bit of kit that is sure to turn heads whenever a user takes it out of their pocket.

"I was inspired to create the Hackberry Pi Zero about three years ago when I found a project about reverse-engineering on Hackaday," Zitao says. "I thought it would be really cool to have a device with a thumb keyboard, so I began reverse-engineering old BlackBerry keyboards and made it technically work. I then saw a project called Beepberry and thought it would be super-cool to create a similar device with a different BlackBerry keyboard. I basically looked to use the same design but mount a Raspberry Pi Zero 2 W instead."

Well-connected

Beepberry – or Beepy as it's now known – is a versatile device designed primarily to run various messaging services via the chat app Beeper. Created by Eric Migicovsky, who founded the Pebble smartwatch, Beepy uses the keyboard of a BlackBerry Classic and a Raspberry Pi Zero W. It allows access to Linux, which can be viewed on a 2.7-inch black and white LCD display.

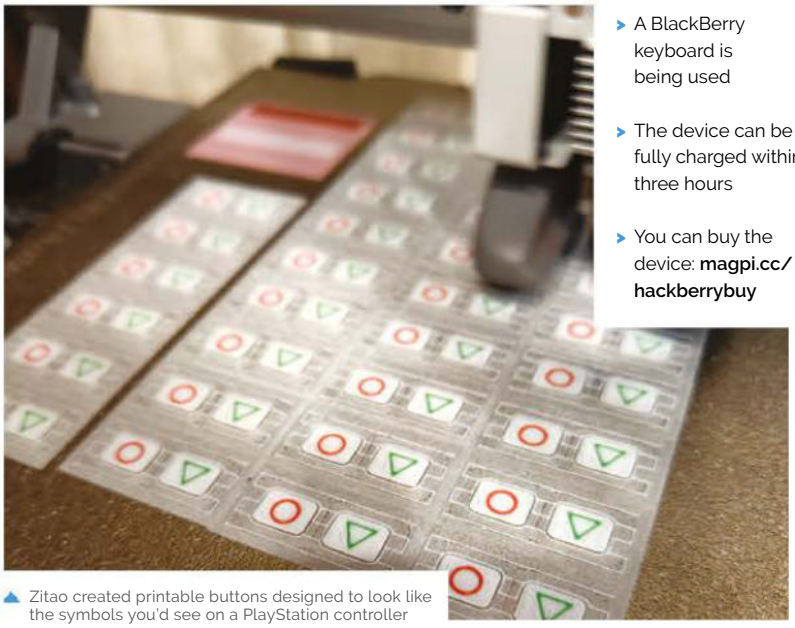
"My start point was to design a learning tool for Linux beginners like me, but also address the pain points from the Beepberry such as using a display with a backlight and adding external USB ports," Zitao says. It's why the Hackberry Pi Zero has three USB 2.0 ports, made possible thanks

The device has a decent battery life. It will run for up to 3.5 hours using a desktop operating system and for five hours using the command line

The schematics and the STL files for the 3D-printed housing are available on Zitao's GitHub page

to the use of an internal hub. "As the project progressed, I found it would also be cool to add a STEMMA-style I2C port for communicating with sensors. In this way, beginners can learn to code with Python."

The device also has an external TF card slot so that the operating system image can be replaced very easily. Flip the device onto its back and you'll find Zitao has added three compartments as well. One of these can be opened to reveal Raspberry Pi Zero 2 W, giving users easy access. The other two house a pair of swappable batteries and, in keeping



▲ Zitao created printable buttons designed to look like the symbols you'd see on a PlayStation controller

Quick FACTS

- It's a handheld Linux terminal
- Raspberry Pi Zero 2 W keeps it slim
- A BlackBerry keyboard is being used
- The device can be fully charged within three hours
- You can buy the device: **magpi.cc/hackberrybuy**

A STEMMA QT port has been added, accessible from the right-hand side. It allows breakout boards and sensors to be connected

with the mobile phone theme, these take Nokia BL-5C rechargeable lithium-ion packs. You're able to replace them within ten seconds without killing the power.

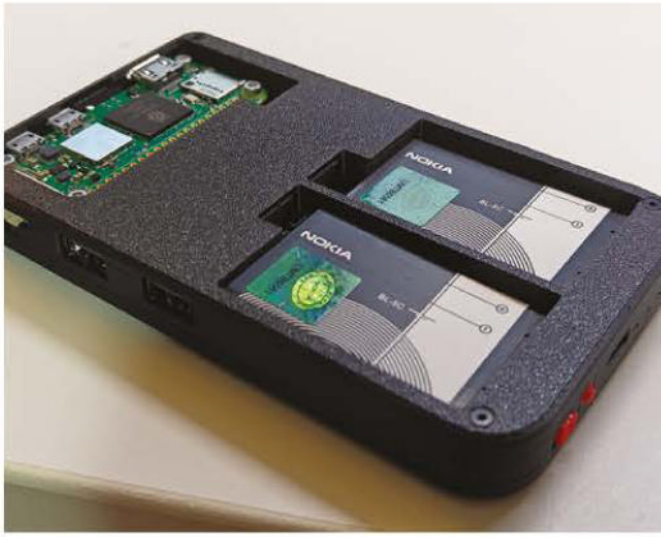
Key to success

Of all of the components, the keyboard is arguably the most eye-catching and Zitao says the choice of BlackBerry keys was rather straightforward. "The BlackBerry keyboards are known to be good quality and they offer a great typing experience,"

> "The choice of keyboard influenced the size of the screen because I needed them to fit alongside each other"

he notes. "The optical trackpad from a BlackBerry keyboard can work as a mouse too and this also offers a very good user experience. The choice of keyboard influenced the size of the screen because I needed them to fit alongside each other." As it happens, it's a perfect fit.

The back of the device is just as smart-looking as the front, with compartments for Raspberry Pi Zero 2 W and the Nokia batteries



Zitao hasn't stuck to using just one BlackBerry Qwerty keyboard. Although he initially chose to incorporate one from the BlackBerry Classic (or Q20), a smartphone that was unveiled in 2014, he has also created another device that makes use of the keyboard from a Q10 (unveiled the previous year). He has also developed a third variant – one that uses a keyboard from the BlackBerry Porsche Design P'9983. And there has been scope for a bit of fun.

One of the devices Zitao has made features a set of colourful buttons showing a circle, triangle, cross, and square, which gamers will instantly spot as having been inspired by Sony's PlayStation controller. "I actually started making a Bluetooth keyboard variant of the BlackBerry keyboards about six months ago and at that time the top row of keys were the original BlackBerry-style keys," he says. "Then a customer suggested I try PlayStation-like buttons. I found they fitted very well and were easy to print."

Mapping the way

The keyboards needed a bit of work in order to get them to operate with Raspberry Pi – notably, hooking them up to a keyboard controller which uses a RP2040 chip. There's an analogue button which needs to be switched on so that the keyboard controller communicates with Raspberry Pi Zero 2 W. If it is turned off, another device can be connected to the USB-C port – a PC keyboard, perhaps – and that will be used to communicate with Raspberry Pi instead.

It's also possible to customise the keymap. "I chose the open-sourced firmware QMK to power the keyboard through the USB interface and one benefit for that is the user can remap the keyboard layout if they want by using the Vial app (**get.vial.today**)," Zitao explains. "The BlackBerry keyboard only has about 40 keys so I designed three layers for the keyboard, which means each key can be mapped into three symbols or letters."

The remapping tool vial is basically a web app and Zitao says Raspberry Pi Zero 2 W doesn't have enough power to open it due to its limited RAM. "I designed a USB-KVM on board to make the keyboard controller chip able to communicate with the external computer so the customer can edit the keymap on their computer," he adds. "At the same time, the hardware can make the Hackberry Pi Zero work as an emergency keyboard."

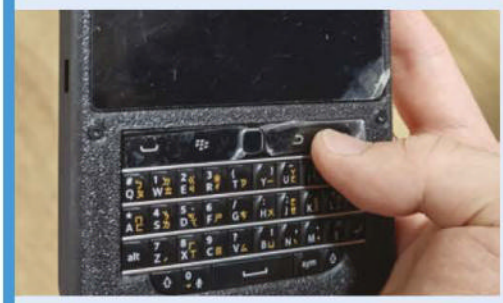
It certainly works well. Hackers are likely to use Kali Linux – an advanced penetration testing distro for ethical hacking and network security assessments – but Zitao just likes to play around. "I've used the devices to learn coding with Python, learn the Linux command-line terminal, and to play some retro games. It really is a lot of fun."

The testing stage shows how the device, regardless of computer used, is connected together before being placed in the case

Creating an advanced version

01 Zitao is now developing a new version of the Hackberry Pi which will use a Raspberry Pi 4 computer rather than Raspberry Pi Zero 2 W. As you can see, it will make for a far chunkier device and fresh design decisions need to be made.

02 This model is not going to be powered by Nokia batteries. Instead, a pair of rechargeable 3500 mAh-capacity batteries with a nominal voltage of 3.6 V are going to be used. Again, this will increase the bulk. A new battery housing has been created.



03 Since a Raspberry Pi 4 computer is larger all round, it does give scope for a bigger screen. As it stands, the upgraded device is very much in the prototype stage and it will need some refining, but it's already looking rather promising.

MIDI Gesture Controller

Extracting an arresting array of sounds from a guitar became a mission for keen coder Gary. He tells **Rosie Hattersley** how he built a Raspberry Pi-based expression pedal

MAKER

Gary Rigg

Gary Rigg is a software developer and keen inventor who's lost count of the number of Raspberry Pi projects he's done.

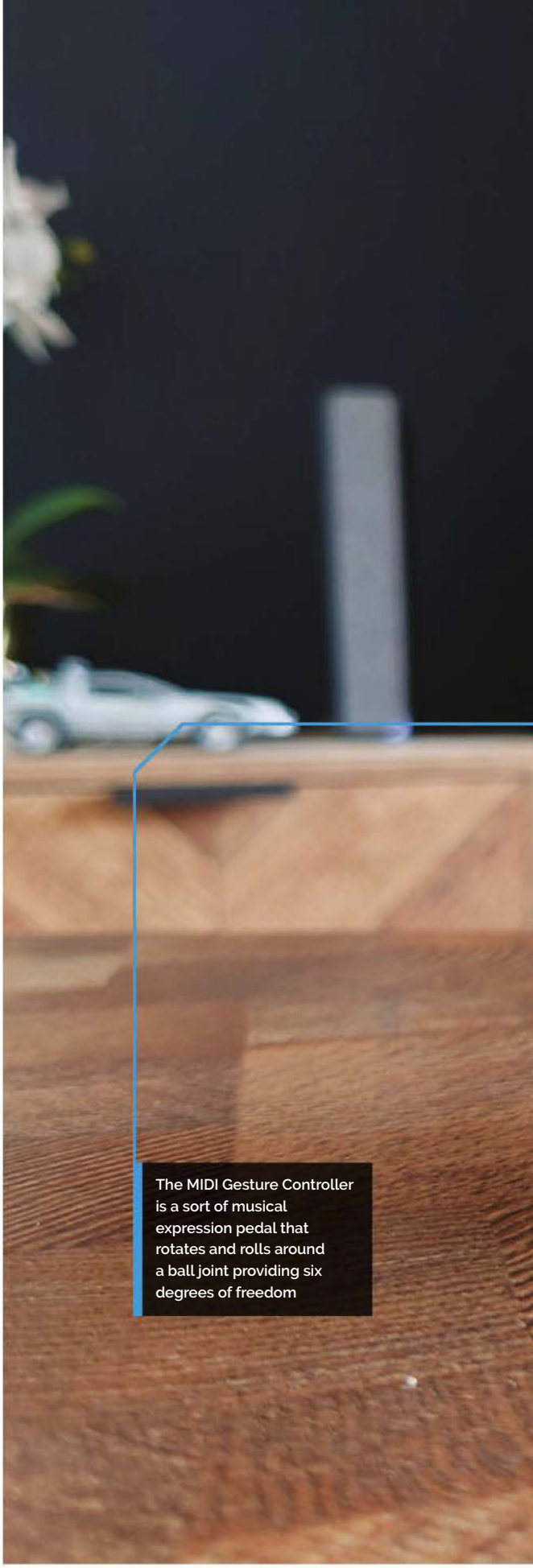
magpi.cc/flatblog

Guitarist and keen coder Gary Rigg says he always thought floor-based controllers – particularly expression pedals – should have a more prominent role. They are usually operated by pressing your foot down for a subtle or more obvious wah-wah or delay effect, but only in a single direction, also known as one degree of freedom (DOF).

You use your foot to "control the pitch of the pedal and the pitch determines the parameter value." Gary reasoned that adding degrees of freedom such as yaw (rotation around an axis) and roll to an expression pedal could extend its pitch parameters. He began pondering what new sounds could be achieved by redesigning how the humble foot pedal was operated. The result is the MIDI Gesture Controller, a Raspberry Pi Pico-based expression pedal that can control three parameters, "which ought to lead to more control while playing live".

New musical direction

Gary hit upon a ball and socket setup since these move through three or more planes of motion in multiple directions. He soon settled on a desk-based rotating puck design, realising that since the expression pedal did not necessarily need to be foot-operated, it could have several additional uses. "It works as well as a hand controller as a foot controller, so could be used for DJs or in a studio," Camera controllers, stage lighting, and other non-musical applications also came to mind. Gary points out that MIDI is simply a protocol and this could be swapped for something else such as an HID controlling gameplay, for example. Sensor



The MIDI Gesture Controller is a sort of musical expression pedal that rotates and rolls around a ball joint providing six degrees of freedom

Quick **FACTS**

- Gary came up with the idea several years ago
- He took apart existing pedals to reuse their cases…
- …and trialled camera tripods instead of a ball
- Future refinements include adding more degrees of freedom…
- …to introduce heave, sway, and surge options

values are sent down a serial line, so the Gesture Controller could theoretically be used in "any situation needing a multi-axis controller".

Give it a try

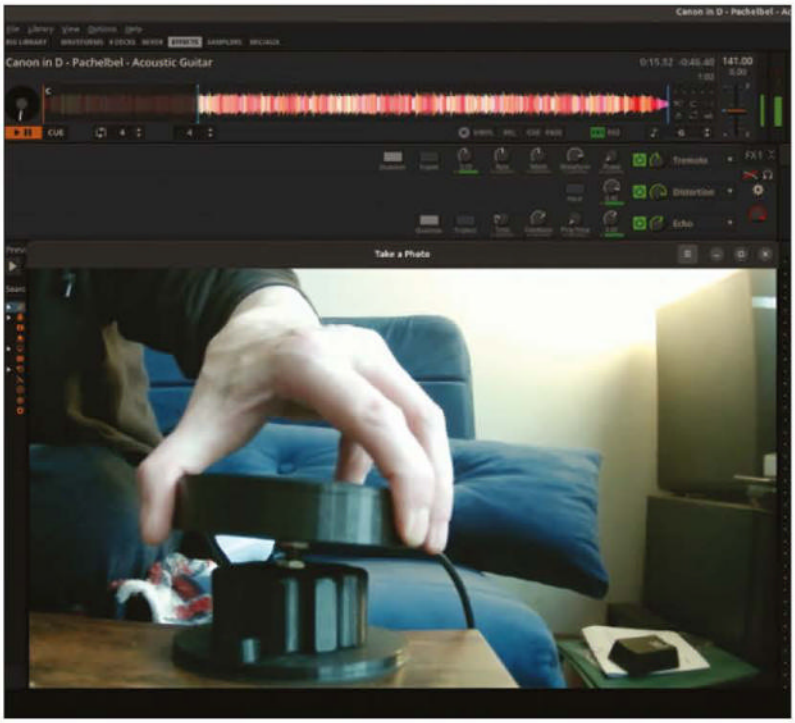
Gary uses Python regularly for his job as a software developer for websites and mobile devices. In "paid work land" he's used Raspberry Pi for IoT projects to control lights and smart devices, in fire alarm panels, and alongside NFC cards and in MQTT Edge devices. As a hobbyist, Gary has created Raspberry Pi-based retro games consoles, set up sensors, and designed a Ghostbusters PKE Meter, so he is fairly confident with prototyping and seeing diverse projects through to completion.

> Pico is an incredible bit of kit as a low-cost microcontroller, and being in Python-land feels like home

He made use of Adafruit's MIDI library and says programming in CircuitPython using Thonny IDE on Raspberry Pi Pico made a lot of sense: "an incredible bit of kit as a low-cost microcontroller, and being in Python-land feels like home." He also found it the best value for money and the most reliable board for his project. Other components – 6DOF AHRS IMU sensor, arcade joystick ball, 3D printer, and neoprene rubber for grip – were bought from The Pi Hut and other stores. The wiring setup was straightforward enough, with the IMU and yaw reset button connected to Raspberry Pi Pico.

Despite Gary's years of experience as a computer scientist and software engineer, the MIDI Gesture Controller project took him several weeks to complete and provided plenty of challenges. Getting a smooth motion on the ball joint was particularly difficult. Having designed the casing in CAD software, Gary says he must have 3D-printed nearly 20 variants to get it right. Another challenge involved getting actual pitch, yaw, and roll values from the IMU (inertial

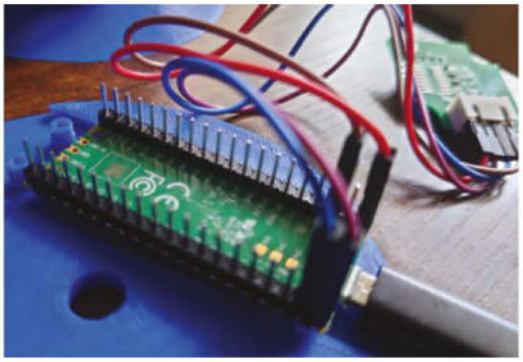
The Gesture Controller can be plugged into a PC as a MIDI control device and works with synthesizers and samplers



Gary's YouTube video amply demonstrates the extra sound possibilities his Gesture Controller can generate

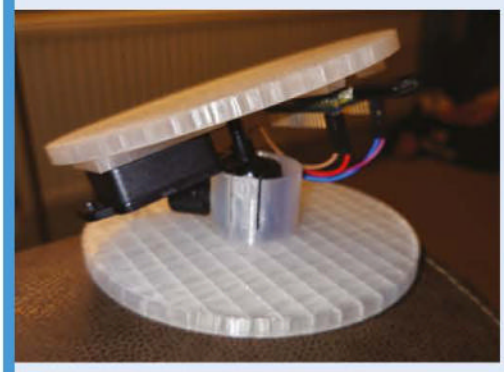
measurement unit). "It took a bit of effort, as did calibrating the ranges and limits of minimums and maximums."

Having first contemplated a multi-DOF expression pedal a few years ago, now the MIDI Gesture Controller is up and running, Gary continues to tweak and improve it and is planning a few extra features. He always likes to have a project on the go, is unafraid to try things, and is a big advocate for experimenting with designs in Tinkercad. A few years ago he launched a Raspberry Pi-based Wi-Fi blocker that caught the press's attention (**magpi.cc/wifinotspot**). The Kickstarter campaign wasn't successful, but it was a fun project and he still owns the trademark for a Wi-Fi 'notspot'.

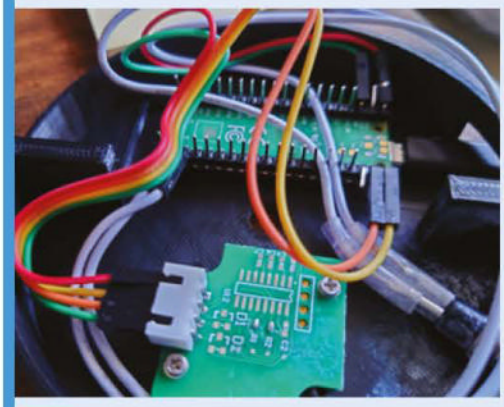


Prototyping the MIDI Gesture Controller with Raspberry Pi Pico, which runs CircuitPython code

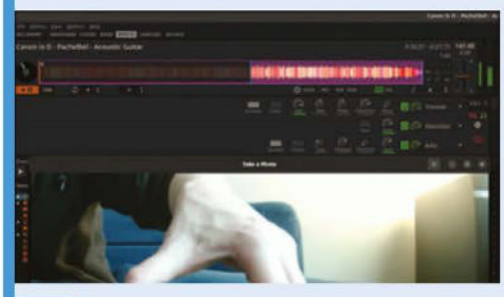
Multi MIDI marvel



01 Gary's Flatcoder blog (**magpi.cc/3dofmidi**) ends with a link to the STL files to 3D-print the MIDI Gesture Controller pedal casing. The puck-shaped device sits atop a ball socket, allowing for several axes of movement. It rotates in response to a Raspberry Pi Pico microcontroller connected to a six-axis AHRS IMU sensor.



02 Raspberry Pi Pico inside the Gesture Controller is attached to an AHRS IMU sensor (which detects the pedal's movements) and via USB to a PC where it can act as a MIDI control device.



03 Gary's CircuitPython code reads values from the IMU sensor, transposes them to within MIDI ranges in the Adafruit MIDI library, and broadcasts the result as a MIDI CC message.

Third Eye for Blind

Md. Khairul Alam's potentially life-changing project aims to use AI to assist people living with a visual impairment. By **David Crookes**.

MAKER

Md. Khairul Alam

Md. Khairul Alam is a developer, maker, and hardware hacker who is currently working as a faculty at the University of Asia Pacific, Dhaka, Bangladesh.

magpi.cc/thirdeyeblind

Technology has long had the power to make a big difference to people's lives and, for those who are visually impaired, the changes can be revolutionary. Over the years, there has been a noticeable growth in the number of assistive apps. As well as JAWS, a popular computer screen reader for Windows, and software that enables users to navigate phones and tablets, there are audio-descriptive apps that use smart device cameras to read physical documents and recognise items in someone's immediate environment.

Understanding the challenges facing people living with a visual impairment, maker and developer Md. Khairul Alam has sought to create an inexpensive, wearable navigation tool that will free up the user's hands and describe what someone should be seeing from their own eyes' perspective. Based around a pair of spectacles, it uses a small camera sensor that gathers visual information which is then sent to a Raspberry Pi 1 Model B for interpretation. The user is able to hear an audio description of whatever is being seen.

A Raspberry Pi 1 Model B is being used, but as the project scales, it's likely he'll use a more powerful model

> "Based around a pair of spectacles, it uses a small camera sensor that gathers visual information which is sent to Raspberry Pi"

There's no doubting the positive impact this project could have on scores of people around the world. "Globally, around 2.2 billion don't have the capability to see and 90% of them come from low-income countries," Khairul says. "A low-cost solution for people living with a visual impairment is necessary to give them flexibility so they can easily navigate and, having carried out research, I realised edge computer vision can be a potential answer to this problem."

Cutting edge

Edge computer vision is potentially transformative. It gathers visual data from edge devices such as a camera before processing it locally rather than sending it to the cloud. Since information is being processed close to the data source, it allows for fast, real-time responses with reduced latency. This is particularly vital when a user is visually impaired and needs to be able to make rapid sense of the environment.

For his project, Khairul chose to use the Xiao ESP32S3 Sense module which, aside from a

Currently, the Xiao ESP32S3 Sense module with its camera sensor is clipped to a normal pair of glasses, but there's scope for a 3D-printed housing

There are loads of wires at the moment (including for the earphones), but the project is still very much in a premature, prototype stage

Quick FACTS

- It's a navigation tool for people with visual impairments
- It's designed to be a low-cost solution
- It uses AI to help identify real-world objects
- Descriptions are read out to the wearer
- It's still a work-in-progress

camera sensor and a digital microphone, has an integrated Xtensa EPS32-S3R8 SoC processor, 8MB of flash memory and a microSD card slot. This was mounted on to the centre of a pair of spectacles and it was connected to a Raspberry Pi computer using a USB-C cable, with a pair of headphones then plugged into Raspberry Pi's audio out port. With those connections made, Khairul could concentrate on the project's software.

As you can imagine, machine learning is an integral part of this project. It needs to accurately detect and identify objects. Khairul used Edge Impulse Studio to train his object detection model. This tool (**edgeimpulse.com**) is well equipped for building datasets and, in this case, one needed to be created from scratch. "When I

To help test the device, Khairul has been using an inexpensive USB-C portable speaker

The connections are reasonably straightforward. Essentially you'll plug the Xiao ESP32S3 Sense module into Raspberry Pi

started working on the project, I did not find any ready-made dataset for this specific purpose," he tells us. "A rich dataset is very important for good accuracy, so I made a simple dataset for experimental purposes."

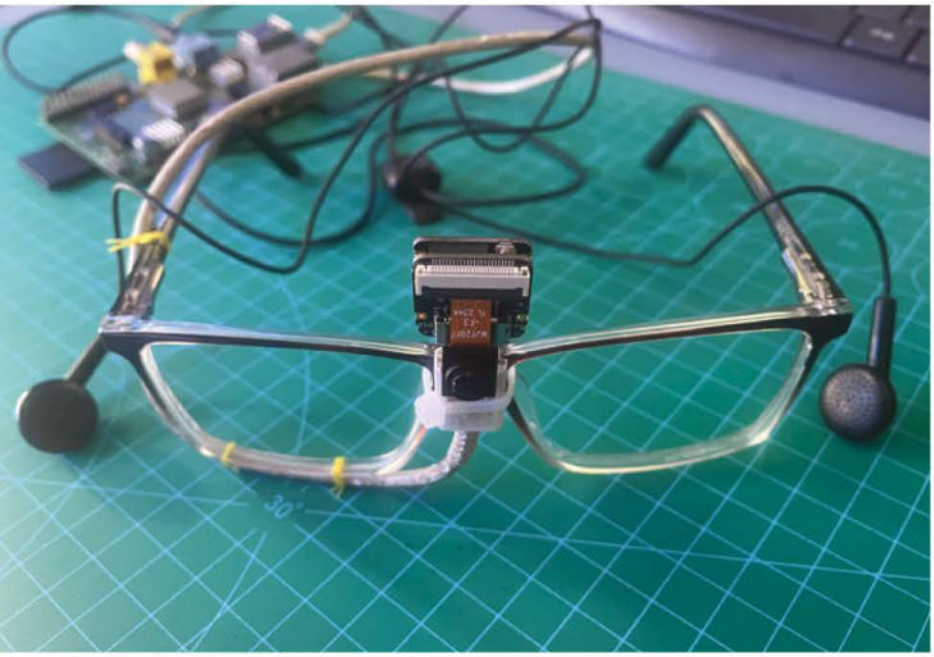
Object detection

Khairul initially concentrated on six objects, uploading 188 images to help identify chairs, tables, beds, and basins. The more images he could take of an object, the greater the accuracy, but it posed something of a challenge. "For this type of work, I needed a unique and rich dataset for a good result and this was the toughest job," he explains. Indeed, he's still working on creating a larger dataset and these things take a lot of time but, when uploading the model to the Xiao ESP32S3 Sense, it has already begun to yield some positive results.

A tidier solution will be needed – including a waterproof case – for real-world situations

When an object is detected, the module returns the object's name and position. "After detecting and identifying the object, Raspberry Pi is then used to announce its name – Raspberry Pi has built-in audio support and Python has a number of text-to-speech libraries," Khairul says. The project uses a free software package called Festival (**magpi.cc/festival**) which has been written by The Centre for Speech Technology Research in the UK. This converts the text to speech which can then be heard by the user.

For convenience, all of this is currently being powered by a small rechargeable lithium-ion battery which is connected by a long wire to enable it to sit in the user's pocket. "Power consumption has been another important consideration," Khairul notes, "and because it's a portable device, it needs to be very power efficient." Since Third Eye is designed to be worn, it also needs to feel right. "The form factor is a considerable factor



– the project should be as compact as possible," Khairul adds.

▲ The Xiao ESP32S3 Sense module gets its power from Raspberry Pi which, in turn, is juiced using a power bank

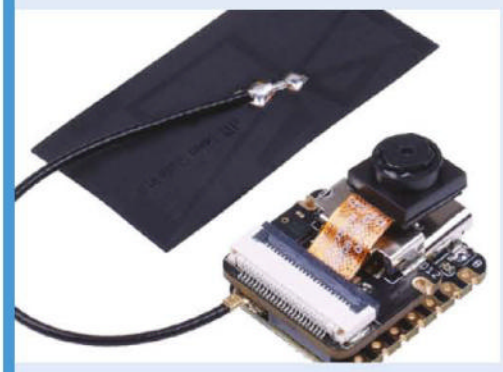
Going forward

Third Eye is still in a proof-of-concept stage and improvements are already being identified. Khairul knows that the Xiao ESP32S3 Sense will eventually fall short of fulfilling his ambitions for the project as it expands in the future and, with a larger machine learning model proving necessary, Raspberry Pi is likely to take on more of the workload.

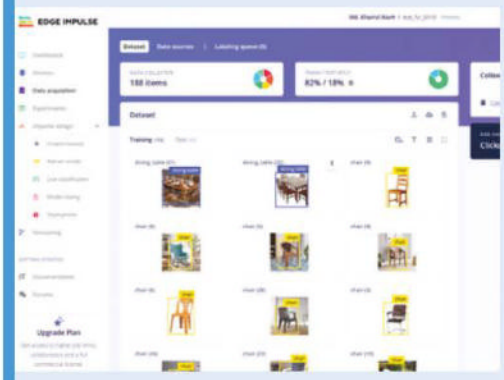
"To be very honest, the ESP32S3 Sense module is not capable enough to respond using a big model. I'm just using it for experimental purposes with a small model and Raspberry Pi can be a good alternative," he says. "I believe for better performance, we may use Raspberry Pi for both inferencing and text-to-speech conversions. I plan to completely implement the system inside a Raspberry Pi computer in the future."

Other potential future tweaks are also stacking up. "I want to include some control buttons so that users can increase and decrease the volume and mute the audio if required," Khairul reveals. "A depth camera would also give the user important information about the distance of an object." With the project shared on Hackster, it's hoped the Raspberry Pi community could also assist in pushing it forward. "There is huge potential for a project such as this," he says.

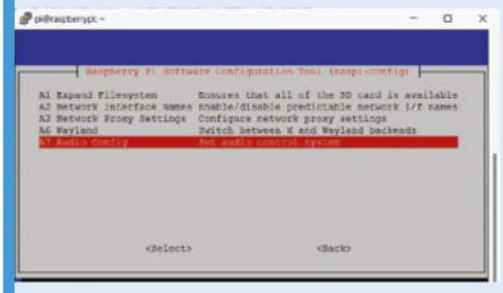
Road to success



01 The Xiao ESP32S3 Sense module, which has a camera sensor, is responsible for capturing images in front of the wearer. Since it is connected to the centre of a pair of spectacles, it will sense what a person would see even if they turn their head.



02 A trained computer vision model has been uploaded to the module. This allows the module to detect and identify particular objects from the real world. This model is currently limited, but Khairul is working on creating a richer dataset containing many more objects.



03 Raspberry Pi uses text-to-speech software to take the module's output and send it, as audio, to the wearer's ears via a pair of headphones. The volume has been set to 100%, but it is hoped users will eventually be able to control this manually.

Adventure Time Self-Playing Guitar

Creative technologist Allie Katz's cosplay creation includes an automated electric guitar with a Raspberry Pi inside. **Rosie Hattersley** tunes in

MAKER

Allie Katz

Artist and self-taught inventor Allie Katz loves using Raspberry Pi in creative technology builds and for wearable projects.

katzcreates.com

Allie Katz is a maker and designer of incredible cosplay outfits and other fun wearables whose tech-enabled work was featured in the National Archives' Spirit of Invention exhibition (magpi.cc/seesawallie).

Allie was keen to create a prop for their Marceline cosplay from the cartoon Adventure Time for the DragonCon convention. Marceline is a 1000-year-old vampire who plays an electric bass she made from her family's heirloom battle axe, and Allie "thought it would be the coolest thing ever if I could make it so I could put on instant live performances as the character." Raspberry Pi 5 became "the beating heart" of the impressive Adventure Time Self-Playing Guitar which features programmable buttons, custom speakers, a touchscreen, "and the ability to be a complete entertainment system on the go whilst also looking like a real bass guitar".

The axe-shaped guitar completes Allie's cosplay based on *Adventure Time*'s Marceline character

Sensible but silly

Allie has form with Adventure Time builds, having created a life-size BMO games console to house

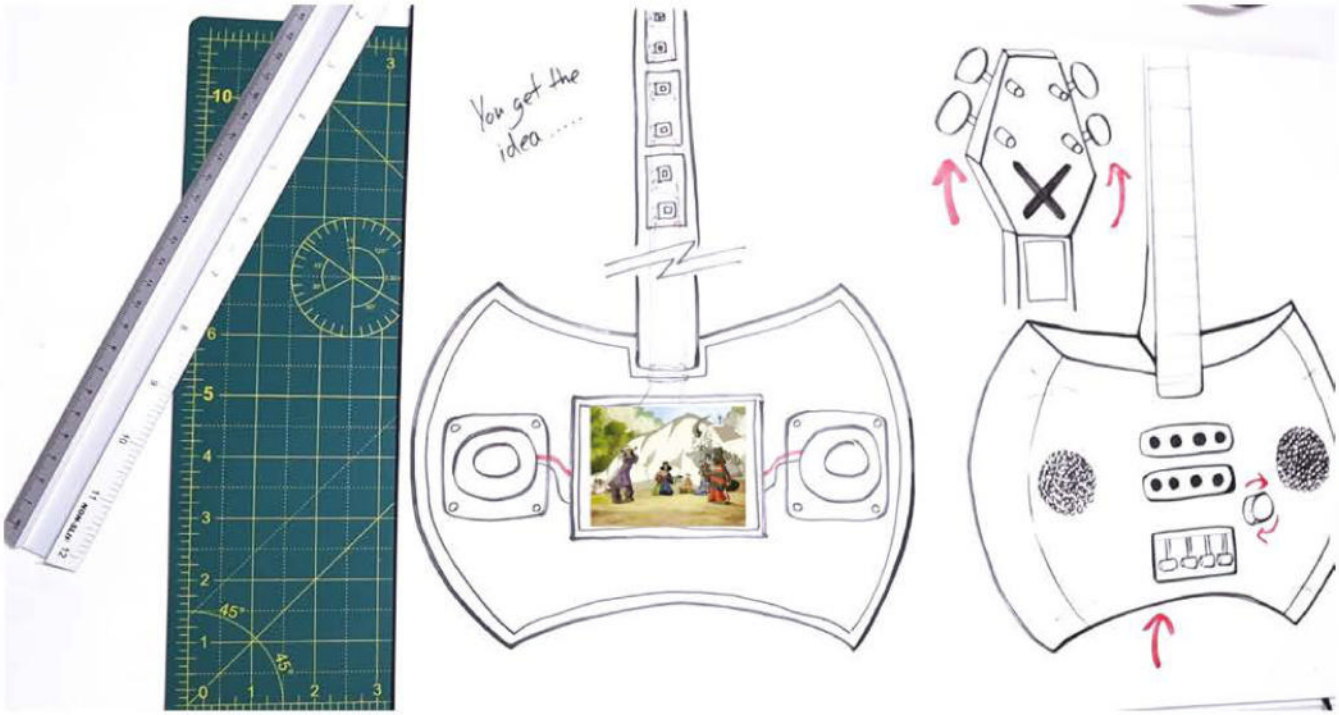
A Raspberry Pi 5-controlled self-playing guitar is the focal point of creative technologist Allie Katz's Adventure Time Marceline cosplay outfit

Allie designed the guitar's body in Fusion 360, 3D-printed it, and used the case to enclose the self-contained entertainment centre

Although the strings don't play, the guitar has programmable buttons, a touchscreen, and custom Bluetooth speakers, with Raspberry Pi 5 as "the beating heart"

Quick **FACTS**

- Marceline's faux guitar uses real bass hardware...
- ...including a guitar bridge and machine heads
- It plays tracks from Spotify and YouTube
- The internal speakers and amp board are battery-powered
- The Bluetooth speakers pump out 30 W of sound!



▲ This project is based on the Adventure Time cartoon, but the design and fabrication was all down to Allie

▲ Allie tries on the newly printed and sanded guitar for size

▼ The cosplay was inspired by Cartoon Network's vampire queen, Marceline

an OctoPrint 3D printer (see Allie's GitHub page, **github.com/katzcreates**).

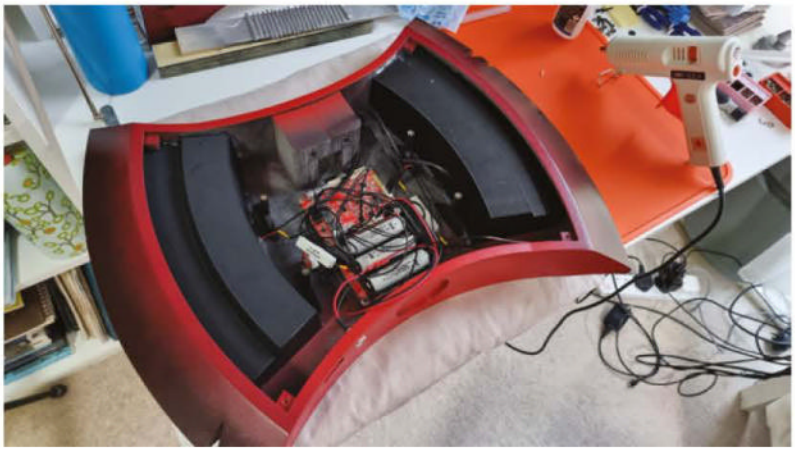
"My technical background is incredibly diverse, but when it comes to electronics I am completely self-taught," reveals Allie. "I got interested in the Raspberry Pi because of how incredibly powerful it was (at a really good price point!) and the community behind it."

Allie chose Raspberry Pi for this "incredibly silly and frivolous" prop project since it would "cover everything needed without me needing to spend tons of time looking for usable peripherals and testing things to make sure that they worked. It was also a chance to try Raspberry Pi 5 for the first time... [I] knew that it would demolish anything I threw at it; [I] didn't want to worry about lag or usability"

Since Allie can't play the bass guitar, it was time for a creative solution that involved real musical instrument hardware and a means of making it play on demand. Allie designed a guitar case to house the electronics, cannibalised small speakers for their innards, and found a way to fool Raspberry Pi 5 into thinking it was drawing the mandated 5 amps, allowing for residual power to connect up a portable battery pack and a generic touchscreen.

Time trial

Allie says the time constraint was by far the biggest challenge, since inspiration came only two months before the DragonCon cosplay event at which it was to debut. "It was a huge undertaking to get everything done in time."



All the electronics, plus a touchscreen, needed to fit inside the custom-designed guitar case and are concealed by a sliding panel

Allie designed their take on Marceline's guitar in Fusion 360, with custom speaker enclosures for the Dayton Audio boards, electronics attachments, and detachable parts plus a sliding panel. Allie says the software side was pretty easy. "Raspberry Pi provides most useful things baked right into the OS. I only had to write some simple Python code to create the custom song buttons."

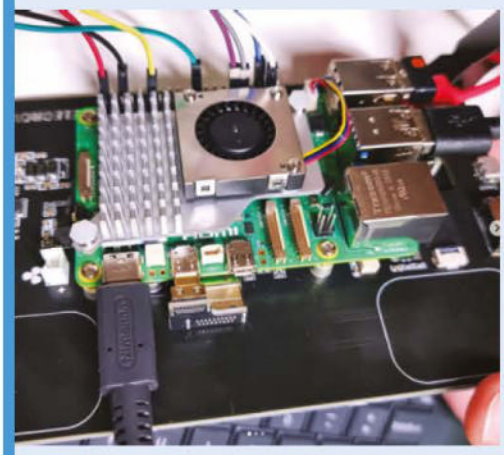
Although some tweaks were needed – "what project would be complete with a couple of iterations?" – these were mainly related to the sliding panel that covers the touchscreen when it's not in use and which needed to be 3D-printed and painted and still be able to slide smoothly. Allie also tried to find an alternative solution to simply playing Spotify in the Chromium browser, feeling certain there would be a Python library for it, "but alas, there was not!"

> "What project would be complete with a couple of iterations?"

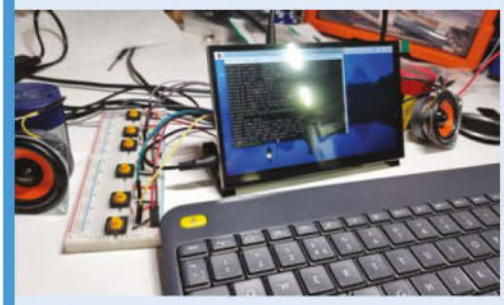
Although designing and creating the Adventure Time Self-Playing Guitar was a considerable task, Allie says the key to any successful build is breaking it into achievable bite-sized pieces. "When tackling a large project, especially if it has elements that are new to you, it's really easy to get a bit overwhelmed and not know where to start or what to do next. Figuring out the broad strokes of a project first, then separating them into smaller and smaller pieces really helps make things feel a lot more manageable. Also, good sandpaper will save your life!" For another Adventure Time build, see **magpi.cc/bmoconsole**.

Strike a chord

01 Unless you have an unwanted electric guitar to hand, you will need to 3D-print one [**magpi.cc/3dguitarmodels**] or design an enclosure for the speakers and project electronics.



02 Speaker enclosures, Raspberry Pi 4 or 5, a touchscreen to select songs, a sliding panel to cover the display, plus wiring and a portable power source all need to fit inside your guitar box.



03 Allie set up buttons to trigger specific songs that were stored on Raspberry Pi and also used Python code to pull tracks from Spotify or YouTube via the Chromium browser that play through the guitar's integrated Bluetooth speakers.

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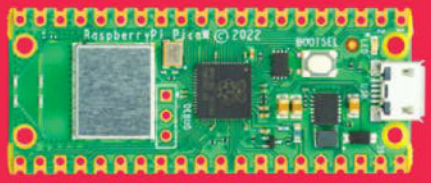

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Get started with your Raspberry Pi

Find out how to connect everything up, run an OS, and start using your Raspberry Pi

By Phil King

Just got your hands on a new Raspberry Pi 500 (or a different Raspberry Pi model)?... You've come to the right place. In this beginner's guide, we'll show you how to set up your Raspberry Pi, use it as a desktop computer, learn to do some coding, and suggest a few projects to embark on. There's just so much you can do with a Raspberry Pi!

Raspberry Pi models

Raspberry Pi computers come in three main form factors...

Raspberry Pi 500 & 400

magpi.cc/raspberrypi500 | magpi.cc/rpi400

These models are built into a compact portable keyboard. So, you can just connect a mouse and display to get started with desktop computing, using the built-in wireless capability to connect to the internet.

All the connections are found on the rear, including a microSD card slot, three USB ports, two micro-HDMI video out ports, and a Gigabit Ethernet port. In addition, there's a 40-pin GPIO header for connecting your own electronic circuits and HATs (via a ribbon cable) for projects.

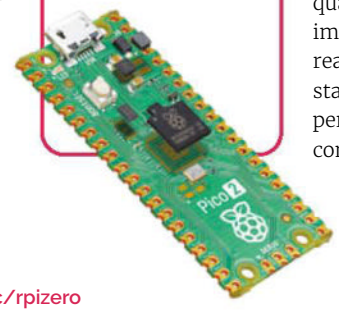
Raspberry Pi 400 is based around the same quad-core 64-bit processor as Raspberry Pi 4, with 4GB of RAM. Raspberry Pi 500 features a higher-speed Broadcom BCM2712 processor for even better performance, along with a VideoCore VII GPU and 8GB of RAM.

Both models are available as a standalone unit or a Personal Computer Kit containing everything you need to get started: a mouse, official power supply, micro-HDMI to HDMI display cable, microSD card preloaded with Raspberry Pi OS, and a copy of *The Official Raspberry Pi Beginners Guide 5th Edition*.

Raspberry Pi Pico

Not a fully fledged computer, this is a microcontroller. Measuring just 21 × 51mm, it's designed for use in physical computing projects. You can connect electronic circuits to its twin GPIO headers. It can be programmed by connecting a computer via USB.

Raspberry Pi Pico 2 has a more powerful processor.



Raspberry Pi 5 & 4

magpi.cc/raspberrypi5 | magpi.cc/raspberrypi4

These single-board computers are in the classic Raspberry Pi Model B form factor: a credit-card-sized bare board. Adding a case is advised – there are many types available, including official Raspberry Pi ones. For Raspberry Pi 5, the official case includes a cooling fan, or you can add an official Active Cooler unit.

Both models feature four USB ports, a Gigabit Ethernet port, wireless connectivity, and two micro-HDMI ports. A 40-pin GPIO header enables the connection of HATs and electronic circuits. With this and the compact form factor, these models are highly versatile. They can also be used with a Raspberry Pi Camera Module and/or Touch Display.

Raspberry Pi 5 features the Broadcom BCM2712 quad-core processor and VideoCore VII GPU for improved performance. It also adds a fan connector, real-time clock, and handy power button. A standout feature is its PCIe 2.0 interface for fast peripherals – using an official M.2 HAT+, you can connect an NVMe drive or AI accelerator.

Raspberry Pi Zero / W / 2 W

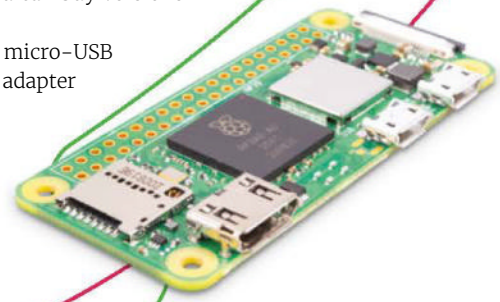
magpi.cc/rpizero2w | magpi.cc/rpizerow | magpi.cc/rpizero

Need something even more compact for your project? Try one of the Raspberry Pi Zero models. Measuring just 65 × 30mm, the board can fit into tight spaces. It also benefits from lower power drain, making it ideal for projects using portable power.

There are three main variants of Raspberry Pi Zero: the original Zero model, Zero W, and Zero 2 W. The 'W' indicates that those models have built-in wireless connectivity. Raspberry Pi Zero 2 W features a processor that's up to five times faster, great for projects requiring extra grunt.

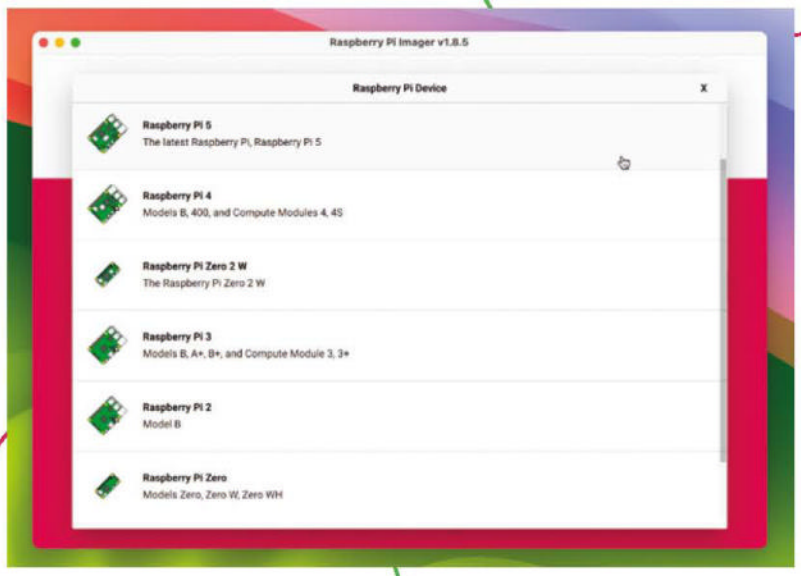
While the standard boards come with an unpopulated 40-pin GPIO header requiring users to solder on a set of male pins, you can buy versions with the pins already attached.

All models have just a single micro-USB OTG port, so you'll need a USB adapter – plus a USB hub if you want to connect more peripherals. Even so, by connecting the mini-HDMI port to a display, you can even use a Raspberry Pi Zero as a desktop computer.



Set up your Raspberry Pi

Install an OS and connect everything

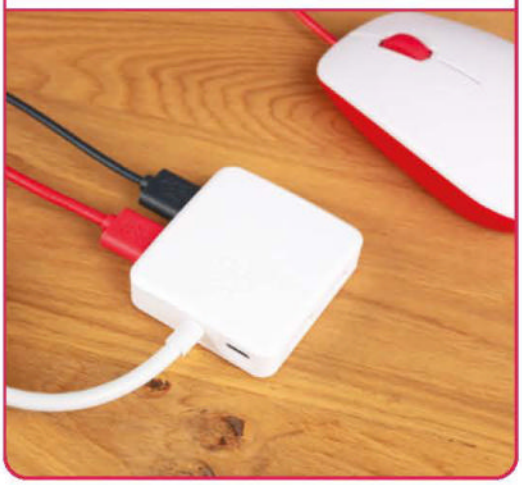


▲ Filter OS versions by model in Raspberry Pi Imager

▼ Select the top option in the list of operating systems

USB Hub

Need more USB ports? The official Raspberry Pi USB 3 Hub (**magpi.cc/usb3hub**) converts a single USB port into four. If you add a micro-USB adapter, you can also use it with any Raspberry Pi Zero model.

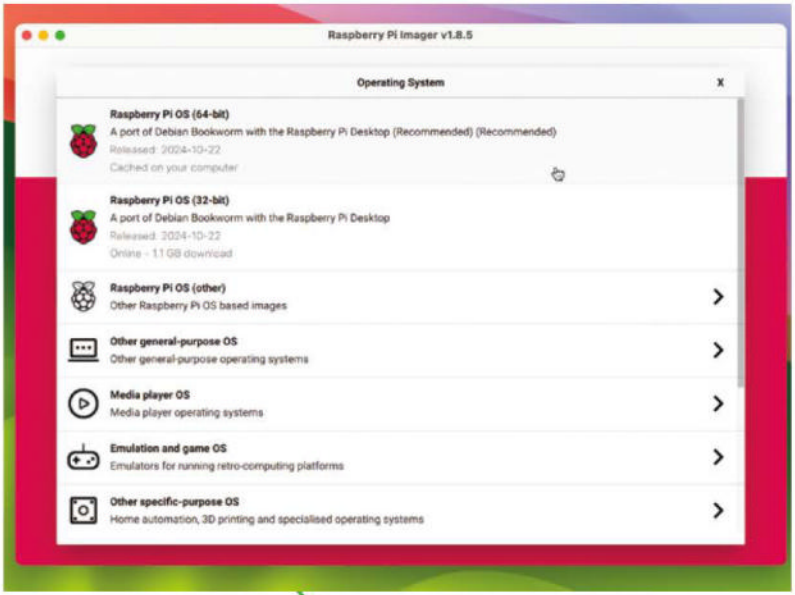


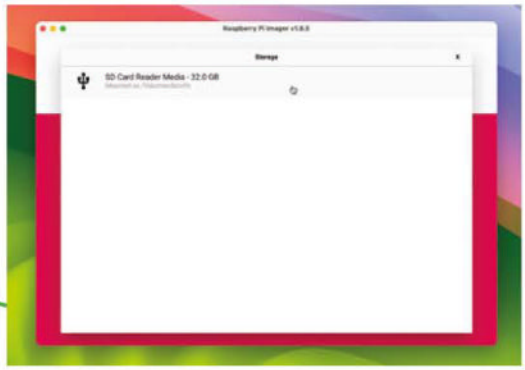
Like any other computer, your Raspberry Pi 500 needs to run an operating system. While several are available, the official one is called Raspberry Pi OS.

If you bought the Raspberry Pi 500 (or 400) Personal Computer Kit, you'll already have Raspberry Pi OS preloaded onto a microSD card. If not, you'll need to write the OS to a card. A high read/write speed is recommended, along with a capacity of 32GB or more, as it will also act as Raspberry Pi's storage. While most brands should work, the sure-fire option is to use an official Raspberry Pi SD Card (**magpi.cc/sdcards**).

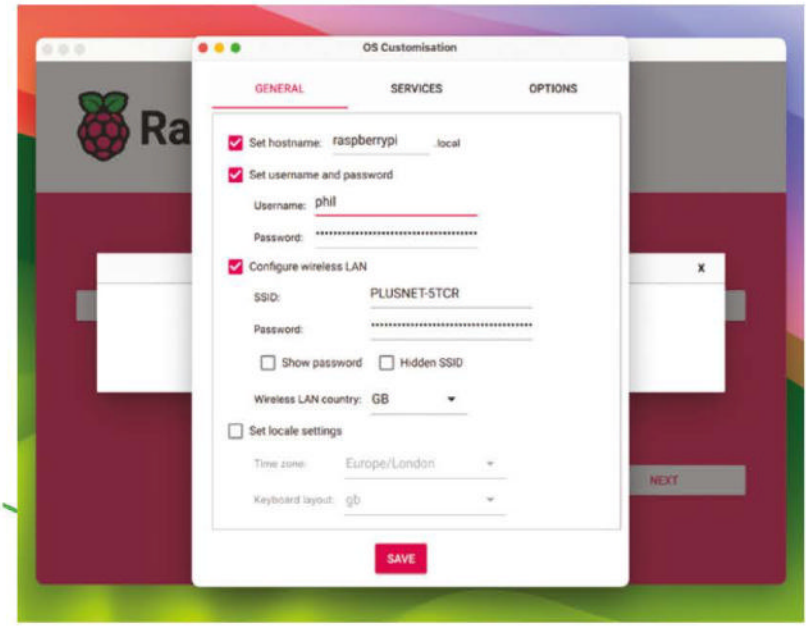
The easiest way to write an OS to the card is to use the official Raspberry Pi Imager tool (**magpi.cc/imager**), which is available for macOS, Windows, and Raspberry Pi computers. In Imager, you can click on 'Raspberry Pi Device' to filter the OS versions for your model. Then click 'Operating System' and select the top option, 'Raspberry Pi OS (64-bit)'. Connect your microSD card (typically via a USB memory card reader) to the host computer, then click on 'Choose Storage' to select it.

Then click on Next and you'll be asked if you want to apply OS customisation settings; click 'Edit Settings' and you may be prompted to prefill your





For 'Choose Storage', select your microSD card



Add a Wi-Fi connection in OS Customisation settings

Wi-Fi credentials from your host computer – click 'yes' to do so, or you can fill them in manually in the OS Customisation Menu that follows if you prefer. In the latter, you should also set a user name and password for Raspberry Pi OS. You can also click 'Set locale settings' and choose your time zone and keyboard layout.

Finally, click Save, then Yes, and Yes again on the Warning dialog. Imager will write the OS to your microSD card, then verify it. You can then remove the microSD card and insert it into the slot on the rear of Raspberry Pi 500.

CONNECT IT UP

To see the desktop GUI, you'll need to connect your Raspberry Pi 500 to a TV or monitor. For this you'll need an HDMI to micro-HDMI cable (or adapter); plug the small end into the primary micro-HDMI port on the rear – the one nearest the USB-C power port; the other one enables you to connect an optional second display.

To navigate the desktop, you'll need a USB mouse connected to any of Raspberry Pi's USB ports. Naturally, you can use Raspberry Pi 500's integrated keyboard to type text.

Finally, you'll need a suitable power supply – for this you should use an official 27W USB-C Power Supply (**magpi.cc/psu**).

With everything connected and the microSD card inserted, turn on the power. Once Raspberry Pi OS boots up, you'll be greeted by its Welcome Wizard, where you can configure a few settings before you start using the OS. It will also give you the option of installing software updates before prompting you to click Restart to reboot your Raspberry Pi.

Raspberry Pi 4 & 5 setup

If you're using a Raspberry Pi 4 or 5 model, the steps for installing the operating system onto a microSD card are the same as for Raspberry Pi 500, using the Raspberry Pi Imager tool. So, follow the steps in the main text to customise the options and flash it to the card.

Connecting up is also very similar. This time, as well as a mouse, you'll need to connect a keyboard to one of your Raspberry Pi's USB ports. Again, you'll need a micro-HDMI to HDMI cable to connect a TV or monitor. On Raspberry Pi, use the primary micro-HDMI port – the one labelled 'HDMI 0', nearest the USB-C power port.

For both models, you can use the 27W USB-C Power Supply (**magpi.cc/psu**) again.

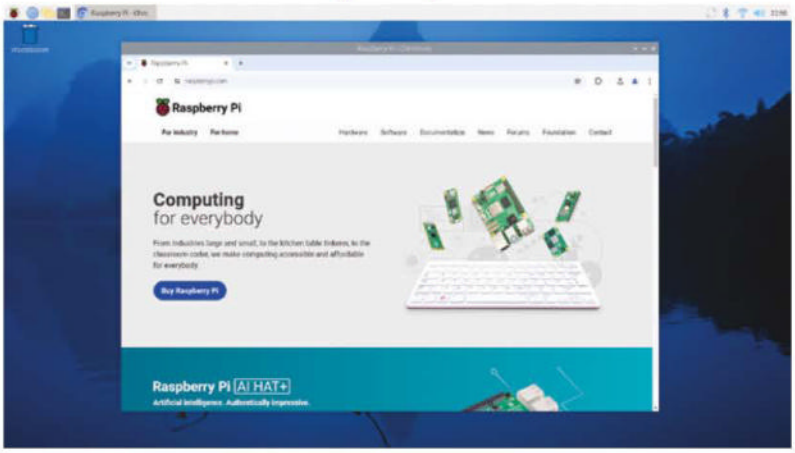
Desktop computing with Raspberry Pi

You can use your Raspberry Pi as a standard desktop computer

The standard version of Raspberry Pi OS comes with a desktop GUI. At the top is a taskbar with a few app shortcut icons on the left, and info/settings icons on the right. Clicking on the Raspberry Pi logo at the top left opens up an applications menu with several categories; click on a category and then an application to launch it.

The folder icon in the taskbar opens a File Manager where you can browse the folders and files of the system, and any removable USB storage drives. It starts by default in your 'home' directory, whose subfolders include **Bookshelf**, **Documents**, **Downloads**, **Music**, **Pictures**, and **Videos**.

The globe icon in the taskbar opens the Chromium web browser, which functions similarly to Google Chrome. You can enter a web address or search term in the bar at the top. It also has tabbed browsing – to open a new tab, press the '+' icon in the tabs bar or **CTRL+T**.



▲ Browse the world wide web with Chromium

INSTALLING SOFTWARE

While the standard version of Raspberry Pi OS includes a few applications, there's lots more software you can install. The easiest way is by using the Recommended Software tool. In the applications menu, select the Preferences category, then Recommended Software to open it.

The applications and tools in Recommended Software are arranged into categories shown on the left. Let's install the LibreOffice productivity suite: select the Office category, then find LibreOffice in the list, tick the checkbox next to it, then click Apply to install it. Similarly, if you ever want to remove a piece of software, you can simply untick its checkbox and click Apply.

As in other operating systems, there are frequent updates for the system and applications. The easiest way to update is when a prompt appears in the desktop taskbar. Just click Install Updates, or Show Updates to list the details first.

To change most system settings, open Preferences > Raspberry Pi Configuration. The tool is split into five tabs, each with a different set of options.

To change the desktop settings, right-click on the desktop and select Desktop Preferences.

OFFICE WORK

Now you have the LibreOffice productivity suite installed, you'll find its six applications in the Office category of the main menu…

Writer: The equivalent of Word, this is an easy-to-use, feature-rich word processor.

Calc: An Excel-like spreadsheet tool for handling numbers and creating charts and graphs.

Impress: A PowerPoint-like application for creating slide-show presentations.

Base: A relational database application for storing and accessing information.

Draw: An illustration program for creating pictures and diagrams.

Math: A formula editor for creating properly formatted mathematical formulae to use in other applications.

LibreOffice is just one of many useful productivity tools you can use in Raspberry Pi OS. You can find a greater selection of software in the Preferences > Add / Remove Software tool.

Shutting down

When you've finished using your Raspberry Pi, it's important to shut it down safely instead of just turning off the power. Select Shutdown from the applications menu, then press Shutdown on the menu that pops up.

Coding and digital making

Learn to code and start creating your own projects

Raspberry Pi makes for a great desktop computer, but it's a lot more versatile than that. For one, it's an ideal platform for learning how to code. The standard version of Raspberry Pi OS has the Thonny IDE (integrated development environment) pre-installed for Python programming. You can also install Scratch 3 – via the Recommended Software tool – if you want to do some block-based coding.

Let's try some basic Python programming. Open the Thonny IDE from the Programming category of the applications menu. The large blank pane is the script area where you will write your program. On line 1, enter the following:

```
print("Hello world!")
```

Here, a `print` statement is followed by brackets that enclose the output (just as for other functions in Python 3); the double quotes enclose a text message, known as a 'string'. Click the Run icon in Thonny's toolbar to run the program; it will print the message to the Shell area at the bottom of the IDE.

Now, let's use a couple of variables – these can store a number or a string.

```
legs = 4
animal = "horse"
print ("A", animal, "has", legs, "legs.")
```

In the first two lines, we name each variable (`legs` and `horse`) and use the `=` sign to assign it a value – in the first case, a number; in the second, a text string. Finally, we use a `print` statement with a series of strings and variables separated by commas to combine their output. The output will be: 'A horse has 4 legs.'

A key part of many programs involves comparing variables and values to determine what step is executed next. For this, we use an `if` conditional statement. For instance:

```
age = input("How old are you? ")
age = int(float(age))
if age > 12 and age < 20:
    print("You are a teenager.")
```

Here, we use the `input` function to assign a variable, called `age`, to a user's typed input. The next line converts the string into an integer. Finally, we use an `if` conditional with the `age` variable to check whether it is greater than 12 and also less than 20. If so, the indented `print` statement below that line is executed.

This is just a very brief introduction to Python coding. To learn more, view the official Python tutorial at **magpi.cc/pythontutorial**.

Raspberry Pi projects

Electronics
Every Raspberry Pi has a GPIO header that enables you to connect and control electronic components. A typical first project is to flash an LED. The Raspberry Pi Foundation's guide to physical computing with Python is a good place to learn: **magpi.cc/elecintro**.

Media centre
Use Raspberry Pi to play movies, TV shows, and music using the Kodi media centre software. Install it in Raspberry Pi OS or use a Kodi-based media player OS such as LibreELEC or OSMC. For more info, read *Build a Raspberry Pi Media Player*: **magpi.cc/mediaplayer**.

Retro gaming
There are software emulators available for most classic consoles and computers. The easiest way to get started is with an emulation platform that bundles a user interface with multiple emulators. For more info, read *Retro Gaming with Raspberry Pi 3rd Edition*: **magpi.cc/retrobook3**.

Smart home
Manage your smart home devices and set up custom automations. The most popular platform is Home Assistant (**home-assistant.io**), a free, open-source operating system. To learn more, check out our 'DIY Home Automation With Raspberry Pi' guide in *The MagPi* issue 129: **magpi.cc/129**.

Touch Display 2

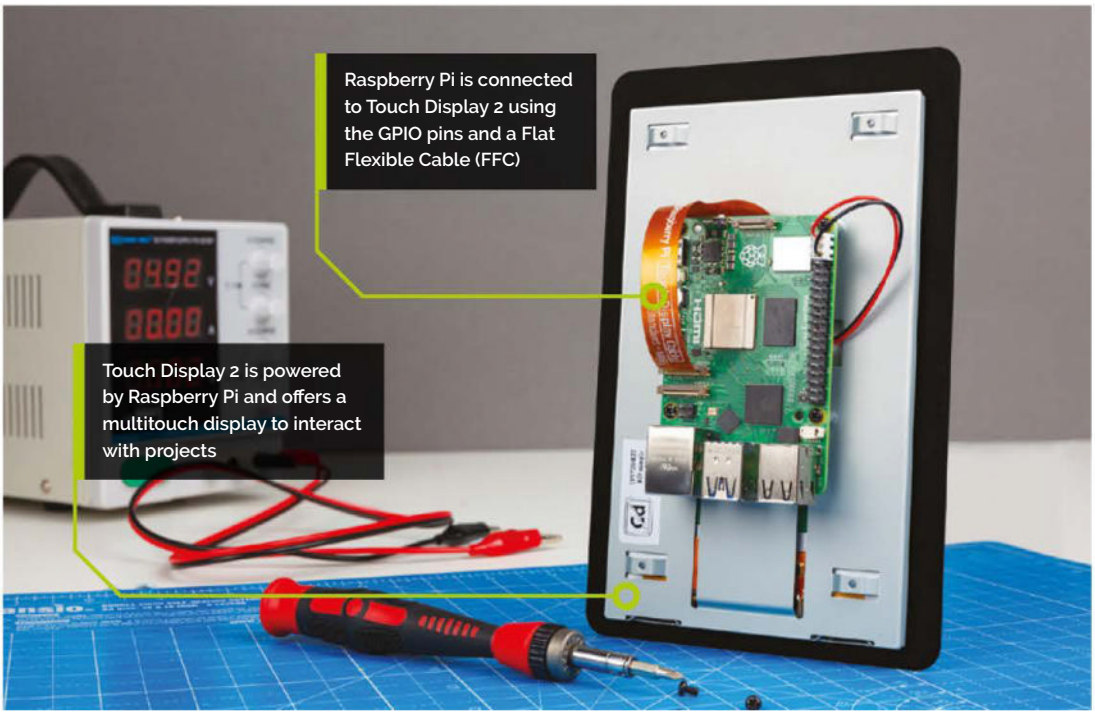
The Raspberry Pi Touch Display 2 is a portrait orientation touchscreen LCD display designed for interactive projects like tablets, entertainment systems, and information dashboards

MAKER

Nate Contino

Nate is a retrofuturist and writes documentation for Raspberry Pi.

lambdalatitudinarians.org



The Touch Display 2 connects to a Raspberry Pi using a DSI connector and GPIO connector. Raspberry Pi OS provides touchscreen drivers with support for five-finger multitouch and an on-screen keyboard, providing full functionality without the need to connect a keyboard or mouse.

Specifications

- 1280×720px resolution, 24-bit RGB display
- 155×88 mm active area
- 7-inch diagonal display
- Powered directly by the host Raspberry Pi, requiring no separate power supply
- Supports up to five points of simultaneous multi-touch

The Touch Display 2 is compatible with all models of Raspberry Pi from Raspberry Pi 1B+ onwards, except Raspberry Pi Zero and Zero 2 W, which lack a DSI connector.

The Touch Display 2 box contains the following parts (in left to right, top to bottom order in the **Figure 1** image):

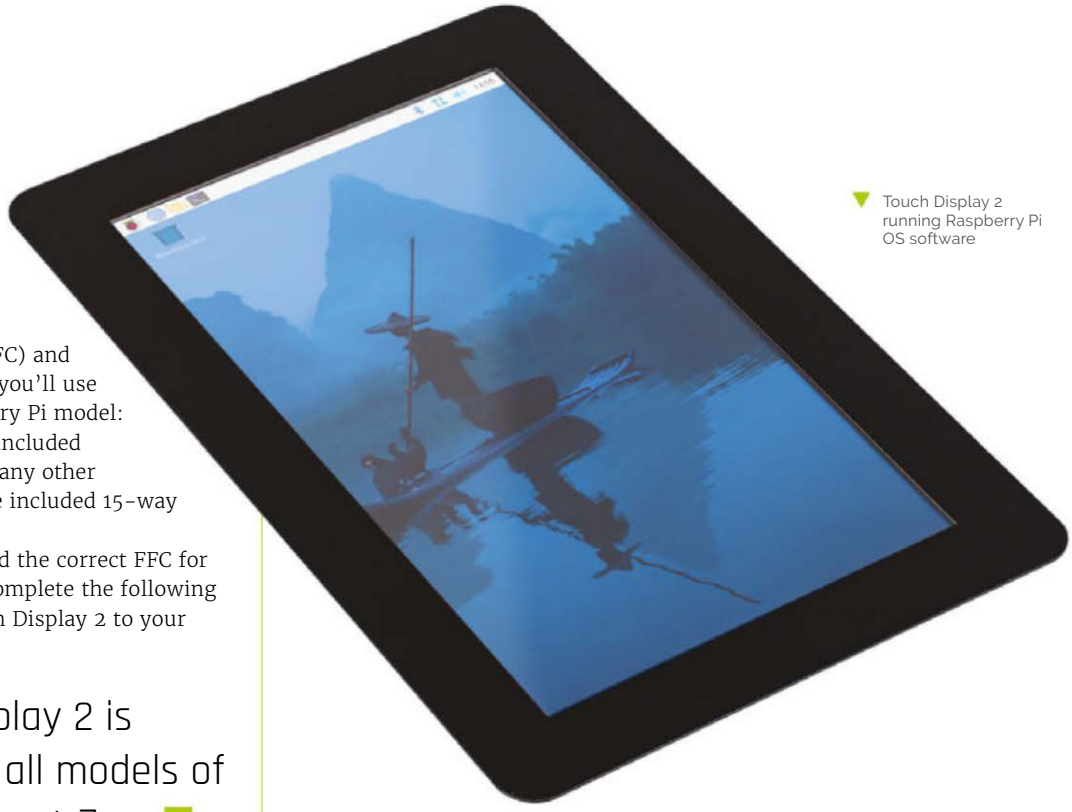
- Touch Display 2
- 8 × M2.5 screws
- 15-way to 15-way FFC
- 22-way to 15-way FFC for Raspberry Pi 5
- GPIO connector cable

Install

To connect a Touch Display 2 to a Raspberry Pi,

You'll Need

- Any Raspberry Pi 1/2/3/4/5 computer (not Raspberry Pi Zero/Zero 2 W)
- Touch Display 2 **magpi.cc/touchdisplay2**



Touch Display 2 running Raspberry Pi OS software

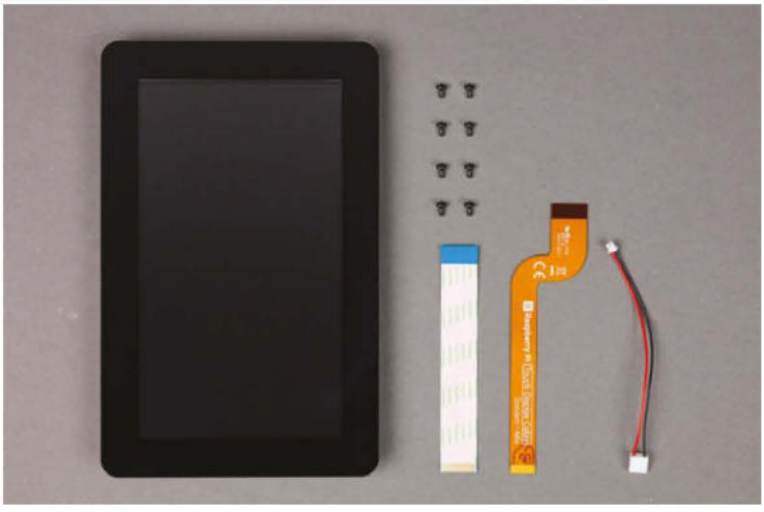
use a Flat Flexible Cable (FFC) and a GPIO connector. The FFC you'll use depends upon your Raspberry Pi model: for Raspberry Pi 5, use the included 22-way to 15-way FFC; for any other Raspberry Pi model, use the included 15-way to 15-way FFC.

Once you have determined the correct FFC for your Raspberry Pi model, complete the following steps to connect your Touch Display 2 to your Raspberry Pi:

> The Touch Display 2 is compatible with all models of Raspberry Pi, except Zero

1. Disconnect your Raspberry Pi from power.
2. Lift the retaining clips on either side of the FFC connector on the Touch Display 2.
3. Insert one 15-way end of your FFC into the Touch Display 2 FFC connector, with the metal contacts facing upwards, away from the Touch Display 2.
4. While holding the FFC firmly in place, simultaneously push both retaining clips down on the FFC connector of the Touch Display 2.
5. Lift the retaining clips on either side of the DSI connector of your Raspberry Pi. This port should be marked with some variation of the term 'DISPLAY' or 'DISP'. If your Raspberry Pi has multiple DSI connectors, prefer the port labelled '1'.
6. Insert the other end of your FFC into the Raspberry Pi DSI connector, with the metal contacts facing towards the Ethernet and USB-A ports.
7. While holding the FFC firmly in place, simultaneously push both retaining clips down on the DSI connector of Raspberry Pi (see **Figure 2**, overleaf).
8. Plug the GPIO connector cable into the port marked J1 on the Touch Display 2.
9. Connect the other (three-pin) end of the GPIO connector cable to pins 2, 4, and 6 of Raspberry Pi's GPIO. Connect the red cable (5V power) to pin 2, and the black cable (ground) to pin 6. Viewed from above, with the Ethernet and USB-A ports facing down, these pins are located at the top right of the board, with pin 2 in the top right-most position (see **Figure 3**, overleaf).
10. Optionally, use the included M2.5 screws to mount your Raspberry Pi to the back of the Touch Display 2.

Figure 1: What's in the box



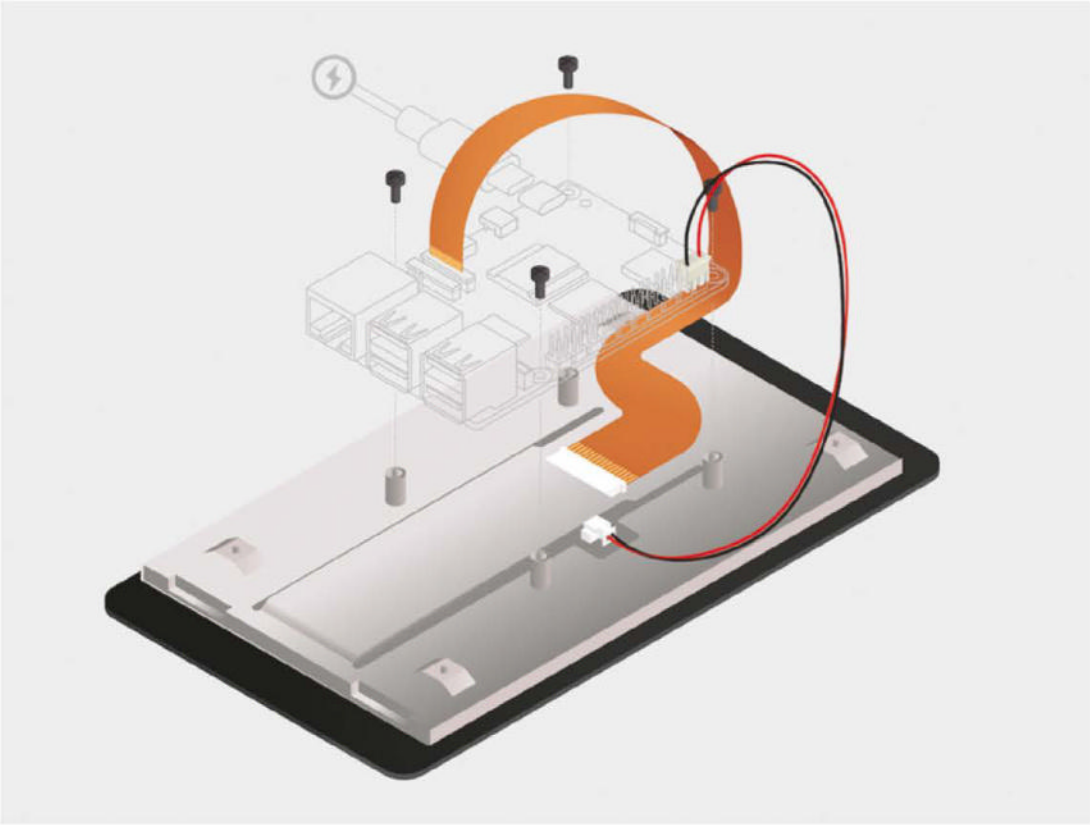


Figure 2 A Raspberry Pi 5 connected and mounted to the Touch Display 2

11. Align the four corner stand-offs of your Raspberry Pi with the four mount points that surround the FFC connector and J1 port on the back of the Touch Display 2, taking special care not to pinch the FFC.
12. Insert the screws into the four corner stand-offs and tighten until your Raspberry Pi is secure.
13. Reconnect your Raspberry Pi to power. It may take up to one minute to initialise the Touch Display 2 connection and begin displaying to the screen.

> The on-screen keyboard should automatically show when it is possible to enter text

Use an on-screen keyboard

Raspberry Pi OS Bookworm and later include the Squeekboard on-screen keyboard by default. When a touch display is attached, the on-screen keyboard should automatically show when it is possible to enter text and automatically hide when it is not possible to enter text.

For applications which do not support text entry detection, use the keyboard icon at the right-hand end of the taskbar to manually show and hide the keyboard.

You can also permanently show or hide the on-screen keyboard in the Display tab of Raspberry Pi Configuration or the `Display` section of `raspi-config`.

In Raspberry Pi OS releases prior to Bookworm, use `matchbox-keyboard` instead. If you use the Wayfire desktop compositor, use `wvkbd` instead.

Change screen orientation

If you want to physically rotate the display, or mount it in a specific position, select Screen Configuration from the Preferences menu. Right-click on the touch display rectangle (likely DSI-1) in the layout editor, select Orientation, then pick the best option to fit your needs.

Rotate screen without a desktop

To set the screen orientation on a device

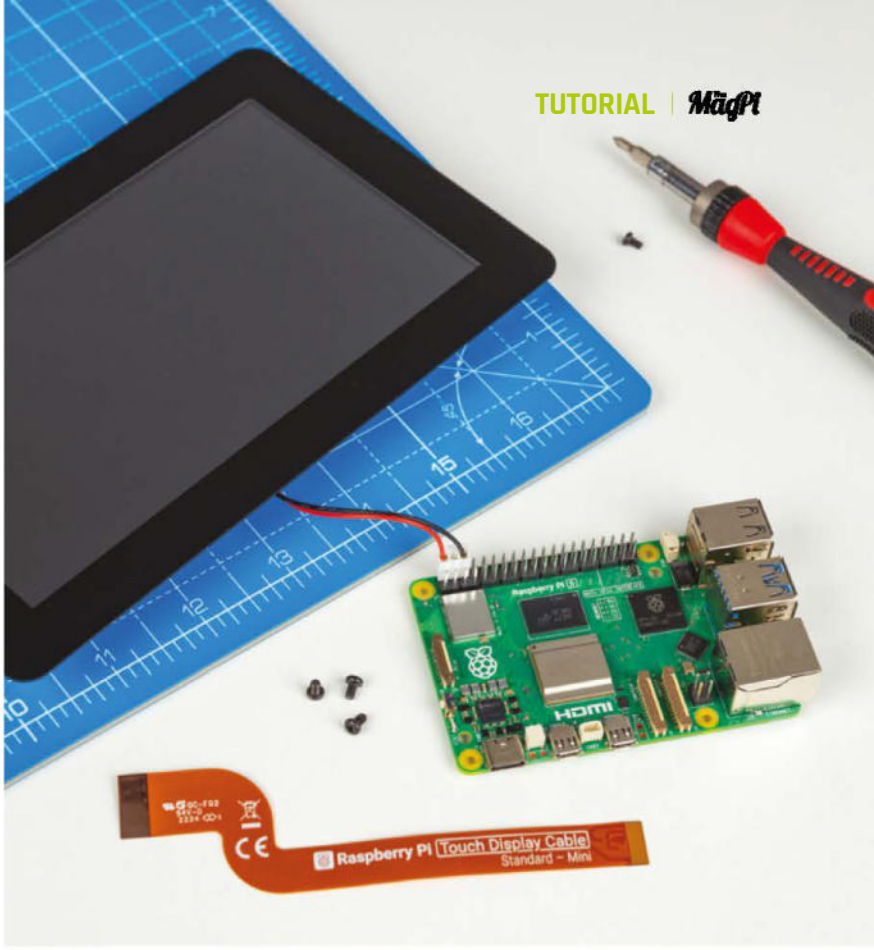
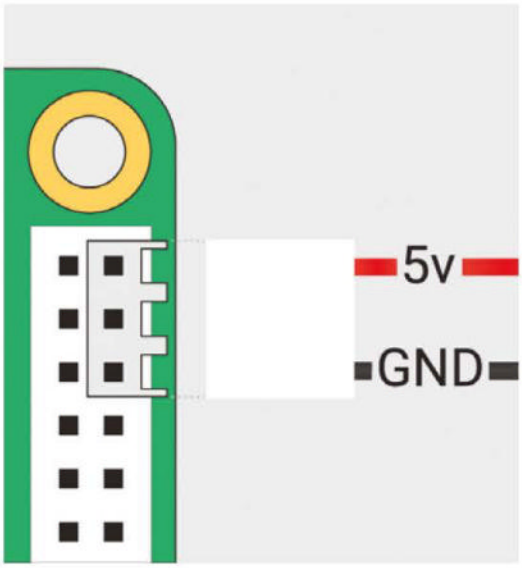


Figure 3: The GPIO connection to the Touch Display 2



that lacks a desktop environment, edit the **/boot/firmware/cmdline.txt** configuration file to pass an orientation to the system. Add the following entry to the end of **cmdline.txt**:

```
video=DSI-1:720x1280@60,rotate=<rotation-value>
```

Replace the `<rotation-value>` placeholder with one of the following values, which correspond to the degree of rotation relative to the default on your display:

- 0
- 90
- 180
- 270

For example, a rotation value of 90 rotates the display 90 degrees clockwise. 180 rotates the display 180 degrees, or upside-down.

Note: It's not possible to rotate the DSI display separately from the HDMI one with **cmdline.txt**. When you use DSI and HDMI simultaneously, they share the same rotation value.

Touch Display 2 device tree option reference

The vc4-kms-dsi-ili9881-7inch overlay supports the following options:

DT parameter	Action
sizex	Set X resolution (default 720)
sizey	Set Y resolution (default 1280)
invx	Invert X coordinates
invy	Invert Y coordinates
swapxy	Swap X and Y coordinates
disable_touch	Disable the touch overlay totally

To specify these options, add them, separated by commas, to your `dtoverlay` line in the **/boot/firmware/config.txt** file. Boolean values default to true when present, but you can set them to false using the suffix `=0`. Integer values require a value, e.g. `sizey=240`. For instance, to set the X resolution to 400 pixels and invert both X and Y coordinates, use the following line:

```
dtoverlay=vc4-kms-dsi-ili9881-7inch,sizex=400,invx,invy
```

Connecting Touch Display 2

Part 02

Build your own streaming media server

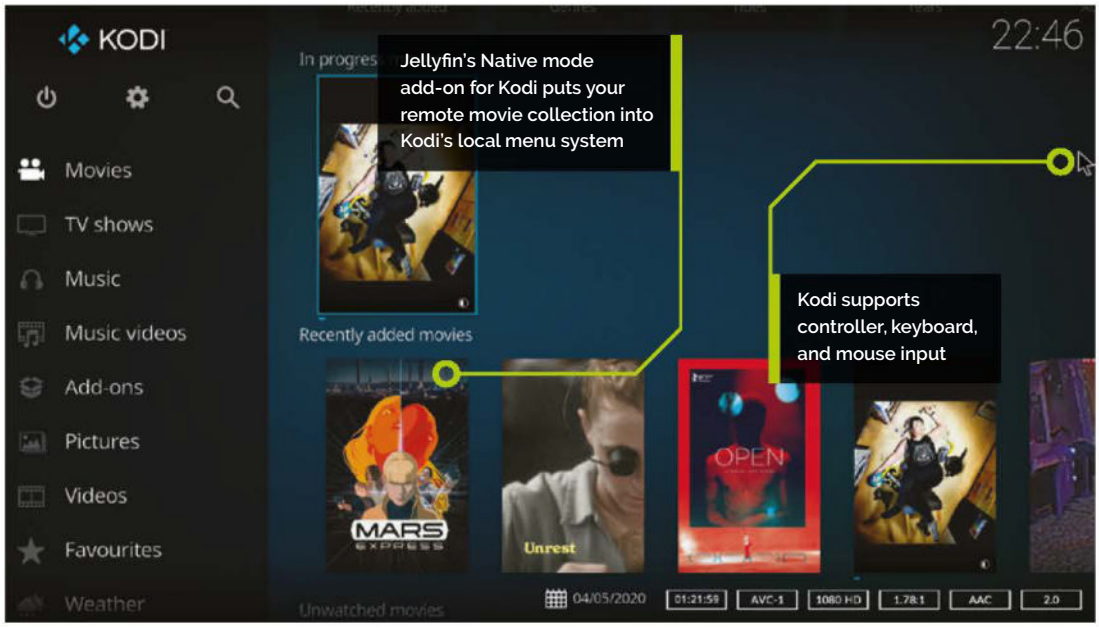
Last month, we used Jellyfin to build a streaming media server. Now, we'll build a specialised LibreELEC-based Kodi box so our TV can talk to that server

MAKER

K.G. Orphanides

KG has been hoarding media since the late 1990s and sees no reason to stop now, just because everything's gone digital.

twoot.space/@owlbear



Following on from last month's tutorial on building your own streaming audio and video server using Jellyfin, we're now going to look at receiving those streams beyond the web interface, with particular focus on building a streaming media receiver box for your TV.

As with the Jellyfin server that we built last month, you'll ideally want to use a Raspberry Pi 4 or 5 with at least 4GB RAM. Depending on how convenient your AV system is to get at, you might want to do all your configuration on a spare monitor and then just plug the Kodi box into your TV or AV receiver once it's configured.

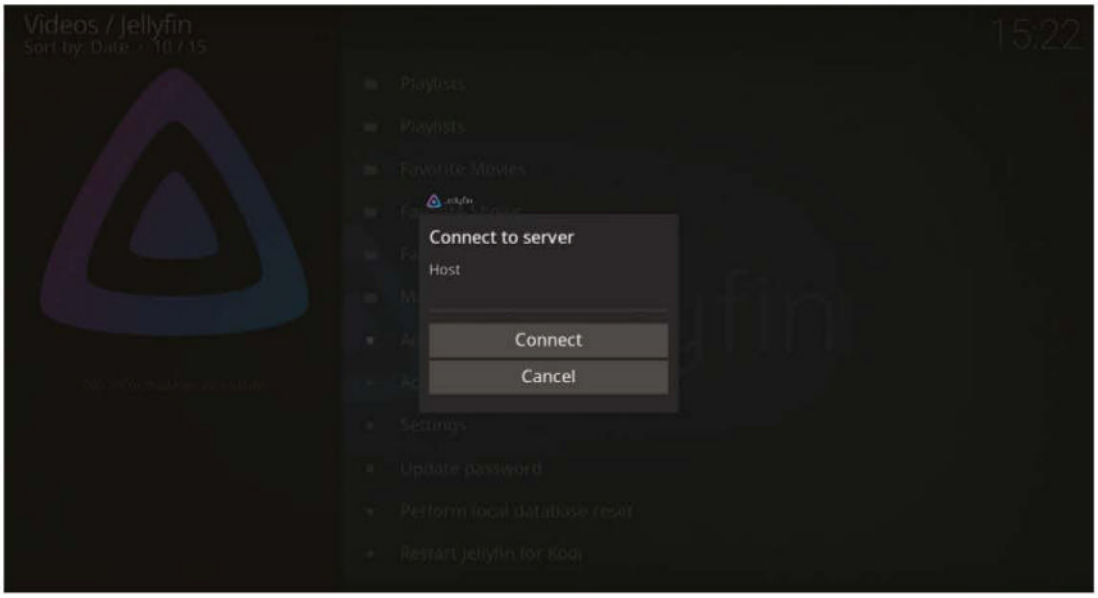
You'll Need

- Wireless keyboard/trackpad (optional)
- Wireless controller

01 Install LibreELEC on an SD card

LibreELEC is a minimalist distro that exists to run the Kodi home theatre suite. We're going to combine that with a deeply integrated Jellyfin plug-in to make a customised Jellyfin receiver. We'll use the Raspberry Pi Imager (**magpi.cc/imager**) to write a bootable SD card. Select which Raspberry Pi you'll be using and under Operating System, scroll down to Media Player OS > LibreELEC and select the suggested version. Select your microSD card and click Next to write the OS to it.

You can connect either a keyboard or a joypad to set up and control LibreELEC. It's worth using



When you install the Jellyfin add-on, you'll have to provide the address and port number of your Jellyfin server

wired peripherals initially. We'll set up Bluetooth controls shortly.

02 Start setting up your Kodi box

Power on Raspberry Pi and follow the wizard to name your new streaming media receiver, connect it to a Wi-Fi network (if you're not going to be keeping it on your wired network), and enable SSH for remote access – you'll be obliged to set a strong password.

You can also enable Samba if you want to be able to drop items into your receiver's hard disk or access content elsewhere on your network, but this isn't necessary as our Jellyfin server will be delivering remote content and we don't wish to confuse the issue with multiple sources.

03 Enable remote access

Navigate to gear icon > System information to see your LibreELEC box's IP address and then SSH in to **root@x.x.x.x** (where the IP address is whatever you just looked up). Alternatively, and perhaps more conveniently, you can install the Web SSH Terminal by using Kodi's interface to go to Add-Ons > Install from repository > LibreELEC Add-ons > Program Add-ons > System Tools > Web SSH. You'll then be able to access Kodi's web SSH interface by going to **x.x.x.x:11111**.

While you're browsing the add-on repositories, you might notice a Jellyfin add-on in LibreELEC's repos. This is the server component, for those who wish their Kodi box to also be a Jellyfin server, and isn't what we require for this project.

04 Add the Jellyfin repository

As we don't intend to use Kodi for anything other than Jellyfin in this project, we're going to use the 'Jellyfin for Kodi' add-on to fully integrate our remote media into LibreELEC's main Kodi interface. If you use your Kodi setup to play locally stored media as well, you should instead use the JellyCon plug-in. Details of both are available at **magpi.cc/jellykodi**.

Once logged into your system's terminal, type:

```
$ wget https://kodi.jellyfin.org/repository.jellyfin.kodi.zip
```

With that done, you can close the web SSH interface and return to your Kodi system.

05 Install Jellyfin

Go to Add-ons > Install from zip file.

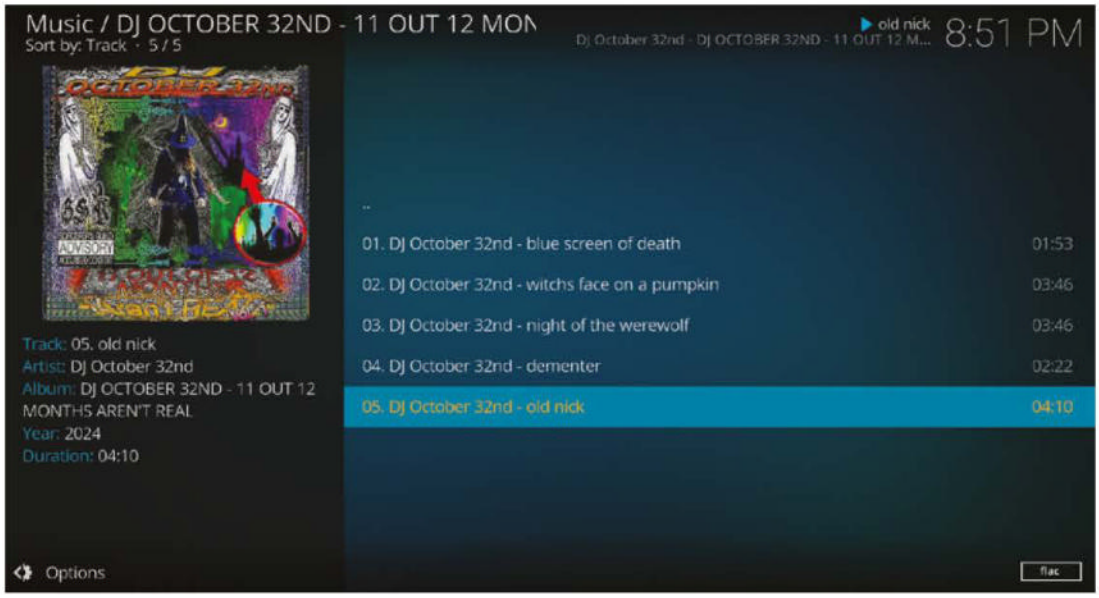
You'll see a message telling you that 'For security, installation of add-ons from unknown sources is disabled.' Select the Settings button in this pop-up. This will take you directly to your Add-ons settings, where you can enable installation

Kodi can pick up live weather data from a variety of services

Warning!
Copyright

UK law does not allow you to copy CDs, DVDs, or other media discs. This feature includes recommendations for numerous services that will sell you downloadable music and movies.

magpi.cc/copyright



Full integration with Kodi, alongside the Jellyfin server's metadata handling, gives you full album art and details when you play music

from unknown sources. Flip the 'Unknown sources' radio button on, say Yes to the personal data responsibility warning, and exit the screen by pressing **ESC**, right mouse button, or circle.

Go to Add-ons > Install from zip file, then browse to the Home folder and select **repository.jellyfin.kodi.zip**.

Now go to Add-ons > Install from repository > Kodi Jellyfin Addons > Video add-ons > Jellyfin.

06 Connect to your server

Once it's installed, a pop-up reading 'Select main server' will appear.

To access the Jellyfin server we set up last month, select 'Manually Add Server' and enter the IP address and port of your Jellyfin server. The default port is 8096 so, whether it's on your local network or accessed via the web, you'll be looking at a format that looks something like:

```
x.x.x.x:8096
```

You'll then be prompted to sign into an account on your server.

The LibreELEC distro adds its own menu to Kodi's standard settings, giving you additional control over system, updates, networking, and peripherals

We suggest creating a new account on your Jellyfin server especially for your streaming media box, so you can easily tweak which libraries it has access to at any given point.

Enter the account's username and password in the Kodi pop-up and click 'Sign in'.

07 Set up the Jellyfin plug-in

You'll be prompted to choose between Native mode and Add-on mode, but Native mode, as well as having fewer of Jellyfin's best features such as media transcoding, doesn't work with recent versions of Jellyfin server. Select Add-on mode, which is already the default. Choose which libraries you'd like to add on the next screen – there's an All option if you want everything – and click OK. If you have a large Jellyfin library, it'll take a while to sync the server's database to Kodi.

08 Navigating your Jellyfin library

Once that's done, you'll be able to access your Jellyfin library from the Add-ons menu. It'll also be used to populate Kodi's main Music, Music Videos, and Videos menus, but this will mostly happen as you listen to music and watch films that Kodi will use to populate its fast-access menus of your favourite. Whether you select the video or music add-on, you'll be taken to the same folder-tree style interface that gives you access to each of your Jellyfin libraries, as well as your playlists, favourites, and management options that allow you to add extra servers, change your server login details and access the settings screen.

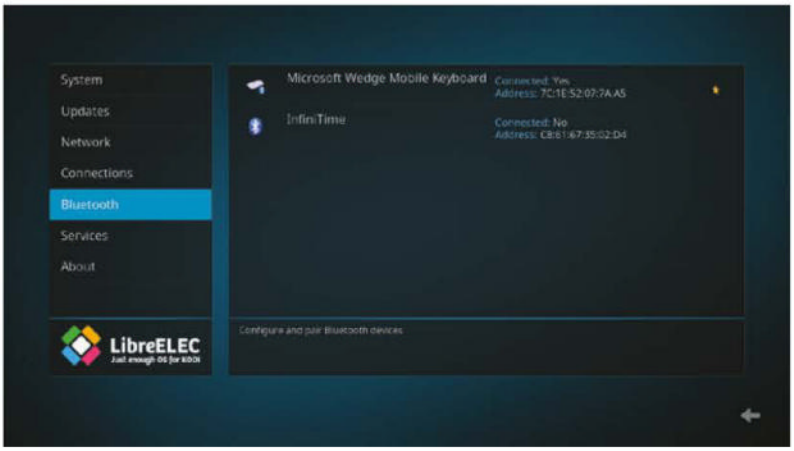
Top Tip

Easy access

To quickly edit config files, copy over files, and browse LibreELEC's file system, you can connect to it remotely via SFTP from most Linux file managers.

09 Jellyfin plug-in settings

The settings available in the Jellyfin for Kodi app include synchronisation options to potentially improve the speed of library syncs, options to ignore TV show specials and make cast and crew members searchable, and set default transcoding options. It's worth bearing in mind that Kodi will resync with Jellyfin upon every reboot, although this won't take as long as your initial sync unless you add a lot of new content to Jellyfin's library. Unlike desktop and mobile Jellyfin clients, the client does not give you full access to the Jellyfin server configuration dashboard.



You can connect Bluetooth devices to LibreELEC, but you'll have to set up an autostart file if you want them to autoconnect on boot

10 Tidy Kodi

Now that you can access your media server, you'll probably want to do a bit of housekeeping in Kodi, such as setting your weather provider, manually setting your location if needed, and removing any unneeded options – we didn't require a PVR, web radio, or games.

In Settings > Interface > Regional, you'll want to set your country to get your expected timekeeping and temperature measurement conventions, and you can set your Timezone country as something different if you prefer the conventions of one locale but live in another. Your interface options also include themes and other visual customisation options.

To connect Bluetooth devices such as keyboards and controllers, go to Settings > LibreELEC > Bluetooth, where you can search, pair, and connect your devices. However, to automatically repair on boot, you'll need to create the file **/storage/.config/autostart.sh**.

See our code listing on this page for an example and **magpi.cc/lelecdocs** for documentation.

11 Other mobile and desktop Jellyfin clients

If you don't need a dedicated receiver box for Jellyfin, you can find clients for Linux (amd64 and aarch64), Windows, and macOS at **magpi.cc/jellydl**, as well as iOS, tvOS and Android clients on F-Droid, Google Play and the Play Store – these include support for Android TV and Amazon FireTV devices. There's even support for Roku and webOS devices. Beyond that, almost any device with a web browser can access Jellyfin via its outstanding web interface.

12 Optimising client playback settings for clients

While you can use the web interface from almost any device, we found that using it on weaker internet connections in particular can highlight problems. For example, if your music collection is mostly in lossless formats such as FLAC and AIFF, expect tracks to stutter upon streaming if you're out of the house with slow mobile broadband. This can be improved by using a dedicated client which will carry out audio and video transcoding for you, but if you still experience issues, using lossy formats such as OGG or MP3 will give you better streaming performance.

The Android client has useful options under Settings > Playback and Settings > Client settings. For improved video codec support, switch from the web player to the client's internal player or an external app such as VLC. If you find that audio tracks are too quiet on any of your Jellyfin clients, disable Normalization, which is on by default in both the Android and Linux desktop clients.

Top Tip

A quick snap

Whether you want to grab a movie still or capture the interface, press **CTRL+S** to take screenshots within Kodi.

/storage/.config/autostart.sh

Language: **bash**

DOWNLOAD THE FULL CODE:
magpi.cc/jellypt2

```
001. #!/bin/bash
002. (
003. sleep 10
004. echo -e "connect XX:XX:XX:XX:XX:XX\nexit" | bluetoothctl
005. sleep 10
006. ) &
```

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TECHNOLOGY IN YOUR HANDS

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OBJET 3D'ART

FORGE

PG 92

ROBOTICS

The best artificial workers for your evil underground factory

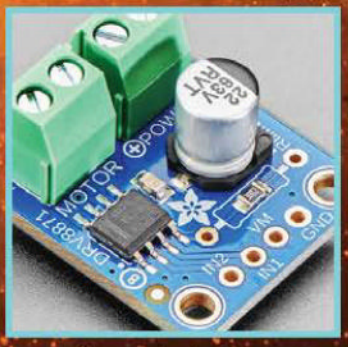
Best of Breed

REVIEW

PG 90

NEORULER GO

A computerised laser measuring device that still uses feet and inches



Micro Journal

By **Un Kyu Lee** hsmag.cc/MicroJournal

The internet is a giant distraction machine. How does anyone get any work done when they're constantly plugged into the mental churn of social media, 24-hour news, and an endless supply of cute cat videos? It takes an iron will to ignore such distractions. Or if you're smarter than that, you could simply cut the distractions out of your life, with something like the Micro Journal: a distraction-free writing device.

Described by the maker as a "modern solution with a nostalgic twist, designed specifically for writers who crave focus and mobility", this foldable device has all the charm of a vintage typewriter. Not only does it have delicious clicky Cherry MX keys, it also uses some of the controls of vintage typewriters. Rather than changing line spacing via a drop-down menu in Microsoft Word, for example, the user rolls a physical knob.

You can choose between AZERTY, QWERTY, DVORAK or any other key mapping you want – you can even remap individual keys to your personal preferences by copying a configuration file to an SD card in the device. Want one? The Micro Journal is out of stock right now, but it'll be back by the weirdly specific time of 6pm Italian time on 14 January 2025.

Right The Micro Journal is built around a Raspberry Pi Zero 2 W


micro Journal Rev.2.ReVamp
using raspberry pi zero 2w and ultra wide screen
and side knobs to emulate page up and down just like the type writer! _
34 words
P: 3/9

The Pet Piano

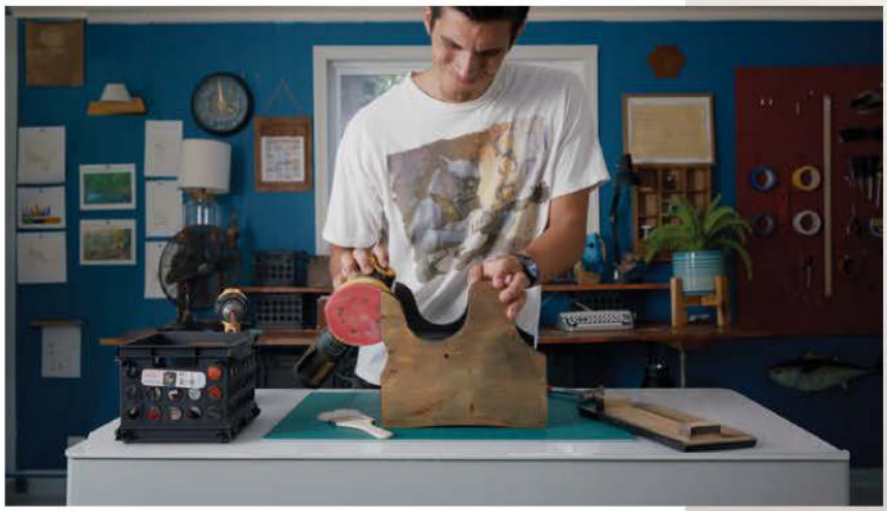
By Aaron Benitez

Thepetpiano.com

The Pet Piano is a brilliant device that teaches your pets to play the piano. Seriously! It includes a keyboard and a food dispenser, and it releases food when a key is pressed on the piano keyboard. What's more, it releases more food if the pet plays an ascending series of notes. The piano can add harmonised notes, so your little Meow-zart will always sound good no matter what it plays, and you can control various parameters from a phone app.

In creating this piano, Aaron built an MDF case, used 3D printing to build the food dispenser (even though he designed it with injection moulding in mind), and printed the keys of the keyboard – he recommends using a springy material such as PETG or nylon rather than PLA or ABS.

Ivan Pavlov taught dogs to respond to external cues to activate their salivary glands. He was awarded the Nobel prize in 1904, and his name will be forever attached to the field of psychology known as reflexive conditioning – better known as Pavlovian conditioning. Aaron Benitez has built a computerised musical instrument that teaches household pets to play the piano in exchange for food. Not only that, but unlike Ivan Pavlov, he has done so without the aid of vivisection, killing precisely 0 dogs in the name of science. Who do you think is more worthy of our applause? Clearly, it's Aaron. We'll have a word with the committee; your Nobel Prize is in the post.



Right
Previous iterations of this project used an Arduino for the intelligence, but Aaron has settled on an ESP32 now


A
B
C
D
NEXT
EN

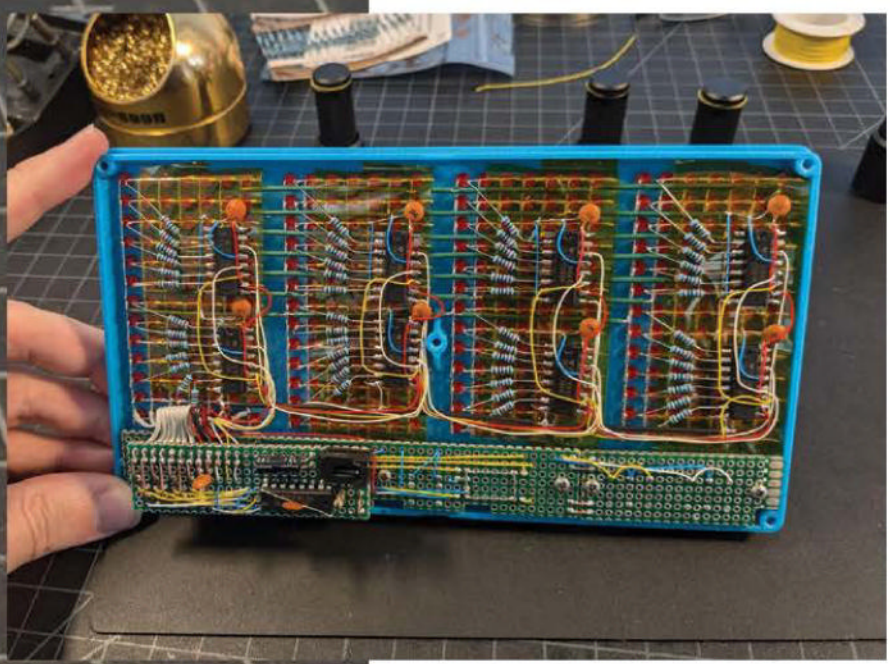
Habit Tracker

By **Dycus** hsmag.cc/HabitTracker

You can get a calendar app on anything that's connected to the internet: your laptop, your phone, your smartwatch can all be used to record regular tasks, so you can see at a glance whether you've put the bins out / gone for a run / practised the guitar that day. But these devices, with their anonymous glowing screens, don't have a matrix of individually wired LEDs and 3D printed physical switches, and that's why they are inferior to this device built by Reddit user Dycus.

Inspired by Simone Giertz's Every Day Goal Calendar, with its super-luxury gold PCB and bamboo frame, Dycus built their calendar to help enforce their daily habits. The days of the year are represented by 364 LEDs; each day, the user presses either the thumbs-up or thumbs-down button to indicate whether they've managed to complete up to four daily tasks – that way, the same 364 LEDs can represent four habits (just not at the same time).

Split into four sections, the 7×52 LED matrix is driven by a Teensy 2.0 with shift registers for the rows and MOSFETs for the columns. If you fancy building your own, the files and code are all available.



Left The internal wiring is incredibly neat and tidy – we'd love to see a version of this build with a clear Perspex back to show it all off

Objet 3d'art

3D-printed artwork to bring more beauty into your life

We're suckers for an original clock design, and this 3D printed effort from James Watts is a great example. Instead of numbers around the analogue clock face, it sports 3D printed hands, with the position of those hands matching where the minute hand of the clock will be. It's slightly baffling – despite our many years on this earth, we were slightly confused by the interface, even though it is at heart just a standard analogue clock.

Mechanically, the Clock2 uses a Clock Kit 011, which is a standard set of components for 3D printed clocks. That, and the fact that James has shared the STL files for all to see on **MakerWorld.com**, means that this build is within reach of pretty much anyone with access to a 3D printer. What's more, James is doing his development out in the open. The smaller clocks around the outside of the clock face don't move – they're just there to help you tell the time. But in a staggering twist of heartbreaking genius, he has purchased twelve watch mechanisms from China for £3 (yes, that's three Pounds Sterling, or €3.59, or $3.77). We can't wait to see the next version!

hsmag.cc/Clock2


CLO
CK2

What's new in FreeCAD Version 1.0

The version 1.0 milestone version of FreeCAD is out now – let's dive in and look at some of the many new features and upgrades

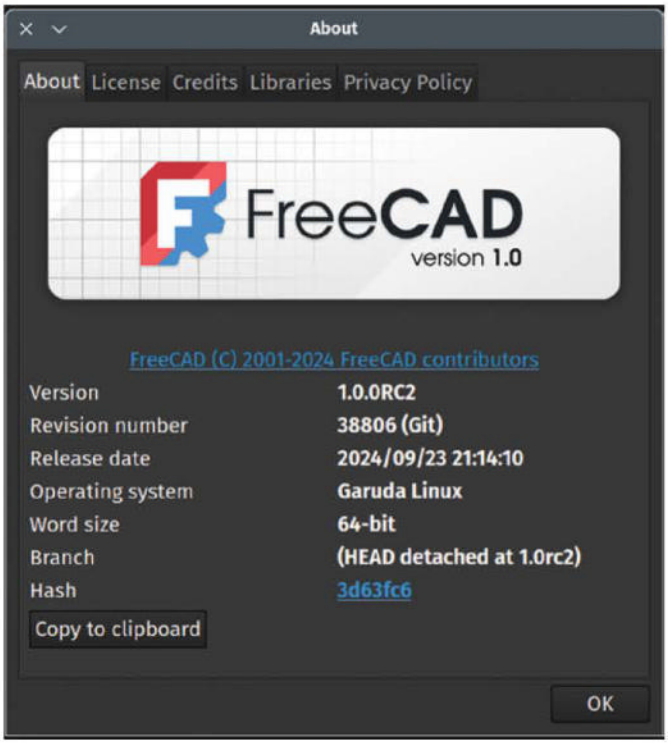
Jo Hinchliffe

@Concretedog

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

It's no secret we are fans of FreeCAD here at Raspberry Pi Press and it's an exciting time for the free and open-source project with the recent release of the landmark version 1.0. There's a huge number of tweaks and updates with some completely overhauled areas looking very different and other subtler small changes. Let's dive in and take a look.

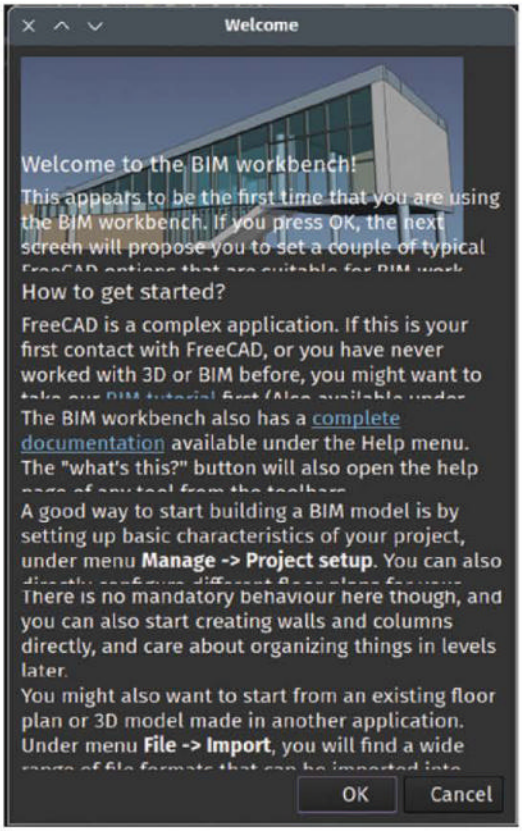
One of the larger headlines surrounding version 1.0 is about the topological naming problem mitigation. Otherwise known as 'TNP' or 'topo naming' the problem is when you have a complex part or an assembly of parts, making a change to a section may reorder the names of the edges, vertices, and faces in your project and this might break your geometry. As a simple example, imagine you have a wheel constrained to rotate around an axle using an edge on the hole at the centre of the wheel. You then redesign the wheel to have spokes and other features which also connect to the central hole edge; suddenly the name of the edge used in the assembly to constrain it is changed as the model is different. You then find in your assembly that the wheel is attached by another point in the design which now has the correct name. This is an oversimplification, but you can see why geometry can break. Often when topological naming problems happened historically, FreeCAD simply wouldn't compute the model and your part or project disappeared in the live preview.



Right
It's wonderful to see the release candidate FreeCAD packages arriving in the version 1.0 release

For version 1.0, a huge amount of work has been undertaken to mitigate this problem. A fork of the FreeCAD project, by Realthunder, originally developed this TNP mitigation algorithm, but the code needed to be carefully worked from that fork back into the main FreeCAD branch. This work has been completed and you should see fewer topological naming issues using 1.0. Note that the language around this is 'mitigation' and not 'fixed': whatever CAD package you use, and whatever underlying geometry engine that CAD uses, you can always create topological naming errors if you try hard enough!

If you are new at the zoo, it's worth noting that FreeCAD uses a workbench approach in that you



Left
The old 'Arch' or architecture workbench has been completely overhauled and is now titled 'BIM' (Building Information Management)

can switch between a large collection of included workbenches and install further community-contributed workbenches, and these all contain curated sets of tools. For example, there are standard workbenches like Part Design, a Sketcher workbench, a Draft one and more, through to exotic workbenches for all manner of things, from rocketry to guitar building!

NEW ASSEMBLY WORKBENCH

One area that was previously slightly confusing was that there were numerous workbenches all focused on creating assemblies. Again, for the uninitiated, creating assemblies in CAD is where you assemble separate parts into some kind of system and you might constrain parts together so they behave in a way that is consistent to the design. In the free-to-download book *FreeCAD for Makers* (**hsmag.cc/FreeCADBook**), we made an assembly with a pulley wheel and axle with some brackets holding it to a base plate (**Figure 1**). In that assembly, we constrained the pulley wheel to the shaft so that you could turn the pulley around the shaft

Numerous parts of the FreeCAD developer community over the years worked on Assembly-themed workbenches, which led to numerous workbenches being available. Of course, this can be a little confusing for new users and also created some confusion in supporting tutorials. For version 1.0, a completely new Assembly workbench is built in to FreeCAD and will be the officially supported workbench as the project moves forward (**Figure 2**).

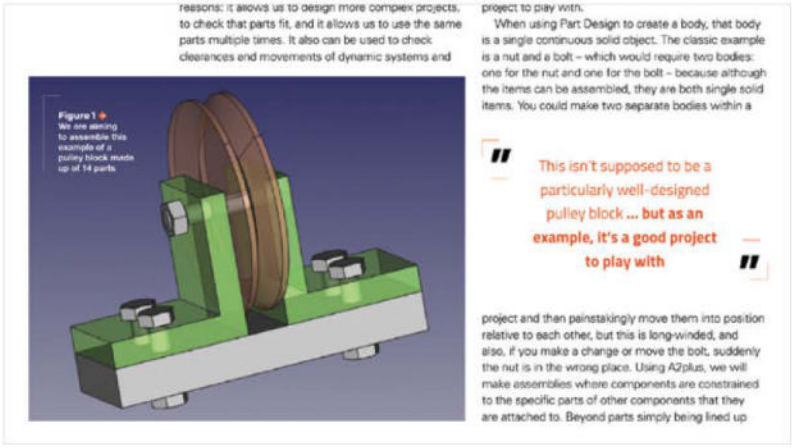
There are lots of updates to the user interface. One of our favourites is that there is now a set of selection filters. This new tool icon appears near the view settings on every workbench and allows you to switch between being only allowed to select edges, vertices, or faces, or you can turn off the filters to be able to select anything. This can help avoid frustration and speed up work; for example, if you are selecting only edges for adding chamfers, you can set the tool to edges only and instantly speed up your process.

> One area in which you'll notice lots of **improvements is the Sketcher workbench**

These filters also simplify situations where you have geometry that is extremely close together or converging to a single point. Previously, if you had two edges converging at a narrow angle, the pick radius of the selection tool could make it very difficult to pick the vertex rather than one of the edges. This is simply not a problem any more: switch the selection filter to vertex only and your problem is solved (**Figure 3**).

One area in which you'll notice lots of improvements is the Sketcher workbench **(Figure 4**). Some tools have been optimised and streamlined. One notable example is the new 'Dimension' tool icon. The Dimension tool allows you to add dimensional constraints contextually based on the geometry you have selected. So, for example, if you draw a rectangle and then, using the Dimension tool, click one of the horizontal lines, it will automatically switch to the horizontal dimension tool. This means you can often create a sketch and then, with just this tool, jump around constraining different

Figure 1
An assembly on the older A2PLus workbench was featured in the *FreeCAD for Makers* book



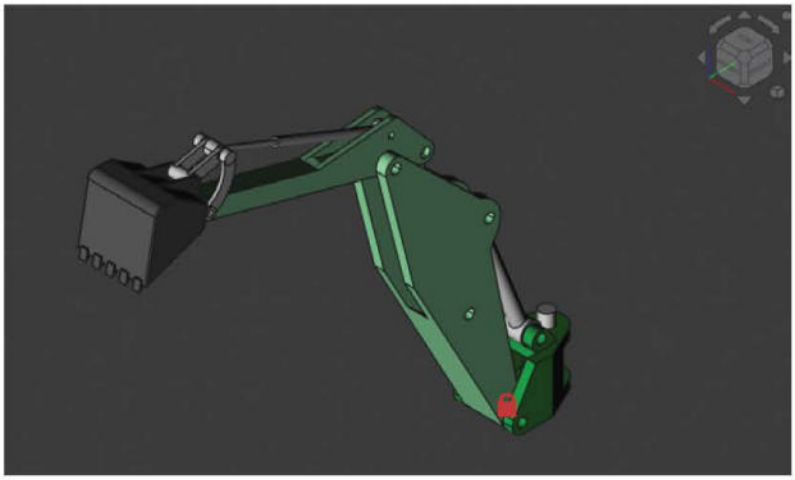


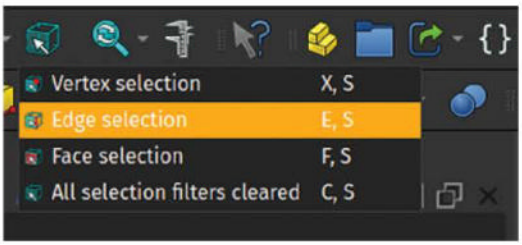
Figure 2
The all-new Assembly workbench

Figure 3
Using the new selection filter tool can speed up the selection of parts, leading to more efficient modelling

parts of the geometry without constantly switching tools. The Dimension tool icon is also a drop-down and so you can sub-select particular tools when needed.

Another change in the Sketcher workbench is the 'On View Parameters' feature. This allows you to constrain parameters as you create geometry in a sketch, rather than the older approach of drawing an object and then adding dimensions. Using the default settings in version 1.0, if for example you select the rectangle tool when you begin to draw a rectangle, the horizontal dimension will have a live parameter input box; you can type a value for the horizontal dimension and then press **ENTER** and you'll automatically switch to the vertical dimension parameter input (**Figure 5**). Adding a value to the vertical input and pressing **ENTER** will finalise your rectangle, which will be dimensionally constrained. These On View Parameters input boxes are available for all drawable geometries from simple single lines through to the more complex tools like the slot tool. If you aren't a fan of this approach, you can turn the On View Parameters function off in the Sketcher preferences menu. If you are a fan, you might want to consider switching to the 'Positions and dimensions' option in the Sketcher preferences. With this option enabled, the positional constraints are also included so that, again using the rectangle tool as an example, when you select the tool there are two On View Parameters inputs to set the start position of your rectangle. Inputting the positional elements again, using the **ENTER** key to switch to the next input box, you continue to add the dimensional constraints and you end up with a fully constrained sketch element.

Figure 4
There are lots of changes and additional tools on the Sketcher workbench hugely optimising sketching operations.

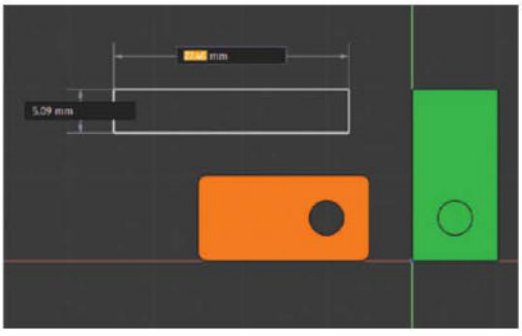


MULTIPLE OPERATIONS

The usage of sketches has also seen some development for version 1.0. One popular improvement is that you can now perform multiple operations on single sketch. Prior to version 1.0, if you wanted to extrude a sketch and then cut a pocket into that sketch, for example, the workflow would be to create one sketch for extrusion, then create another sketch on the face of the extrusion to then perform a pocket operation. It's now possible to streamline this process into a single sketch.

For example, if we create a new body on the Part Design workbench and then create a sketch in the XY plane, we can then draw a rectangle in a sketch. Next, we place two nested circles in it and perhaps a hexagon shape. We can then close the single sketch. Back in the Part Design workbench, we can now select the rectangle and click the Pad tool. In the Pad dialog we can set a length, but let's also set the direction to reversed. This creates the pad but leaves the sketch visible on the upper face. Next, let's multi-select our circles and again click the Pad tool. We can pad the circles up into a cylinder. Finally, make the sketch visible again and select the hexagon elements; clicking the Pocket tool, we can cut a hexagonal pocket into our rectangular pad (**Figure 6**). This multi operation on a single sketch approach is an additional feature so, like many of the new features in version 1.0, it's still

Figure 5
Using the new On View Parameters allows you to add positional and dimensional constraints whilst generating new sketch items, making the sketch process much more efficient



possible to work using the pre-version 1.0 approaches for maximum flexibility.

You may well notice in version 1.0 that things just look nicer! There are many improvements to the general look and feel of FreeCAD, including a revised start page. There are more options regarding themes and also optional improvements such as transparency in window overlays and more. There are more themes and more theme options, so it's a great time to tinker with your setup and find options you enjoy. Another visual aspect is that movement of models in the preview window has been optimised and there are subtle but attractive improvements in how models in preview animate into position. Speaking of the preview window, you can now customise a light source for your model. To play with the light source, click Edit (FreeCAD on macOS), then Preferences to open that window. Click the Display drop-down and then select Light Sources. You can now see a collection of Light Source controls (**Figure 7**). First of all, note that you can turn the light source off/on by toggling the checkbox in the upper right corner. Next to the checkbox is a colour selection tool; this I set to the default of a white light. If you change the colour of the light source, it'll obviously change the colour appearance of your models. The light source settings also persist, so if you forget you changed it you might wonder why all your designs are now a funny colour! There is an obvious slider bar for intensity and then you can grab the small conical handle and manipulate the angle of the light source. Note that the small grey sphere in the centre of the preview window adjusts so you can see the effect of the light source angle on it. Once happy with your light source, you can click Apply and then OK to close the Preferences window.

It feels like we've covered a lot of new functions in this article, but this is in no way a complete list! There are so many changes in version 1.0, it's hard to do them all justice. If you really want to delve into all the changes, the version 1.0 release notes can be viewed here: **hsmag.cc/FreeCADv1Notes**. Finally, we'd just like to acknowledge that FreeCAD is made by a huge team of contributors globally, all working together to give us this amazing CAD package. We'd like to express our thanks to the entire community and wish them every success with version 1.0 and beyond.

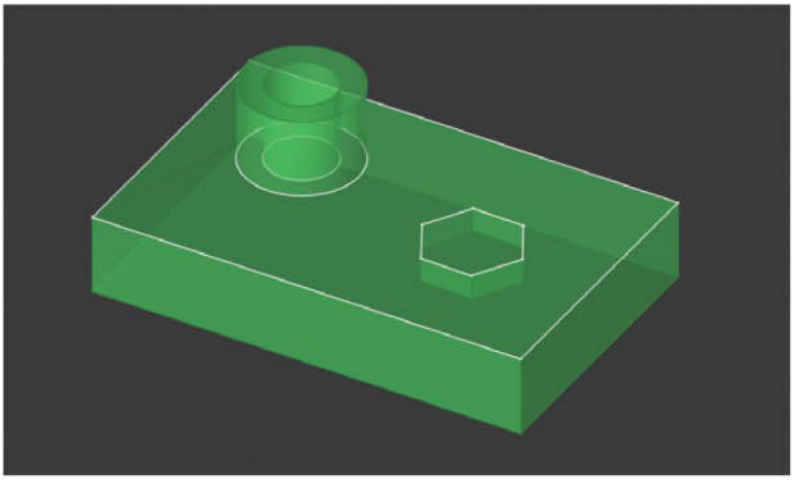


Figure 6 It's now possible to perform multiple operations to components within a single sketch

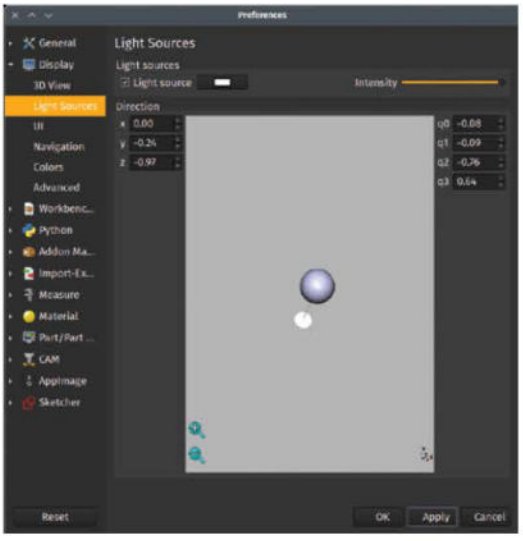


Figure 7 Editing the light source preferences for custom lighting

SPLASH SCREENS

Sometimes it's easy to overlook the improvements that don't really add any new functionality. One such improvement is that in the release candidate version 2 we've used for this article, there is a fantastic collection of splash screens with example FreeCAD projects displayed as FreeCAD launches. We've spotted ones featuring finite element analysis of disc brake rotors, architectural church models, the Thor open-source 6 degrees of freedom robotic arm, an XY format 3D printer, and much more. Whilst they don't add anything to the functionality of FreeCAD, they are excellent and it's quite inspiring to see what kind of complex projects FreeCAD can create.

QUICK TIP

Your author has also written a 'getting started' mini tutorial on the new FreeCAD Assembly workbench on the official FreeCAD blog: **hsmag.cc/FCAssemblyGuide**

Needful things: telescopic gauges

A look at the tool that tells you when you are professionally boring.

Dr Andrew Lewis

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

Above
A measure with multiple names, the telescopic gauge is also called a slip gauge or a boring gauge. While there are a few variations, they all look like a metal T shape with a knurled handle. In this image you see a telescopic gauge at the front, next to an internal snap gauge and a rather unusual bore or drill hole micrometer

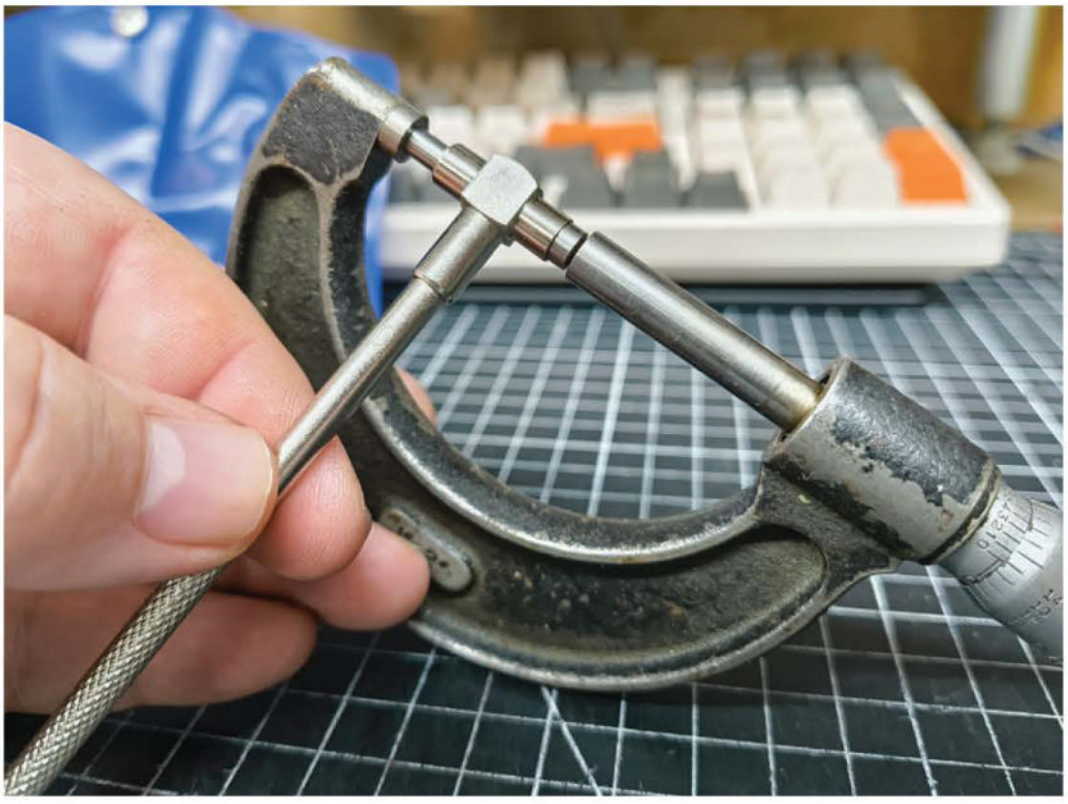
Telescopic gauges are a great way to start an argument between professional machinists. They're a tool for measuring interior diameters, so you'll mostly use them when you're trying to measure the diameter of a bore or slot. In this article you'll see what the fuss is all about, and learn how to properly use a telescopic gauge.

The cause of the contention between machinists over telescopic gauges is that they are indirect measuring devices, and the measuring process has several steps. Using a telescopic gauge is a learned technique, and until you can reproduce the technique reliably, it's likely that inaccuracies will creep in to your measurements. Whether this matters depends on whether you care about the odd micron or two creeping in or out of your measurement. Telescopic gauges also have a single point of contact with each side of the bore, so it's not always easy to tell whether your gauge is accurately positioned at the widest part of the bore, or that the bore is consistent in multiple directions. These are valid arguments for precision work, and if precision really matters then you should be considering a more effective tool like a three-point bore micrometer or internal micrometer.

So how exactly do you use a telescopic gauge to get the best results? The gauge itself is a T-shaped metal tool comprising a handle and two probes. In some gauges, both of the probes will be sprung, so that they push inwards and then spring back out. Other gauges will have only one sprung probe and the other probe will be rigid. There's a nut at the end of the handle that lets you lock the bar in place. It works a little bit like a brake, and the more you tighten the nut, the harder it will be to move the sprung probes. This is an important fact, because you need to get a feel for how tight you set the nut when taking a measurement.

QUICK TIP

It can be a bit fiddly trying to hold the micrometer, gauge, and do adjustments at the same time. You can get micrometer stands to help with this issue, or just use a splodge of hot glue.



Left
As you have probably realised by now, the telescopic gauge is only half of the equation when it comes to taking a measurement. The gauge allows you to reproduce the internal diameter, but then you need to measure that diameter using a micrometer. You can think of the telescopic gauge as an add-on for your micrometer, expanding its functionality to the measurement of interior spaces. It's a cheaper alternative than a dedicated bore gauge, and if you're not doing rocket science then it's probably going to work just fine

Below
There are lots of more accurate and repeatable ways to measure an inside diameter, but the telescopic gauge often wins out because it's cheap, easy to carry around, and doesn't need to be calibrated separately

Using the tool isn't really that difficult, but you need develop a consistent technique so that you can get repeatable results. Begin by inserting the telescoping gauge into the space that you're trying to measure, with the nut loose so that the sprung probes are free to snap to each side of the space.

Position the gauge so that it's at a slight angle to the sides (such that the probes are not perfectly perpendicular to the measured sides), and then tighten the nut on the end so that the probes will hold their position but can be moved with gentle pressure. This is the tricky part, because getting the 'feel' for this level of tightening will need to be learned by practice, and the tension feels different for different brands and sizes of telescopic gauge.

In one movement, adjust the position of the gauge so that the probes are perpendicular to the sides of the space you're measuring. Immediately take the gauge over to a micrometer so that you can measure the distance between the tips of the probes. Repeat this measurement a few times to be sure that you're getting consistent results. Once you've achieved a fair level of consistency, you'll be free to unleash your moderately accurate metrology skills on the unsuspecting world.

> Tighten the nut so that the probes will hold their **position but can be moved with gentle pressure**

VIDEO DEMOS

It's actually quite difficult to describe the measuring process without showing it in real life – but a quick search for 'how to use a telescopic bore gauge' will give you a bouquet of contradictory advice videos that you can paste together into a technique that will work well for you.

PART 02

Build a Pico software-defined radio

By connecting our Raspberry Pi Pico-based SDR to an antenna, we can listen to a wide range of radio signals

Phil King

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

Jon Dawson's Raspberry Pi Pico-based software-defined radio can be built using fairly standard through-hole electronic components and a couple of chips on a PCB protoboard or solderless breadboard. We covered creating the main circuit in the first part of this guide; now to install the firmware on Raspberry Pi Pico and connect it up to an antenna – via an optional band pass filter – and some headphones or speaker to try it out.

Based around a Raspberry Pi Pico, an analogue switch (aka multiplexer/demultiplexer), and an op-amp, this SDR receiver enables you to listen in to radio signals with a frequency of up to 30 MHz – in the long wave, medium wave, short wave, and amateur HT bands – from halfway around the globe.

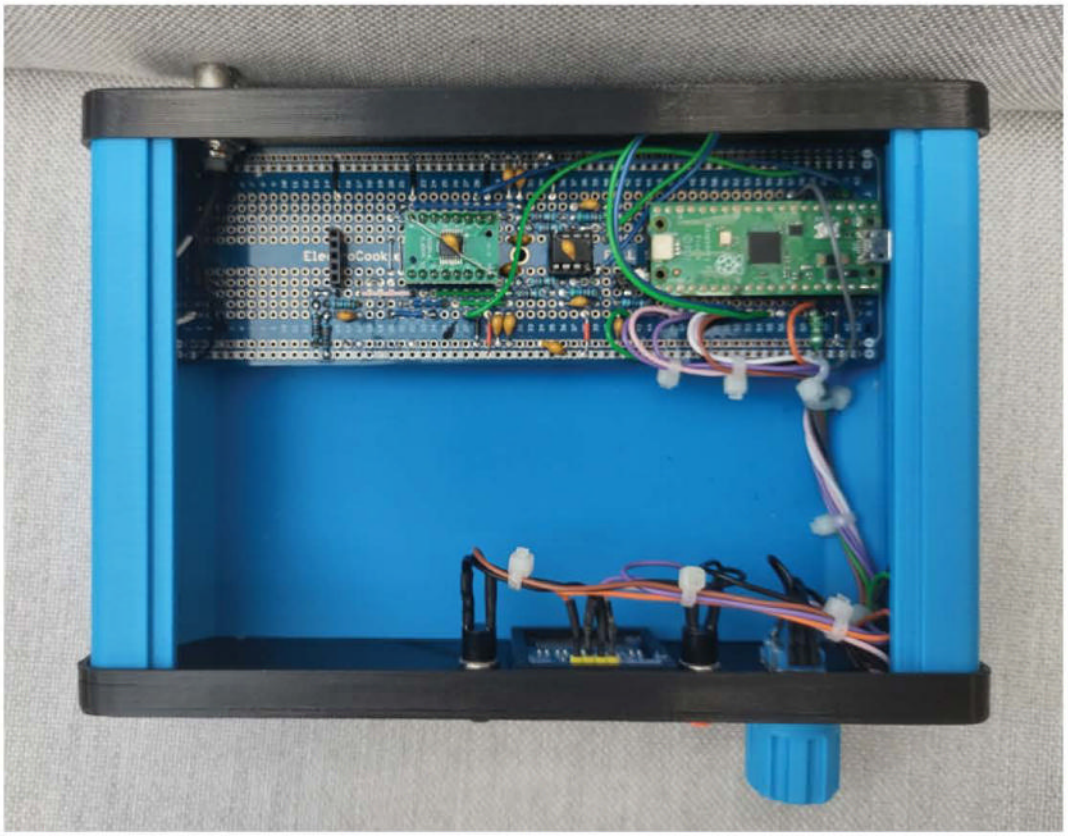
HOW IT WORKS

Full details of how the Pico-based SDR works can be found on Jon's blog page: **hsmag.cc/PicoSDR**. In short, the main circuit routes radio signals from an antenna – boosted by a low-noise amplifier (LNA) – to an analogue multiplexer chip (74CBTLV3253), which forms part of a Tayloe quadrature sampling detector. Based on a local oscillator close to the

Right
The finished Pico SDR looks great in a 3D printed case – the STL files are in the project GitHub repo

QUICK TIP

We've used the low-cost MCP6022 dual op amp, but you could swap it out for a different one. Jon has tested a few, listed on his blog.



Left
The main circuit, shown inside the optional 3D printed case, which has cutouts for the display, controls, audio output, antenna input, and Pico USB connection

desired listening frequency, generated by Pico's PIOs, the multiplexer switches the incoming radio signals rapidly between four paths. These samples are then combined and amplified in the dual op amp to generate lower-frequency I and Q (in-phase and quadrature) signals that can be sampled using the analogue-to-digital converter in Raspberry Pi Pico.

Running Jon's custom firmware, Raspberry Pi Pico does some clever stuff such as oversampling the signals to remove unwanted alias signals. Using PWM, it then outputs the final samples to a 3.5mm audio output, to which you can attach headphones or powered speakers to listen in. A rotary encoder and buttons are used to selected the desired radio frequency, with the interface info displayed on an OLED screen.

So the first thing to do, if you haven't done so already, is download the firmware for your Raspberry Pico and install it. While it's possible to build the firmware from the source code in the GitHub repo, Jon has thoughtfully provided it in a precompiled UF2 file that you can flash to Pico – visit **hsmag.cc/PicoSDRfirmware** and download the relevant UF2 file for your Pico model: standard Pico or Pico 2 – there are two versions for the latter, to use its ARM Cortex M33 or RISC-V cores.

Flashing the firmware to Pico involves the same process you'd use for any other UF2 firmware file, such as standard MicroPython. While holding its BOOT button, connect Pico via USB to a computer to mount it as a mass storage drive. Then drag the UF2 file into it to copy it over.

> "Raspberry Pi Pico does some clever stuff such as oversampling the signals to **remove unwanted alias signals**"

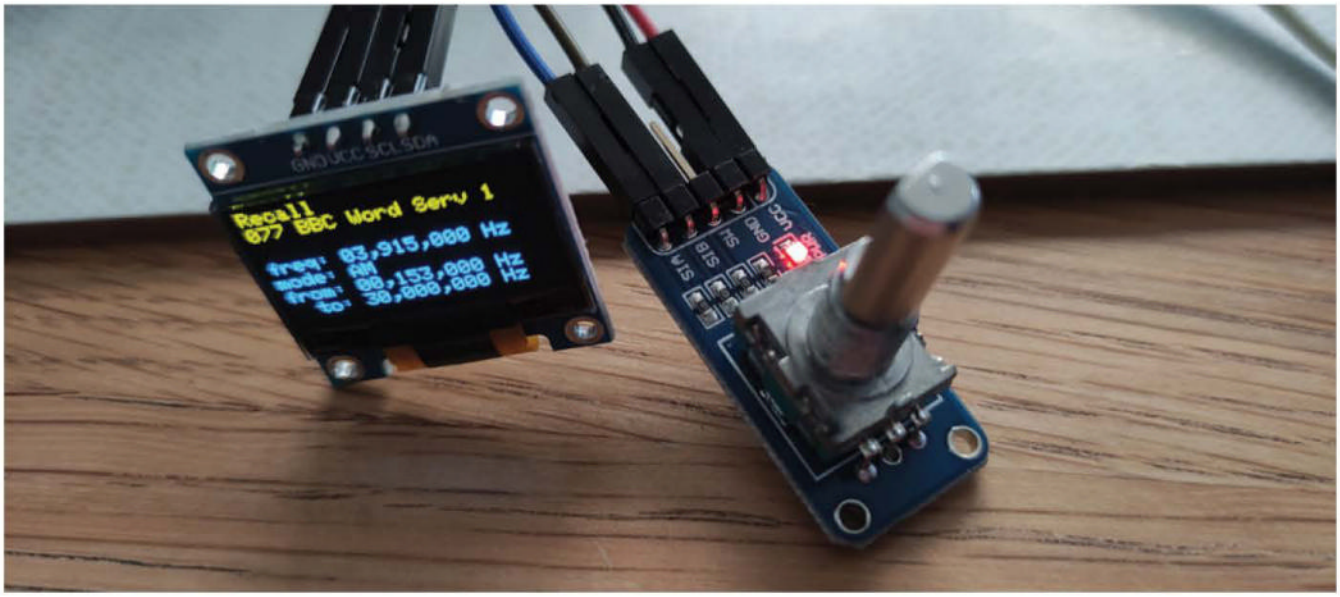
ADD AN ANTENNA

If not done already, solder signal and ground wires to the BNC (or SMA) female antenna connector (signal to the central part and ground to the outer ring/mount) and connect them to your main circuit – the signal wire is connected, via some resistors and capacitors, to pin 9 of the multiplexer. Alternatively, you can connect it via an optional band pass filter – more on that later.

The only other bit of soldering you'll need to do now is to wire a standard 9V battery connector to the power and ground pins of the wideband LNA which will boost the signal from the antenna. Remember to disconnect the battery when not using your SDR.

YOU'LL NEED

- Raspberry Pico / Pico W / Pico 2
- PCB protoboard or solderless breadboard
- 100µH inductor / ferrite bead
- MCP6022 dual op amp
- 74CBTLV3253 4:2 analogue multiplexer
- Wire stripper/ cutter tool and wires
- Capacitors: 2× 200pF, 1× 10nF, 4× 56nF, 3× 100nF, 1× 470nF, 3× 10µF, 1× 100µF
- Resistors: 4× 82Ω, 1× 100Ω, 1× 1kΩ, 2× 10kΩ, 2× 56kΩ
- 128×64 0.96-inch OLED
- 2× push-buttons (momentary)
- Rotary encoder
- 3.5mm stereo headphone jack
- Radio antenna, such as a YouLoop or similar
- Wideband LNA
- BNC (or SMA) female antenna connector



Above
Use the rotary encoder to choose a preset or adjust the frequency; the OLED shows all the details

For the antenna, you could use a random wire antenna in a high location, preferably outdoors, or in the attic. We opted for an indoor YouLoop-style antenna which offers good noise cancellation and is more portable. It includes a couple of connector boxes – phase inverter and output – and two flexible SMA cables. Connect the parts together, with the phase inverter at the top and the output at the bottom, and the antenna should form a fairly rigid loop that you can hang up for better reception – near a large window is best. Connect the supplied SMA cable to the RF input of your LNA, then an SMA-to-BNC cable to the female antenna connector you soldered earlier. You're now ready to start receiving radio signals.

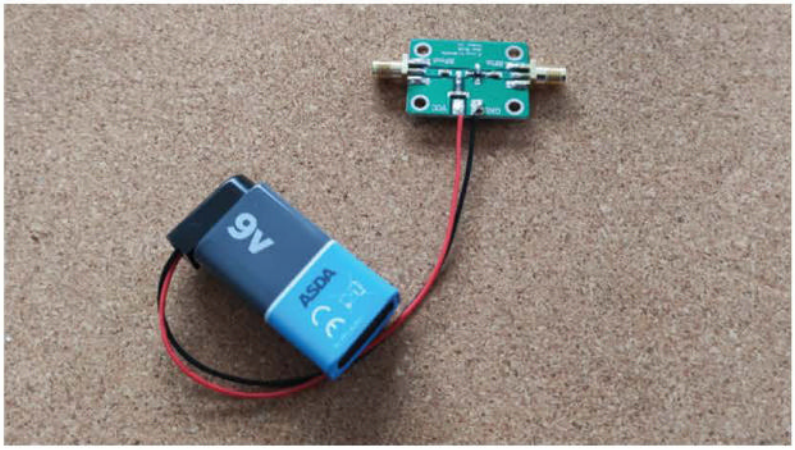
> "The user interface comprises a rotary encoder and a **couple of buttons to go forward and back through the menu system**"

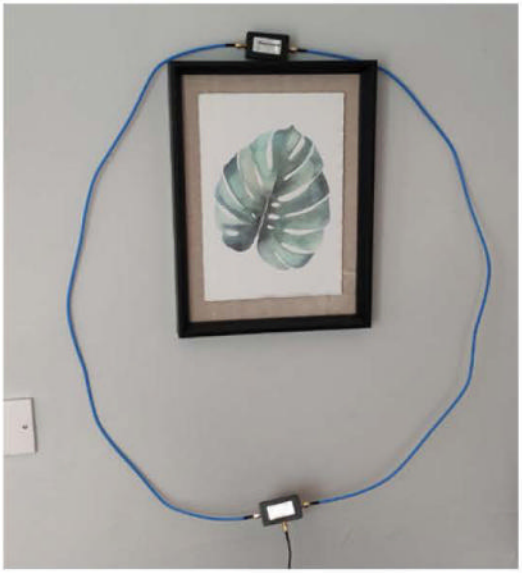
TURN ON, TUNE IN

Connect some headphones or powered speakers to the 3.5 mm audio jack. Then turn on the SDR by connecting a suitable 5 V DC supply (or power bank / battery pack) to Pico's micro-USB port (or USB-C on Pico 2). On the OLED screen, you'll see a 'spectrum scope' graph for the current frequency range.

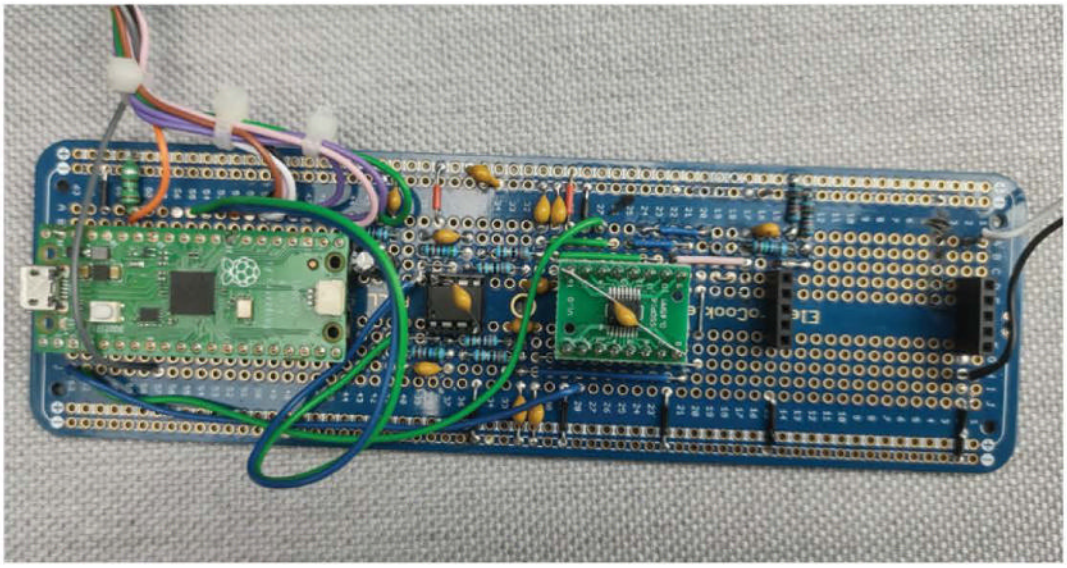
The user interface comprises a rotary encoder and a couple of buttons to go forward and back

Below
A 9V battery is used to power the wideband LNA, which boosts RF signals from the antenna





Above
A YouLoop-style antenna can be used indoors and is highly portable, so try different positions to get the best reception



Left
Built on a prototyping breadboard, Jon's circuit includes a Tayloe detector to convert radio waves into lower-frequency I and Q signals that Raspberry Pi Pico's ADC can sample

through the menu system. By turning the encoder, you can fine-tune the current frequency. To change it altogether, press the forward button to enter the menu, then again on the Frequency option that appears. To select a desired frequency, you can now select digits in turn with the forward button and use the encoder to change them.

To make things easier, the SDR features 512 memory slots for storing either a single frequency or a band of interest. Some are already stored by default – go to Menu > Recall and use the encoder to browse through them and listen in. You'll find frequency ranges for MW (medium wave), LW (long wave), plus various bands for SW (short wave), SSB (single side-band modulation), CW (continuous wave), and teletype modes such as PSK, FT8, and RTTY. You'll also find some familiar UK stations such as Radio 5 Live and TalkSport, along with some from other territories around the world. You can even listen in on CB (citizens band) channels; "That's a big 10-4!"

Other SDR menu options include AGC (automatic gain control) speed, bandwidth, squelch (noise gate), auto notch (filter), frequency step, CW tone frequency, and hardware config.

TAKING IT FURTHER

You may want to house your Pico SDR in a case. Jon has you covered there, too, as he's put all the 3D printing files for his custom-designed case in the project GitHub repo (**hsmag.cc/PicoSDRCase**). There's no lid, but you could always add one.

Another upgrade possibility is to add an external amplifier (and small speakers) to the SDR. Jon has experimented with using an inexpensive PAM8403 amp module, which can provide up to 3W output into a 4 ohm load.

While the Pico SDR works as a standalone unit, you can also connect it to a PC's sound card to explore digital teletype modes such as FT8. Jon has even used it to receive weather FAX transmissions with maps – see his blog for more details.

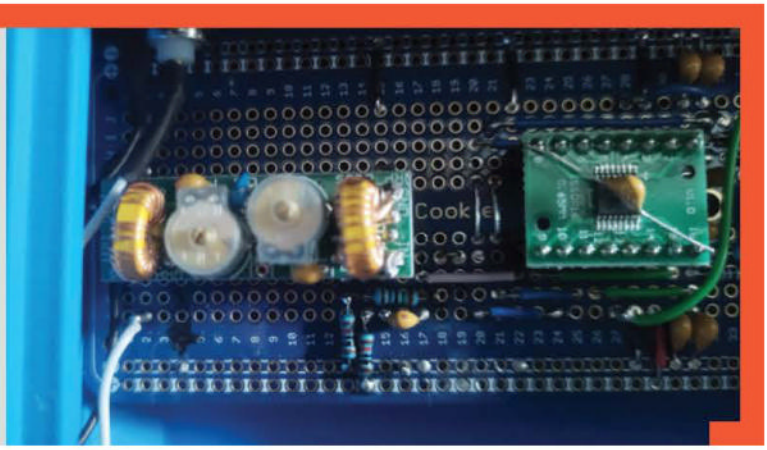
QUICK TIP

For more ideas for add-ons and improvements, keep an eye on Jon's blog, where he is continually upgrading the Pico SDR.

ADDING A **FILTER**

On some frequencies, you may find that you get some unwanted interference from other bands. This is where the use of an optional band pass filter comes in, such as the ones sold by QRP Labs (**shop.qrp-labs.com/BPF**). Simply connect the antenna feed from the LNA to your circuit via the filter – Jon included female headers in his circuit for this purpose. He recommends starting with a filter for the 20m band: "It is one of the most popular amateur bands and it gives excellent long-distance propagation during the daytime." The 40m band is his next choice: "It gives excellent propagation at night, starting around sunset."

You can still easily bypass the filter if you want to try out other bands; the band-pass filters just give an extra level of rejection of unwanted signals.



PART 02

Make your own programming language: Compiling a language

Build your own programming language part 2: creating a high-level language compiler

Rob Miles

@robmiles

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

Last issue, we saw how we can make an interpreter by using C switch statements to select behaviours based on the content of program code. This time, we are going to make a compiler which takes Python-Ish statements and produces low-level code.

A compiler takes high-level code and produces lower-level instructions for use later. Some produce 'machine code' – instructions that can be executed by hardware in a computer. Others produce 'intermediate code' which is run by an interpreter program.

Figure 1 shows what we're building. We'd like to write 'move 100' to tell the robot to move – far easier to remember than the 'MF' low-level command. The compiler's job is to recognise the command and then output the relevant low-level code to move the robot.

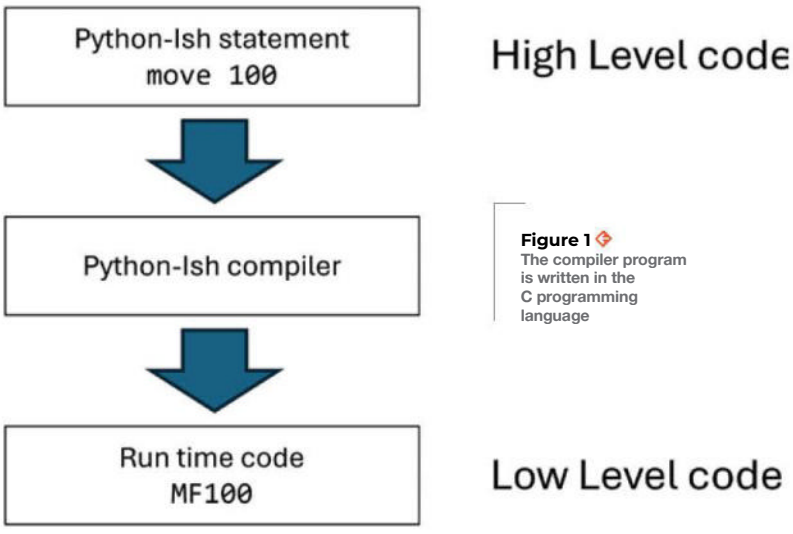


Figure 1 The compiler program is written in the C programming language

A LITTLE LEXICAL ANALYSIS

The compiler needs to be able to work out the meaning of a code statement. This process is called 'lexical analysis'; it sounds complex, but just involves applying the rules of language to the input. One lexical rule for Python-Ish is that a statement starts with either a 'command' or the name of a variable. A command is something recognised as being part of the language; e.g., **`if`**, **`else`**, and **`while`**. Python-Ish also contains special commands for robot actions such as **`angry`**, **`happy`**, and **`move`**. If the compiler sees a statement starting with a command, it generates the low-level code for that command. Let's look at how this works.

```
// command numbers:          0     1     2...
const byte commandNames[] =
                                "angry#happy#move...
```

The **`commandNames`** variable is a long string which contains all the commands for the 'Python-Ish' language. Each command is separated from the next by a **`#`** character. The compiler takes the first word in the statement it is working on and finds the matching command. It does this by searching through the string for a match and noting the position of the match. In the code sample above, the position of each command in the string is shown in the comment above the string. The **`angry`** command is at position 0, **`happy`** at 1, and so on. These numbers are defined in the program as shown below.

```
#define COMMAND_ANGRY 0
#define COMMAND_HAPPY 1
#define COMMAND_MOVE 2
#define COMMAND_TURN 3
```

The function **`decodeCommandName`** extracts the command from the statement being compiled and

then returns the position of that statement in the **commandNames** array.

```
int commandNo = decodeCommandName();

result = processCommand(commandNo);
```

The statements above show how the command number is decoded and then passed on to a function called **processCommand**. This function uses a **switch** construction to select the function which will run for a particular command.

```
int processCommand(byte commandNo)
{
    switch (commandNo)
    {
    case COMMAND_ANGRY:// angry
        return compileAngry();

    case COMMAND_HAPPY:// happy
        return compileHappy();

    case COMMAND_MOVE:// move
        return compileMove();
    ...
    default:
        return compileAssignment();
}
```

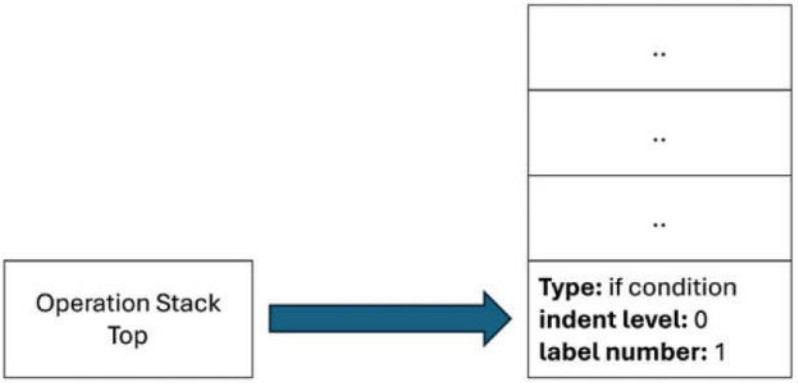


Figure 2
There are ten slots in the operation stack, so in Python-Ish you can nest up to ten blocks

The 'compile' functions generate the low-level commands that perform that action. The **compileMove** function will generate an **MV** low-level instruction. There are compile functions for every command. But sometimes a statement doesn't start with a recognised command. This means that it must be the name of a variable which is being assigned a value. In this situation, the **switch** statement will perform the default case, which calls the **compileAssignment** function. Let's look at how that works.

ASSIGNING ASSIGNMENTS

The rules of Python-Ish are that if a statement doesn't start with a recognised command, it must be an assignment of a value to a variable.

```
count = 0
```

The above statement sets the value of the **count** variable to 0. In part 01, we saw how variables are

BUILDING IN EXTENSIBILITY

Python-Ish has been designed to make it very easy to add new commands or command options. Suppose we wanted to add a 'dance' command to Python-Ish to make the robot perform dance moves. First, we'd add the command **dance** to the end of the **commandNames** string. This makes the compiler recognise a new word. Next, we define a symbol giving the position of the command in the command string. There are 40 commands in Python-Ish, so **dance** would be command number 41.

```
#define COMMAND_DANCE 41
```

Next, we decide on the dance moves the robot should perform when the command is given, and put them into a command string:

```
const byte danceCommand[] PROGMEM = "MF10\rCA\
rMF-10\rCA";
```

These four low-level statements make the robot move forwards and backwards 10mm. The **\r** characters mark the end of each low-level command. The **CA** commands tell Python-Ish to wait for the robot to finish moving before performing the next statement. Next, we write a **compileDance** function to output these low-level instructions:

```
int compileDance()
{
    // send dance moves
    sendCommand(danceCommand);
    return ERROR_OK;
}
```

Finally, we add a call to **compileDance** to the **switch** statement that decodes command numbers:

```
    case COMMAND_DANCE:// dance
        return compileDance();
```

Now, when the compiler sees a **dance** statement, it will generate the moves. A command can be followed by a variable or an expression which can control the code behaviour. Look at the **compileMove** function in the **script.cpp** source file to find out more about this.

QUICK TIP

If you want to see this command list in all its glory, take a look in the **script.c** source file.

QUICK TIP

If the compiler detects something wrong with the source code (perhaps an expression with a missing operator), it will generate an error number. There are 59 different errors that can be detected.

created and managed. The `compileAssignment` function generates the low-level variable commands that perform the assignment. Now we know how to create a variable, the next thing we need to understand is how we change it when the program runs. We do this by evaluating an expression.

EXPRESSING EXPRESSIONS

```
count=count+1
```

The statement above adds one to the value in the **count** variable. The part of the statement on the right-hand side of the **=** operator is an expression which is evaluated each time it is performed. Here, the expression works out the value of **count** plus 1. The job of the compiler is not to perform this calculation; instead, it must make sure that the expression is correct and then generate low-level instructions which will perform the calculations when the program runs.

The compiler checks that the expression contains operands (in this case, **count** and 1) and an operator (the **+**) in the correct sequence. It then generates a low-level VS statement to tell the variable manager in the low-level language that a variable is being set to the value of the expression. Code in the low-level language then performs the calculation when the program runs.

```
VScount=count+1
```

The VS low-level command causes the interpreter to perform the Variable Set behaviour when the program runs. We now know how a Python-Ish program can manipulate values; next, we need to discover how it can make decisions.

DECISIONS, DECISIONS

In part 01, we saw how the Python-Ish low-level language provides support for labels and jumps. But these are hard to use and manage. What we really want to write is something like the statements below:

```
if d < 100
  red
  turn 180
  move 100
green
```

This is part of a program to make a cowardly robot display a red pixel, turn 180°, then run away whenever it gets within 100 mm of an object. The **if** statement at the start of the block uses the test **d < 100** to decide whether to turn and run. The indented statements following the **if** will be performed if the result of the test is true. Python-Ish uses indenting to indicate when statements are in a block. The **green** statement is not controlled by the **if**. The pixel is always turned green. The red pixel is only displayed while the robot is turning and moving. Let's take a look at how these statements are converted into low-level ones.

```
int compileIf()
{
  // move on to the next label
  labelCounter++;

  // push the if onto the operation stack
  push_operation(IF_CONSTRUCTION_STACK_ITEM,
                 labelCounter);
```

GRAMMAR SCHOOLING

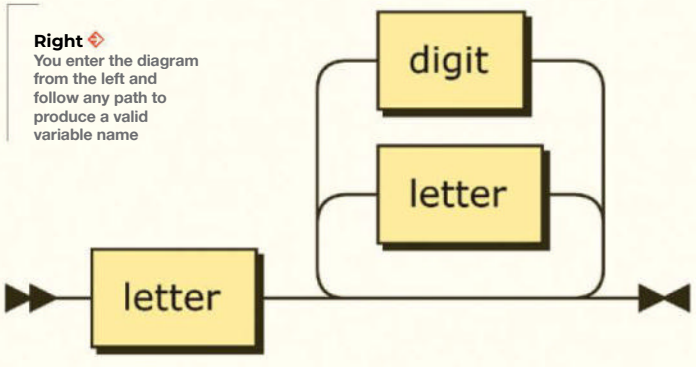
You use a grammar to describe a language. English grammar identifies the parts of a sentence (such as verbs, nouns, and adverbs) and establishes rules for how these parts are structured and used. Python-Ish has its own grammar too. It has been written using a language called Extended Backus-Naur Form (EBNF). Which is an impressive name for something which is quite easy to use. For example, consider how we could describe how, in Python-Ish, a digit can be any of the characters 0–9:

```
digit ::= ( '1'|'2'|'3'|'4'|'5'|'6'|'7'|'8'|'9'|'0')
```

The grammar statement above describes a symbol called **digit** which can be any of the given characters. The vertical bar (**|**) in the list of values means 'or'. We could describe a symbol called **letter** which can be any of the characters A–Z in the same way. Now that we have these symbols, we can describe other things in terms of them. We can use the symbols to define what constitutes a valid variable name. We don't want variable names to start with a digit because they would get mixed up with numbers, so we make them start with a letter. In other words, a variable called **X2** would be fine, but a variable called **2X** would be incorrect. This convention is used in just about every programming language. The statement below shows how we can express this.

```
variablename ::= letter (letter | digit)*
```

The grammar statement above is expressing that a **variablename** is made up of a letter followed by any number of letters or digits. The ***** means "from zero to many" and it applies to the things in brackets before it. The entire Python-Ish language can be described in a collection of grammar statements. There are tools which can take grammar statements and express them graphically. The author used one at **rr.red-dove.com/ui**.



Right You enter the diagram from the left and follow any path to produce a valid variable name

```
  int result =
    dropComparisonStatement(labelCounter, false);

  // reserve a label for use by else
  labelCounter++;

  // remember that we have started a block
  previousStatementStartedBlock = true;
  return result;
}
```

The **compileIf** function is called when an **if** command is detected. It gets a new label value and adds an **if** condition onto the operation stack. The label specifies the destination of a jump around the code in the block. The label will be added to the low-level code when the compiler detects the end of the block. This stack is how the compiler 'remembers' that indented statements following the **if** are inside a block.

Figure 2 shows the operation stack. This is how Python-Ish remembers where it is when compiling blocks. For each entry, the type of the block is stored, along with the indent level for the start of that condition, and the number of the label to be generated at the end of the condition.

```
struct stackItem {
    byte constructionType;
    int count;
    byte indentLevel;
};
```

The code above shows the C structure for each **stackItem**. A C structure groups together properties in a single item. The compiler keeps track of the current indenting level by checking the position of the first character of a command and stores that value in the **indentLevel**. When the compiler sees a statement at the same level of indent as the **if** statement on the top of the operation stack, it knows that the block has ended. It then generates the label with the **count** value from the **stackItem** it has just removed from the operation stack. That marks the end of the block.

```
CFd<100,l1     -> jump to label l1 if d greater than
                  100
PNr            -> turn the pixel red
MR180          -> rotate 180
CA             -> wait for the rotate to finish
MF100          -> move forward 180
CA             -> wait for the rotate to finish
CLl1           -> label l1
PNg            -> turn the pixel green
```

The low-level code above is the result of compiling the **if** construction, with added comments. Note that the label statement (**CLl1**) is produced when the **green** statement is compiled. The compiler notices that the **green** statement is indented to the same level as the **if** construction (not the inner block), and so it gets the **stackItem** from the top of the stack and uses the label number in it to make this label. The **CF** construction at the top of the code branches to this label if the condition controlling the statements is false. This causes the statements to only be obeyed when the condition is true, which is what we want. The compiler uses a similar mechanism to implement an **else** clause and loops which continue while a given condition is true.

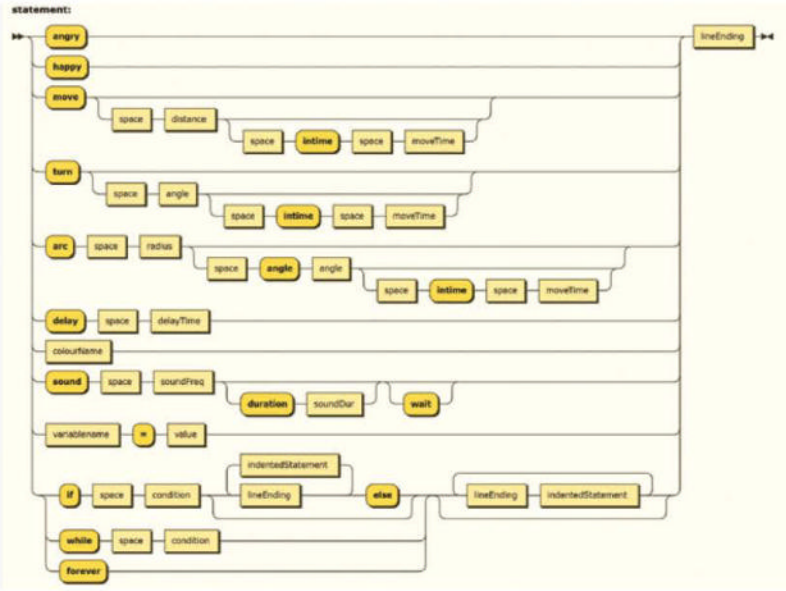


Figure 3 Items in boxes are other language components. Bold words are commands

LEARNING THE LANGUAGE

Figure 3 shows the statement types in Python-Ish. The author thinks that it is important that nothing involving computing should ever be seen as 'magic'. If this pair of articles has removed some of the magic from how programs are made to work, he will consider it a success.

SIMPLE IS SMALL

You might be looking at the way that commands are stored and managed in Python-Ish and wondering why the author didn't use classes and data structures such as dictionaries to make the code easier to write. The language was originally created to run on an Arduino Uno device which has only 24kB of program space, 2kB of ram for variables, and 1kB of data storage for programs. The author decided to implement things at the lowest level possible to keep the code small and fast. This meant storing things in long strings and then using simple loops to search through them.

QUICK TIP

Remember that compile functions don't perform a command; instead, the functions output low-level instructions for the interpreter to perform when the program runs.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Budget engraving pen

Personalise and customise gifts and mementos with an individual engraving

Alert!
Power Tools

Be mindful of problems caused by power tools. Be careful of strain from vibration, noise hazards and (if necessary) wear protective clothing and goggles. Do your research first!

magpi.cc/powertools

Nicola King

@holtonhandmade

Nicola King is a freelance writer and sub-editor. Heads up: everyone she knows is likely to get something engraved this holiday season!

YOU'LL NEED

- **An engraving tool/pen**
- **An item of your choice to engrave**
- **Stencils/pattern you've designed**
- **Mat to protect the work surface**
- **Goggles/dust mask**
- **Damp cloth**
- **Sandpaper** (if engraving wood)
- **Paint/wood stain/oil** (if engraving wood)

Engraving is the process of marking a surface, usually flat and hard, in order to create a textural and visual effect. In other words, material is removed in order to make a structural surface where the background stands out. The types of base materials that can be engraved include metals (we are, of course, familiar with how items of jewellery can be engraved), plastics and acrylics, glass, wood, leather, and even stones.

Given that a certain holiday gift-giving season is upon us, this author thought that engraving might be a topical area to explore, as very inexpensive engraving tools can really make your gifts stand out with your own unique decorative touches. So, in this article, we are going to attempt some simple and economical engraved customised designs, adding that personal touch without a hefty price tag.

We purchased an engraving pen from a well-known supermarket for under £5. The pen came with two interchangeable engraving tips, reusable stencils of letters, numbers, and a couple of other designs, and even two batteries to power it. In addition, a user manual was included, and it's worth underlining that you should make sure that you read any guidance that comes with any pen you buy so that you are up-to-speed on the safety aspects of using such a tool. The pen claims that it is suitable for engraving on hard materials such as glass, metal, wood, and could also be used on leather.

At this point, let's make it clear that this is a very inexpensive pen – you can pay a great deal more for more sophisticated tools and you will probably, to use an old adage, get what you pay for. However, we are just dabbling here, with no intention of creating great works of art or of engraving any precious metals. So, with that in mind, let's get to work.

Above
You can achieve much fancier results than this with lasers and other expensive tools, but a basic pen, or even a rotary tool, can give that personalised touch that others might appreciate. If nothing else, this is the perfect entry point into the creative world of engraving

Left
Stencils were a very quick way to achieve a design on wood. The better quality the stencil, though, the longer it should last – thin plastic was a little flimsy

> You can pay a great deal more for more sophisticated **tools and you will probably get what you pay for**

QUICK TIP

Practise, practise, practise… you won't become confident and accomplished overnight, so practise on something that you can throw away afterwards before attempting to engrave a more expensive item.

GOOD ON WOOD?

So, the first item that we decided to try to engrave was made of wood. It feels like there's something very traditional about etching a design into wood as it's a craft that has been done for literally thousands of years. It's worth underlining that what we are doing here is not pyrography, which is a totally different type of craft where you effectively decorate a piece of wood by burning an outline with a pyrography tool. Here, we are simply cutting a design on the surface, not burning it in.

We thought it best to begin by using the stencil templates that came in the pack, and we selected a wood slice to work on as it was small, manageable, and we had some to hand. The stencils have a sticky back to them, so we were able to attach them easily, and they were stable while we were engraving. However, we found that the pen did easily clip the edges of the plastic stencil when it was switched on and removed parts of the plastic, so these stencils probably won't last long. We also found that the pen had to be held very lightly and not pushed too far down onto the wood, or it stopped working completely. After we had finished, we lightly sanded the area to remove rough or uneven spots.

Once we persevered, we did get an acceptable result, but we would recommend that you stain, paint, or oil the wood afterwards as that is far more likely to

MATERIAL MATTERS

So, you're keen to give engraving a go, but you may not be sure what to actually engrave. Here are a few material pointers that will mean your imprints impress:

- Firstly, it is advisable to use a 'soft' material for your first project, primarily because this will be easier to control. So, something made of leather, plastic, or even wood is a good option. Leather belts, wallets, phone cases or bags would be suitable, but have a scrap piece handy to try your new skill out on first. Blank plastic coasters are often available online and are a great choice. Wood is a really popular engraving material and a softer wood, such as pine, would make a great starter project. How about purchasing an inexpensive, plain wooden cheese board or cutting board or a wooden photo frame and personalising it for yourself or a new owner? Poplar, cherry wood, and plywood also make suitable first choices. If you want to engrave a metal base, brass or copper are two of the slightly softer metals, so you might be wiser to try these before something harder like steel.

- It may seem obvious, but the flatter your surface material is, the easier your engraving work will be. For example, if you try to engrave the curved surface of a piece of tree bark, you're going to have a harder time than when engraving a flat, plain wooden bookmark, coaster, or a small hanging sign for someone's garden. As a beginner, you really don't want to have to concern yourself with angles, or repositioning your pen every few seconds because of tricky curvature.

- Whatever material you choose to engrave, do make sure that the surface you are engraving is clean and dry before you get underway. For example, if you are engraving on plastic, give it a wipe over to get rid of dust and dirt particles. If you are engraving wood, it is important that the wood is untreated. So, if the wood has any paint or other surface covering on it, you'll first need to sand it back to its natural finish, make sure it is completely dry, and then start work.

Left
This pen came with two standard 1.5V AA batteries, but you can swap those out for rechargeable ones if you prefer. It also came with two tips – the one already in situ is for engraving wood, metal, and leather, while the other more pointed tip is for working specifically on glass only

MAKE YOUR MARK

If this low-cost pen does not appeal, there are other ways to engrave your materials, but you might need a slightly bigger budget, so let's take a look at other engraving options:

- Cutting machine add-ons – if you own a cutting machine like a Cricut Maker or a Maker 3, you can get an engraving tip that will allow you to engrave thin acrylic, aluminium, stainless steel, wood, and things like thin leather too. So, this is a very easy way to start engraving. You do need to make sure that anything you want to engrave fits under the roller bar, though. Also, bear in mind that this is only going to work on flat items.

- Rotary tools, or something like a Dremel Multi-Tool, can also be used to engrave materials. Check out the instructions of any rotary tool that you own to see what's possible and what attachments, if any, you might need to add to your collection.

- Once you become more practised and maybe want to commit to more serious engraving techniques, you might want to purchase individual tools to try hand engraving on metal for jewellery making purposes. The fine detail and small scale of such projects means you would need graver tools, scrapers to clean surfaces, 'scorpers' to cut/carve larger areas, and so on. You can also buy chisels to engrave on wood – huge fun and very affordable, but it takes patience, precision and practice, and is very slow. The most ancient and traditional way of engraving wood is, after all, by hand.

- Perhaps you already own or have access to a CNC machine, in which case you are already very well positioned to use it to try out engraving. The CNC machine's accuracy and precision, and suitability for detailed work, are big advantages. You can also buy laser engraving machines designed specifically for that purpose, but these can be expensive. On the plus side, using a tool like this is very quick and accurate: just line it up and press a button! So, check out which engraving tools/machines/lasers are available to use at your local hackspace or makerspace, as this would be a wise place to start if you just want to try out various options.

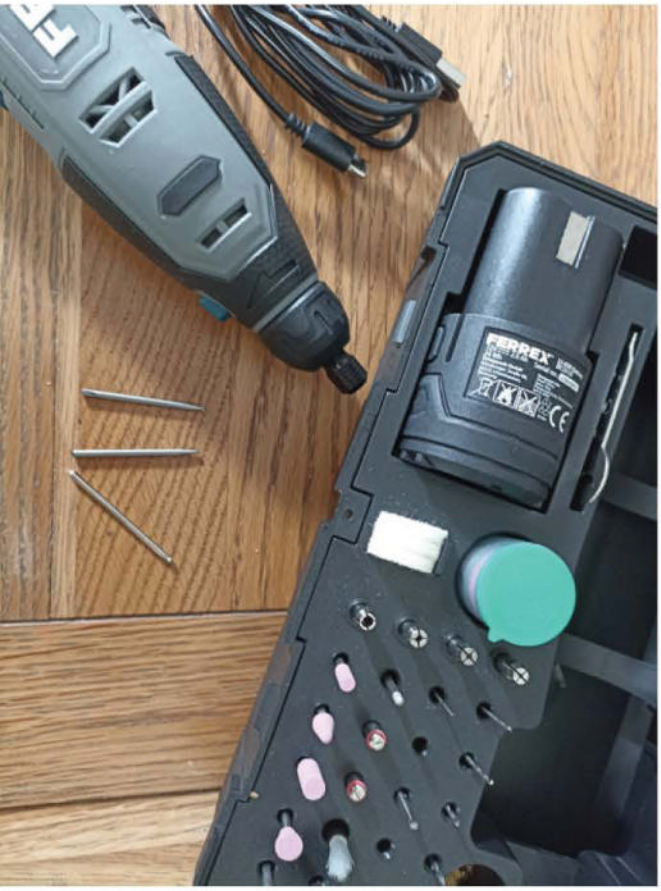
bring out your design from the background. You don't have to be too neat as, once it's dry, you can sand away excess paint or stain.

It's worth mentioning that if you want to use your own design or something you've printed out, you'll need to first transfer the design onto the wood, or other surface, where you want to engrave. You could use carbon paper for this, or you could use a very fine tip on a rotary tool to outline the design with some small holes, then go over the design with a pen, connecting the holes to form the image that you can then engrave in more detail.

CRYSTAL CLEAR

Next, we found a glass tea-light holder that was in need of some decoration. So we changed the tip on the pen to the more pointed one, which more resembles the diamond burr bit you'd use on a rotary tool for example, and set to work. This proved slightly more tricky as the surface is curved and not flat, so you do need to hold the item very firmly to stop it rolling away as you work. We chose to use the stencils included once again as it was the easiest option. But, if you wanted to use a custom design, all you really need to be able to do is find or draw a design, transfer it onto the glass somehow as mentioned previously,

Above
Deciding what to engrave is the biggest decision, but don't go out and buy things for your new hobby. Just have a look around your home or workshop – glass jars can be decorated and turned into little vases, old pieces of wood can be used to practise on, a bread board can have a touch of decoration added, and so on. Upcycle and improve!



and then just follow or trace the lines that you've transferred – you do not need to be any kind of artist, and that is actually worth reiterating when it comes to many crafts. Experienced engravers clearly have a huge amount of skill, but not possessing those skills is not a barrier to trying out a craft like this. If you are lucky enough to be something of an artist, you can always try the freehand approach on your surface and see what happens!

The main thing that we bore in mind when engraving on glass is that it is a much more delicate surface and, if you try and engrave too deeply, you can break the glass. Also, slow, even movements seem to help, and it's really important that you don't apply too much pressure to the glass.

We were happy with the end result, though, and it felt much quicker to get a result on glass than on wood, which needs a bit more effort to get a more deeply etched design.

SCRATCHING THE SURFACE

Our engraving pen made its mark, but it is really a hobbyist type of tool that won't give you breath-taking results and, given the price, that's no surprise. However, it is useful for decorating small gifts and does show the recipient that you've gone an extra mile.

ENGRAVED IN HISTORY

If we take a look back at the long history of engraving, hand engraving is the traditional and oldest form of the art and it was born many centuries ago. In fact, it's thought that some of the first engravings took the form of chiselled shells, after one such example – estimated to be between 540,000 and 430,000 years old – was found during an archaeological dig in Java, Indonesia. Experts suspect that whoever made the engraving probably used something like a shark's tooth to engrave a simple zig-zag pattern on the now fossilised object. In addition, the art of the Upper Palaeolithic era saw engraving on bone and ivory, while petroglyphs, or 'rock art', were chiselled into rocks around the world in many prehistoric cultures.

Moving forward, the Romans engraved bronze and iron dies so that they could cast coins, and Roman craftsmanship was also evident in the creation of 'intaglios', carved gemstones which were usually mounted in rings. They used precious and semi-precious stones such as garnet and amethyst, and experts think that this technique, where artisans carved an image into the stones, probably originated in ancient Mesopotamia. Often the images were of gods and goddesses, but sometimes they were more personalised and some functioned as seals, so the owner would press it into wax to leave their 'signature'.

The engraving of glass using a wheel was also a popular art form, with decorative scenes and figures cut into glass objects – examples can be found as far back as the first century and up to the fourth century CE in places including Rome and Cologne. But it was the Middle Ages when craftsmen (usually goldsmiths by trade) started to engrave a variety of metals, adding intricate patterns to jewellery, for example. Swords and other arms were also often ornately engraved by the fourteenth century. In 15th century Germany, artisans began engraving copper plates and used them to print images on paper.

The evolution of engraving continued over the centuries, and the burin as we know it today, a steel cutting tool, became more widely used by craftsmen. A burin, also known as a 'graver', has a steel shaft, a handle, and a sharp cutting face, and was used to engrave designs into metal and wood, and is still used by some for hand engraving.

The Industrial Revolution in the 18th century obviously also played a role too, due to the whirlwind of changes that it brought to the world. Steam-powered printing presses meant stamping became mechanised, and steel replaced copper as an engraving material as it was much harder and able to withstand mechanised presses.

Into the 20th century, personalised engraved items became very popular – think sporting trophies, cups, and shields. Then the 1960s saw the arrival of lasers and, although engraving is still sometimes done by hand, high-tech lasers mean that the engraving of an item can now literally take seconds as opposed to hours.

From our experience, we suspect that a rotary tool with its higher-speed rotating tip might give a slightly better result, and you'd probably be able to engrave more deeply and perhaps with more control. Whatever you do decide to engrave, and with whatever tool, do remember that practising on something that can be thrown away is a great way to start, as many materials are unforgiving and once you've made a mistake it's hard, if not impossible, to rectify.

Obviously, we have not covered engraving in huge detail here, and there are numerous ways of diving deeper. You could find a course local to you or online that covers the aspects you are interested in. For example, these particular courses concentrate on hand engraving: **handengravers.org.uk/courses**. There's also a multitude of books and online tutorials on the subject, and plenty of tools ranging from the most basic pen to very sophisticated engraving tools – the choice is yours!

Above
As an alternative, a good rotary tool will usually come with some engraving tips. This one has a couple of such tips, along with all of the other useful bits and pieces that you might need, including sanding paraphernalia. Rotary tools are versatile, and this one is a little more weighty than our pen and perhaps more effective

Hozo NeoRulerGO

Tiny but precise measuring and multi-scale digital roller ruler for makers, DIYers, and draughtspeople

HOZO £55 [£47 now] / $59 [was $69 at launch] | **hozodesign.com**

By Rosie Hattersley

Right The tiny NeoRulerGO's scales are precise to less than 1 mm

Measuring straight lines and regular shapes is easy. Undulating curves, awkward insides of boxes and cupboards, and hard-to-reach corners and coves can be a pain to size up accurately. Tiny devices such as our very own Pico and Pi Zero present challenges too, should you be inclined to design a case or enclosure as part of a Raspberry Pi project. With home refurbishment, craft, and project design ideas on our minds, we were only too happy to test Hozo's NeoRulerGO – a tiny 45 g digital rolling ruler that clips onto a belt or slips into a pocket.

The lightweight gadget has a month-long standby battery life and recharges via its USB-C connector in two or three hours. The clever design hides the USB-C port at one end, revealed when you firmly yank off the silver plastic retaining clip.

The NeoRulerGO has three modes: Ruler, Scale Ruler, and Customized Scale Ruler, plus a Settings menu. Cycle through metres, inches, feet, centimetres and millimetres, or select 'fit in' using the NeoRulerGO's hard plastic buttons. Two red laser beams emitted at right angles are used to locate the start point. Roll along, keeping the device perpendicular for the most accurate reading, and lift the NeoRulerGO off the surface to lock in the reading.

There is a Corner to Corner option to measure internal corners for which the NeoRulerGO needs to begin and finish at 45 degrees, swinging along the length. The 93 different scales translate to and from 1:100,000 with an accuracy of 1 mm based on the markings on the original drawing, impressing an architect friend who uses a £500 Leica DISTO professional laser measure.

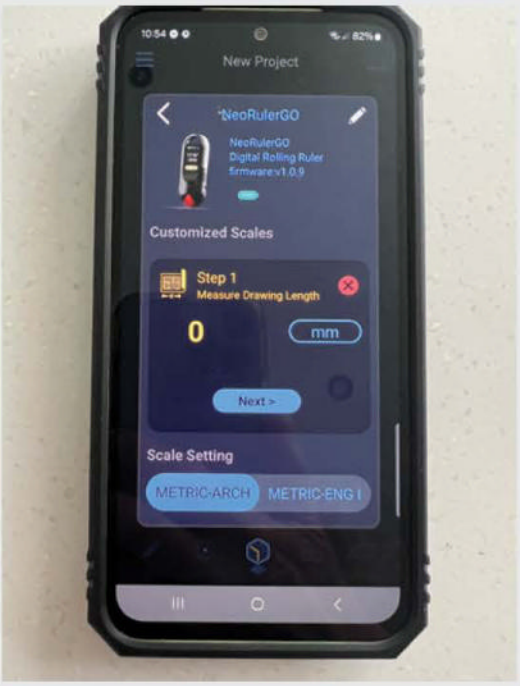
Right
The chosen mode scrolls as an animation across the 1.14in LCD

PETITE BUT PRECISE

Hozo packs plenty of features into the NeoRulerGO, but the trade-off for its teeniness is that it's fiddly to use. Deviations and bumps in the course of rolling can also cause measuring to stop and start again, so make sure you sense-check the reading. These can be exported to the Meazor Android or iOS app for inclusion in a project or simply saved as a list. Hozo helpfully includes configuration options on the NeoRulerGO and within the app to change the screen orientation and left- or right-handed use, so it's a matter of working out which settings work best for you.

> We found NeoRulerGO ideal for awkward spaces **and shapes, including curved surfaces**

We used NeoRulerGO to take accurate measurements for bathroom spaces and fittings, including the trim needed for the circumference of a partially curved mirror. Its precise measurements were also helpful when stretching and blocking hand-knitted pieces that needed to be a fixed size and accurately sewn together, and when trying to design an enclosure for a Raspberry Pi to be fashioned from assorted materials of varying thicknesses and flex. It was really handy being able to simply cycle through measurements to see how a reading translated metric and imperial measurements down to the nearest ±1mm, reassuring us when sourcing components.



Left
The Meazor app can automatically import measurements to a project

SPECS

- **Weight** 45g
- **Dimensions** 31×18×146mm
- **Screen** 1.14in
- **Wheel** 30mm
- **Battery** 300mAh
- **Resolution** ±0.02in (0.5mm)
- **Accuracy:** ±0.04 inch (1mm) + (Dx0.5%) in ideal circumstances
- **Features:** Inches, feet, metres, centimetres, millimetres; 93 built-in scales, customisable scales (100K:1 to 1:100K)

VERDICT

Despite a few handling issues, we found NeoRulerGO ideal for measuring awkward spaces and shapes, including curved surfaces, with none of the jeopardy of using a retractable metal ruler that might spring back painfully at any moment.

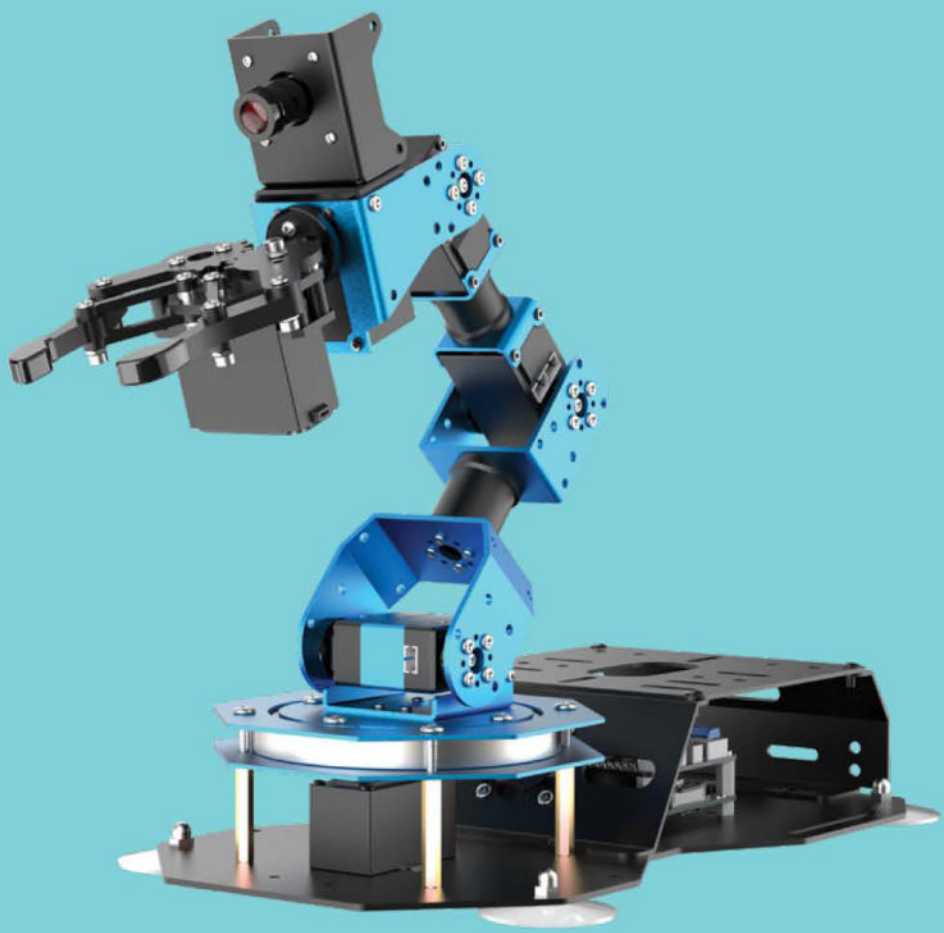
9/10

ONLY THE BEST

Robotics

Get things moving with this selection of Raspberry Pi robots

By **Phil King**



When it comes to physical computing projects, there's little quite so satisfying as getting a robot to move across the floor – whether you are controlling it manually or have programmed it to navigate autonomously, using sensors and/or a camera to detect and avoid obstacles in its path.

It's little wonder, then, that Raspberry Pi robotics kits are so popular. There's a huge range available, so we can only cover a small selection here. While robot cars are the most common type, equipped with two or more wheels, there are also walking robots featuring servo-powered legs.

Then there are smaller-scale versions of probably the most common robots found in industry: multiple-jointed robotic arms that have multiple degrees of movement and can pick up and move objects with a gripper. Equipping one with a camera enables it to use computer vision to detect and sort items.

While a kit is great for getting started with Raspberry Pi robotics, you could always build a custom robot from individual components such as geared motors, wheels, a motor driver, and a purchased or 3D-printed chassis. Let's get moving…

Trilobot Base Kit vs PiCar-X

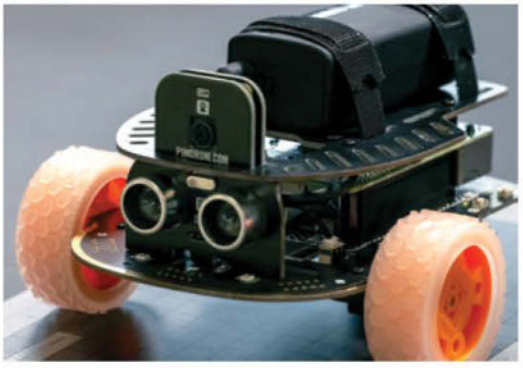
PIMORONI £53 / $56 | pimoroni.com

SUNFOUNDER £71 / $90 | sunfounder.com

There are many two-wheeled Raspberry Pi robots around, but the Trilobot stands out due to its clever design and LED underlighting. It's simple enough for robotics newbies, while offering plenty of possibilities for adding more functionality via numerous ports and hackable headers.

The kit contains everything needed apart from a Raspberry Pi, microSD card, power bank, and optional Camera Module v2 or v3 – which fits in a mount on the front, along with an ultrasonic distance sensor.

A dual H-bridge motor controller is integrated into one of the two PCBs that form the chassis, with two mini JST sockets to connect short cables to pre-soldered shims on the metal-gear motors – no soldering or screwing required. Two moon buggy wheels are supplied, along with a standard metal ball castor to be attached to the rear of the board. While it's not the speediest robot, the 110:1 motors provide good torque. A dedicated Python library (not yet compatible with Raspberry Pi 5) makes it easy to program.



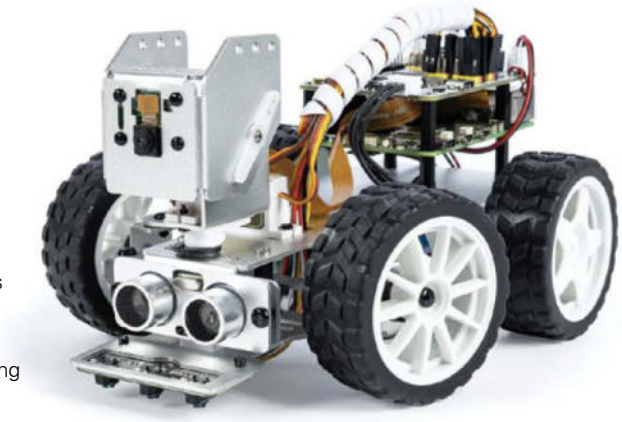
Left
The supplied ultrasonic distance sensor and optional Camera Module are mounted at the front of the Trilobot

Below
The smart PiCar-X can drive itself, exploring its environment with the help of sensors and a camera

Billed as an 'AI smart car', the PiCar-X is an impressive self-driving robot that can be used with most Raspberry Pi models (not supplied with the base kit) and offers a good introduction to robotics. With so many parts, assembly of the kit takes quite a while, but is aided by well-labelled components and clear print instructions and online videos.

As well as packing ultrasonic distance and line follower sensors, the PiCar-X features a camera mounted on the front, with pan and tilt servos to move it around. Another servo is used to steer the front wheels, while the rear ones are driven by two motors. Everything is wired to a Robot HAT that sits atop Raspberry Pi and also handles power from the rechargeable twin-cell battery pack.

Online documentation guides you through installing the software and programming the PiCar-X with Python – or Ezblock, via a mobile app. Code examples include line following, computer vision, and maze navigation. There's even the option to interact with it using GPT-4o AI.



VERDICT

Trilobot Base Kit

A clever design with plenty of options for expansion.

9/10

PiCar-X

Well designed and feature-packed, it's a great starter kit.

9/10

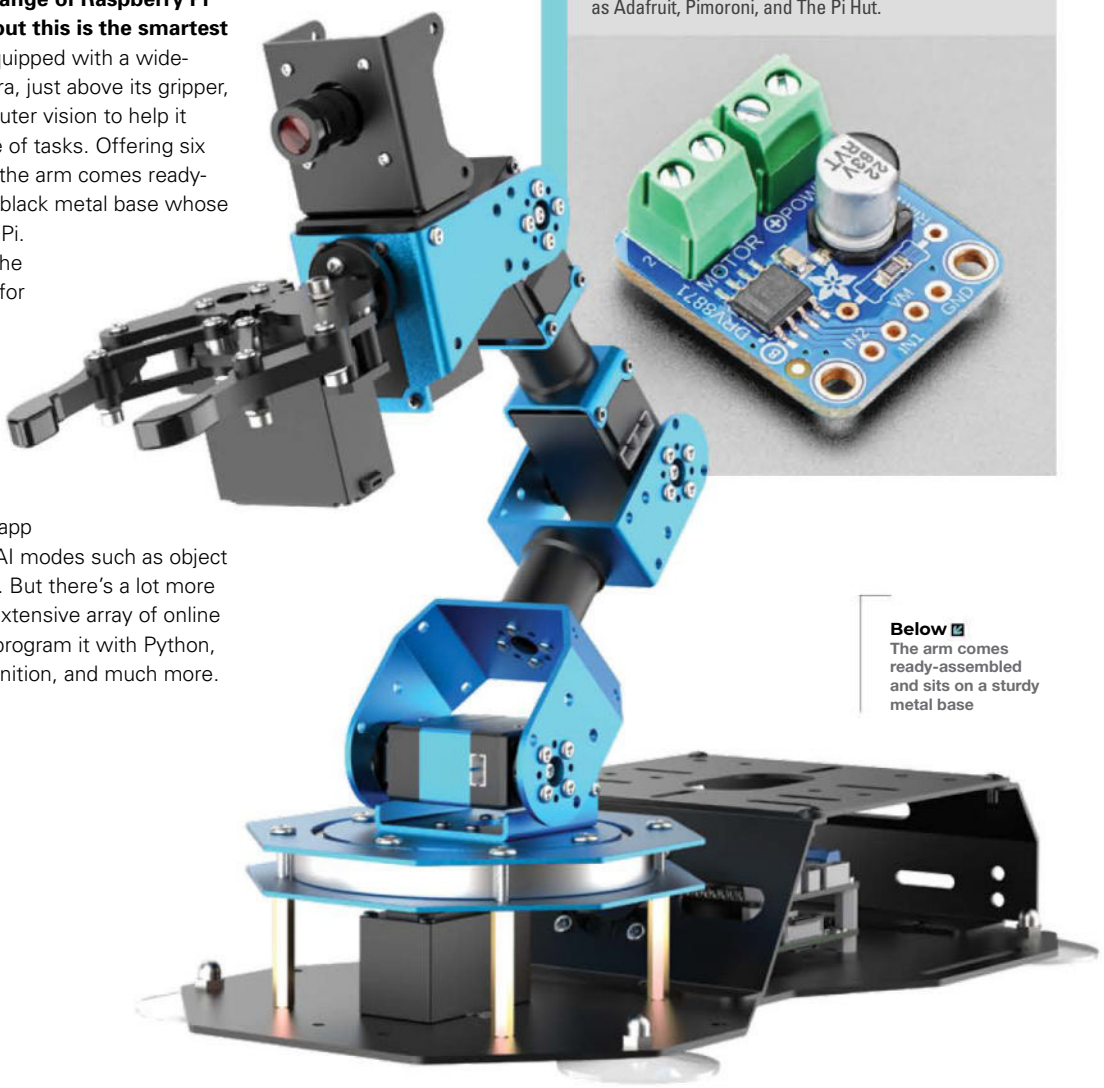
ArmPi FPV AI Vision

HIWONDER ◈ **£236 / $300** | **hiwonder.com**

There's a wide range of Raspberry Pi robotic arms, but this is the smartest we've seen. Equipped with a wide-angle HD camera, just above its gripper, it uses AI computer vision to help it perform a range of tasks. Offering six degrees of freedom (6DOF), the arm comes ready-assembled, sitting on a solid black metal base whose rear section holds Raspberry Pi.

The Standard kit features the robotic arm, breakout board (for Raspberry Pi 4 or 5), power supply, paper 'map', wooden blocks, coloured balls, and tags. The Advanced version adds some flat-pack shelving for 'warehousing' operations.

A smartphone companion app is the easiest way to try out AI modes such as object tracking and face recognition. But there's a lot more you can do: by following an extensive array of online tutorials, you'll learn how to program it with Python, use OpenCV for image recognition, and much more.



Below
The arm comes ready-assembled and sits on a sturdy metal base

VERDICT

ArmPi FPV AI Vision

A sturdy robotic arm with 6DOF and computer vision.

9/10

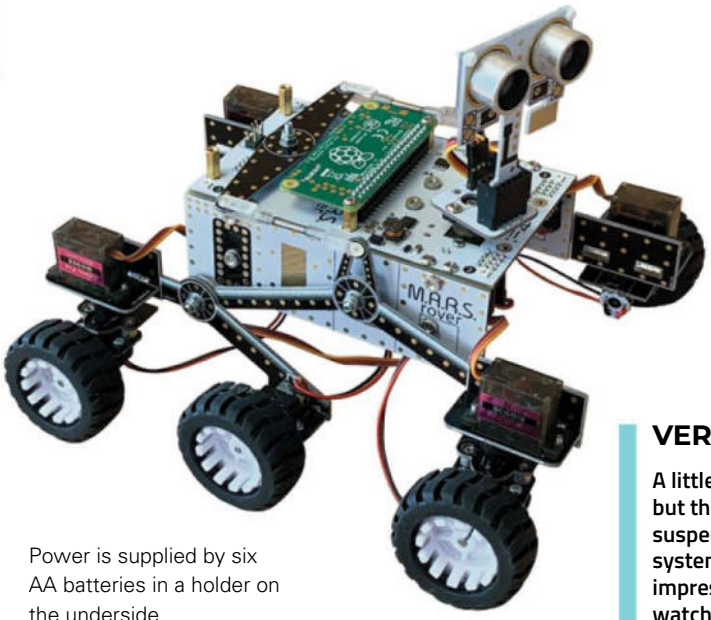
MOTOR DRIVER BOARDS

VARIOUS ◈ **From £8 / $8** | **various**

Instead of buying a complete kit, you can build your own custom robot using individual components and a 3D-printed or purchased chassis. One thing you will need is a dual H-bridge motor driver breakout board to drive the wheels both forwards and backwards. There's a wide range of driver boards available from online retailers such as Adafruit, Pimoroni, and The Pi Hut.

MARS Rover

4TRONIX £127 / $160 | 4tronix.co.uk



While most robotic vehicles have two or four wheels, this one is equipped with six – including steerable ones at both the front and rear, which makes for improved manoeuvrability.

It also features the same rocker-bogie suspension system as NASA's Curiosity Mars rover, on which it's modelled. This allows the six wheels to move up and down semi-independently so they all maintain contact with the ground over rough terrain while the rover's body stays perfectly level. It can even clamber over fairly large garden rocks.

You'll need to assemble the rover from the kit, including adding a rotatable mast with an ultrasonic sensor, along with your own Raspberry Pi Zero.

Power is supplied by six AA batteries in a holder on the underside.

Software-wise, there's a Python library with a few code examples. Also, check out our two-part tutorial in *The MagPi* issues 145 and 146.

VERDICT

A little pricey, but the suspension system is impressive to watch in action.

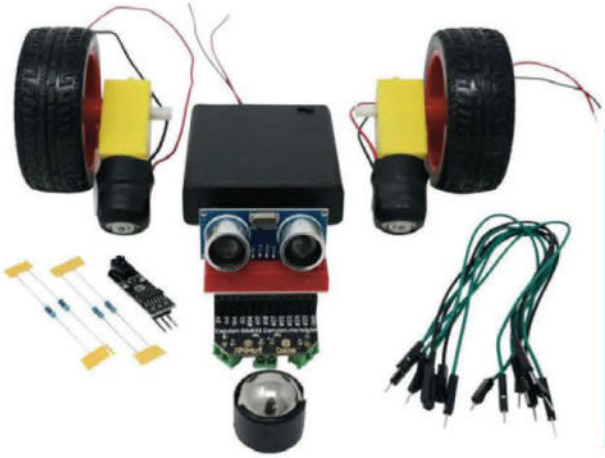
8/10

CamJam EduKit #3

CAMJAM / THE PI HUT £20 / $21 | thepihut.com

Above Modelled on NASA's Mars Curiosity rover, it really looks the part

Below Build a two-wheeled robot at very little cost



If you want to dip your toe into the world of Raspberry Pi robotics with little outlay, this kit to build a simple two-wheeled robot is ideal.

It's been around for a few years, and is fairly basic compared to some – it doesn't even include a chassis for the robot, so you either need to adapt the kit's cardboard box or supply a chassis of your own. Still, it does offer great value.

You get a motor driver board (which should work with any Raspberry Pi computer model, even early ones), a couple of large wheels, a ball castor, two DC motors (the yellow plastic variety), mini breadboard, 4× AA battery holder, resistors, and jumpers. You even get a couple of sensors: ultrasonic distance and IR line-follower. Best of all, the comprehensive tutorials guide you through a series of exercises, coding with Python.

VERDICT

CamJam EduKit #3

An entry-level kit that's a good place to get started with robotics.

8/10

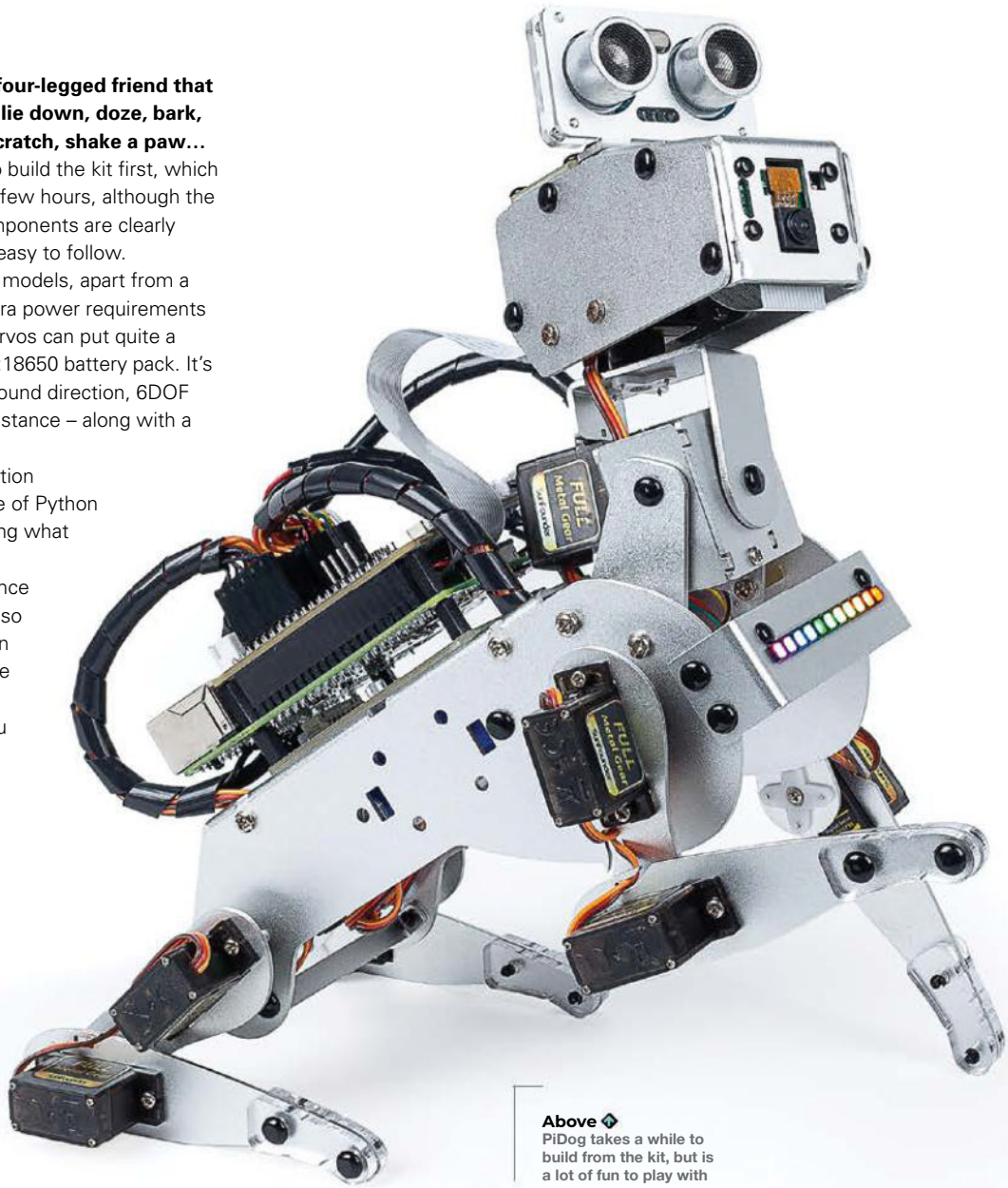
PiDog

SUNFOUNDER | £ 157 / $180 | sunfounder.com

PiDog is a fun four-legged friend that can walk, sit, lie down, doze, bark, howl, pant, scratch, shake a paw… You do have to build the kit first, which can take a fair few hours, although the numerous components are clearly labelled and the instructions easy to follow.

PiDog will work with most models, apart from a Raspberry Pi 5 due to the extra power requirements – those twelve metal-gear servos can put quite a strain on the rechargeable 2×18650 battery pack. It's also packed with sensors – sound direction, 6DOF IMU, dual touch, ultrasonic distance – along with a camera mounted in its snout.

Detailed online documentation (**pidog.rtfd.io**) covers a range of Python example programs showcasing what PiDog can do – including the impressive ability to self-balance on a tilting surface. There's also the option to control it with an iOS or Android app, with a live camera feed and face/object tracking. With a USB mic, you can even talk to PiDog using GPT-4o AI. Clever boy!



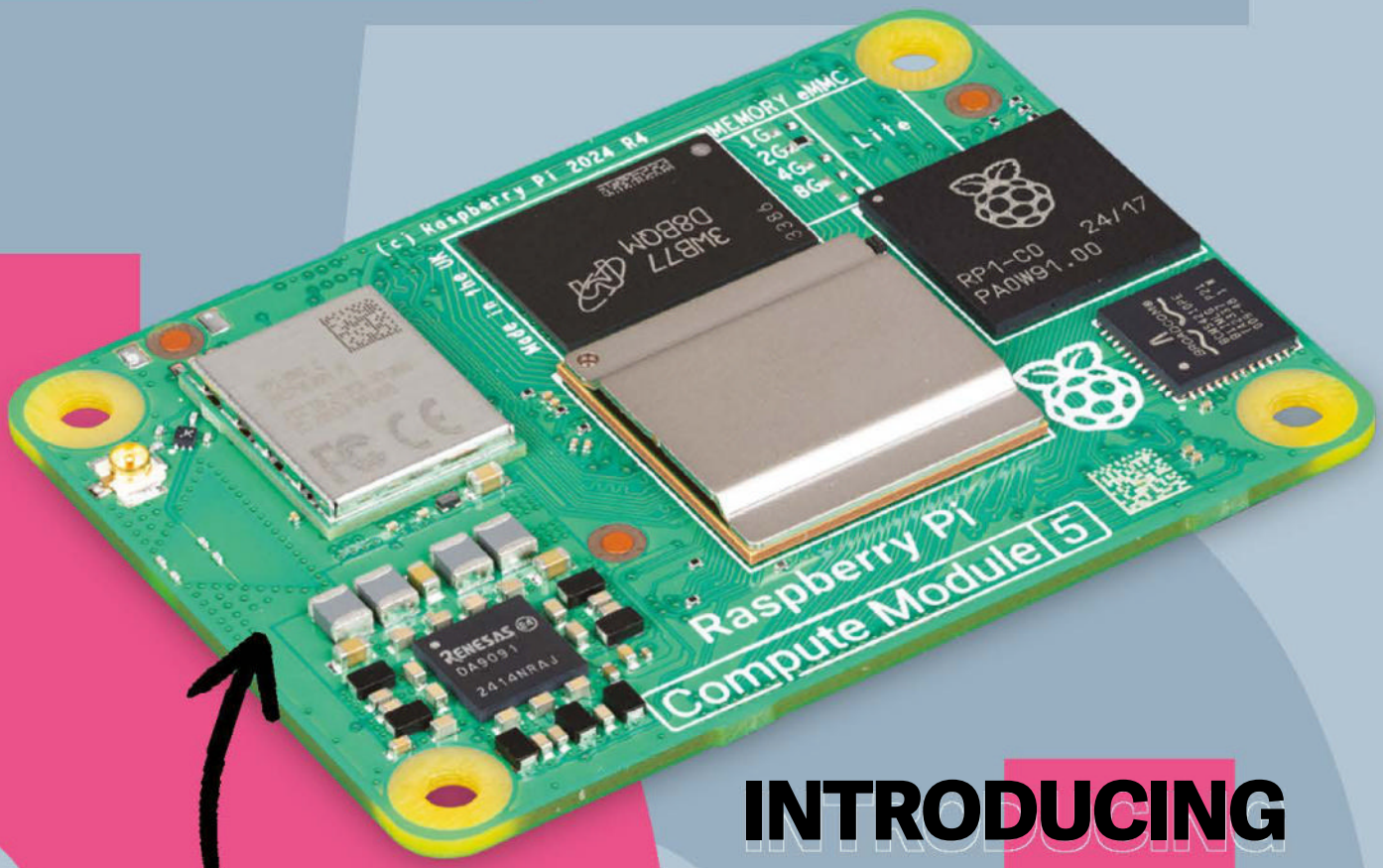
Above
PiDog takes a while to build from the kit, but is a lot of fun to play with

VERDICT

PiDog

A smart canine companion with great possibilities for further training.

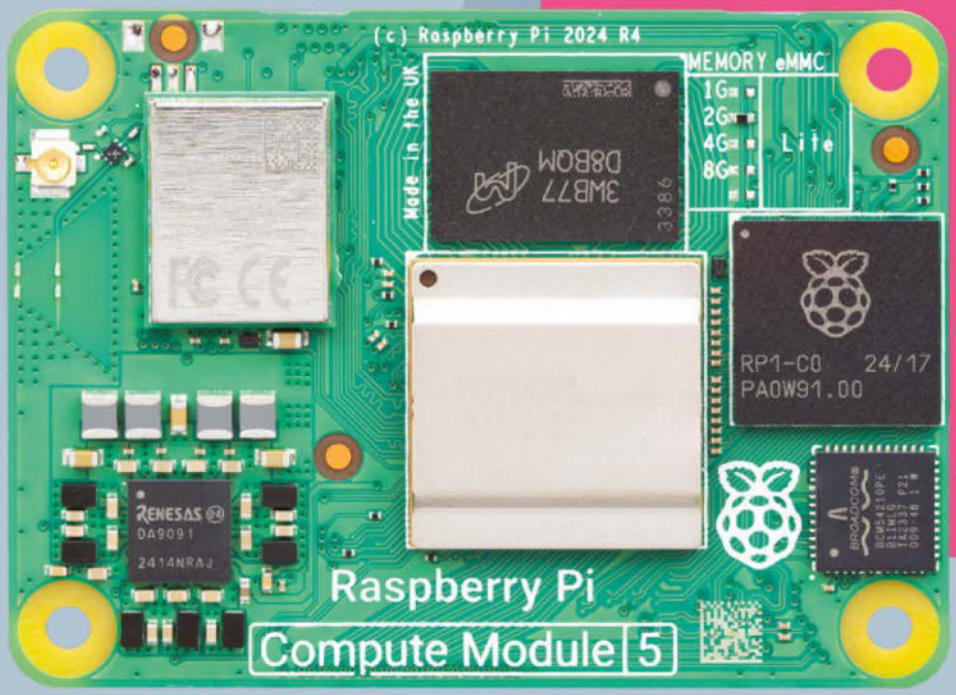
9/10



INTRODUCING COMPUTE MODULE 5

Modular version of Raspberry Pi 5 on sale now from $45

BY EBEN UPTON



Raspberry Pi Compute Module 5 packs the power of Raspberry Pi 5 into a modular system

We're happy to announce the much-anticipated launch of Raspberry Pi Compute Module 5 (magpi.cc/cm5), the modular version of our flagship Raspberry Pi 5 single-board computer, priced from just $45.

An unexpected journey

We founded the Raspberry Pi Foundation back in 2008 with a mission to give today's young people access to the sort of approachable, programmable, affordable computing experience that I benefited from back in the 1980s. The Raspberry Pi computer was, in our minds, a spiritual successor to the BBC Micro, itself the product of the BBC's Computer Literacy Project.

But just as the initially education-focused BBC Micro quickly found a place in the wider commercial computing marketplace, so Raspberry Pi became a platform around which countless companies, from startups to multi-billion-dollar corporations, chose to innovate. Today, between 70 and 80 percent of Raspberry Pi units go into industrial and embedded applications.

While many of our commercial customers continue to use the 'classic' single-board Raspberry Pi form factor, there are those whose needs aren't met by that form factor, or by the default set of peripherals that we choose to include on the SBC product. So, in 2014 we released the first Raspberry Pi Compute Module, providing just the core functionality of Raspberry Pi 1 – processor, memory, non-volatile storage, and power regulation – in an easy-to-integrate SODIMM module.

Compute Modules make it easier than ever for embedded customers to build custom products which benefit from our enormous investments in the Raspberry Pi hardware and software platform.

> **"OUR FRIENDS AT KUNBUS AND TBS HAVE BUILT SUCCESSFUL PRODUCTS ON COMPUTE MODULES"**

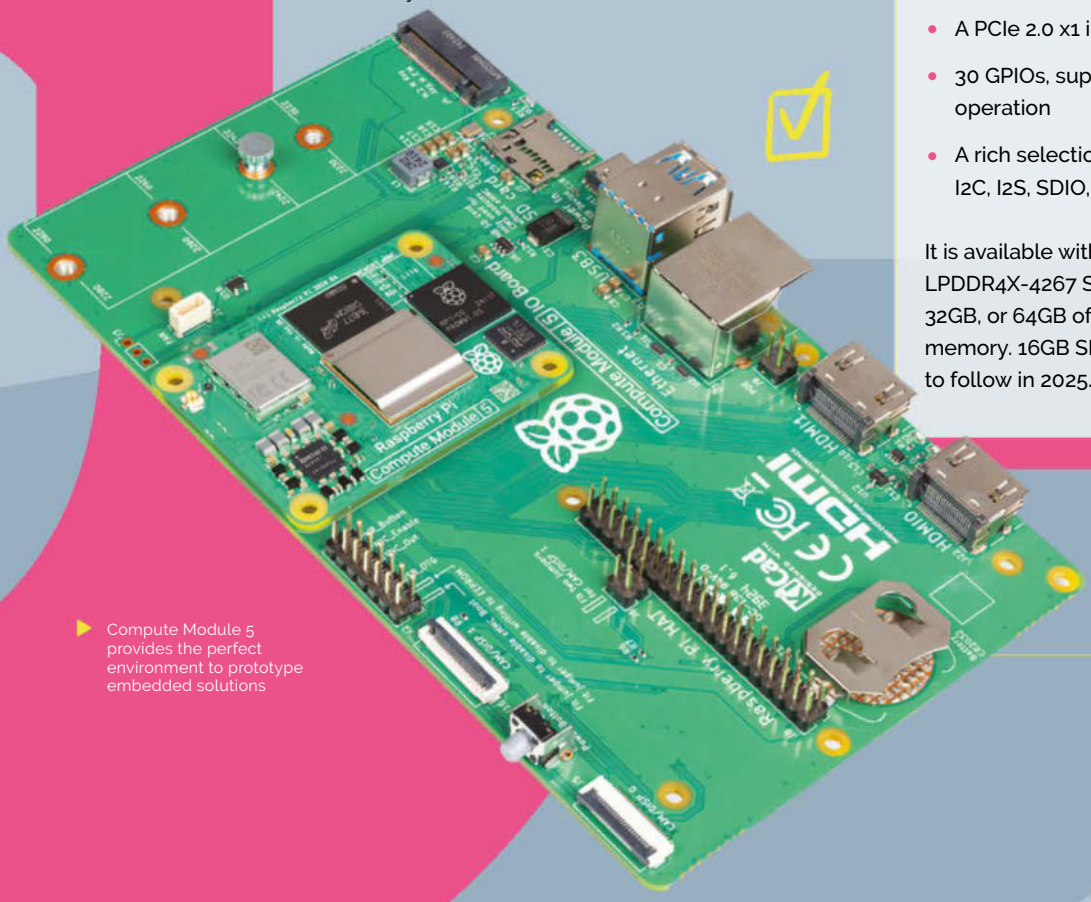
Every subsequent generation of Raspberry Pi, except for Raspberry Pi 2, has spawned a Compute Module derivative. And now, we're happy to announce the launch of Compute Module 5, the modular version of our flagship Raspberry Pi 5 SBC.

Compute Module 5 is mechanically compatible with its predecessor, Compute Module 4, exposing all signals through a pair of high-density perpendicular connectors, which attach to corresponding parts on the customer's carrier board. Additional stability is provided by four M2.5 mounting holes arranged at the corners of the board.

There are a small number of changes to the pin-out and electrical behaviour of the module, mostly associated with the removal of the two two-lane MIPI interfaces, and the addition of two USB 3.0 interfaces. A detailed summary of these changes can be found in the Compute Module 5 datasheet (**magpi.cc/cm5ds**).

Early adopters

The Raspberry Pi Compute Module 5 launch is accompanied by announcements of Compute Module 5-based products from our friends at KUNBUS (**magpi.cc/revpic5**) and TBS (**magpi.cc/oneboxpro25**), who have built successful products on previous Raspberry Pi Compute Modules and whom we have supported to integrate our new module into their latest designs. Other customers are preparing to announce their own Compute Module 5-powered solutions over the next weeks and months. The world is full of innovative engineering companies of every scale, and we're excited to discover the uses to which they'll put our powerful new module. Try Compute Module 5 for yourself and let us know what you build with it.



Compute Module 5 provides the perfect environment to prototype embedded solutions

Meet Compute Module 5

Compute Module 5 gives you everything you love about Raspberry Pi 5, but in a smaller package:

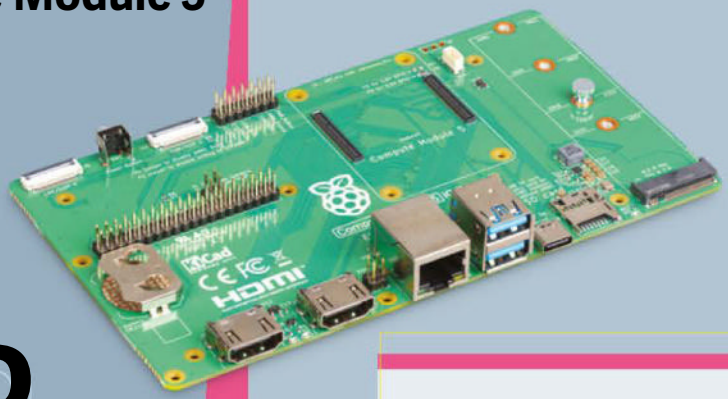
- A 2.4GHz quad-core 64-bit Arm Cortex-A76 CPU
- A VideoCore VII GPU, supporting OpenGL ES 3.1 and Vulkan 1.3
- Dual 4Kp60 HDMI display output
- A 4Kp60 HEVC decoder
- Optional dual-band 802.11ac Wi-Fi and Bluetooth 5.0
- 2 × USB 3.0 interfaces, supporting simultaneous 5Gbps operation
- Gigabit Ethernet, with IEEE 1588 support
- 2 × 4-lane MIPI camera/display transceivers
- A PCIe 2.0 x1 interface for fast peripherals
- 30 GPIOs, supporting 1.8V or 3.3V operation
- A rich selection of peripherals (UART, SPI, I2C, I2S, SDIO, and PWM)

It is available with 2GB, 4GB, or 8GB of LPDDR4X-4267 SDRAM, and with 16GB, 32GB, or 64GB of MLC eMMC non-volatile memory. 16GB SDRAM variants are expected to follow in 2025.

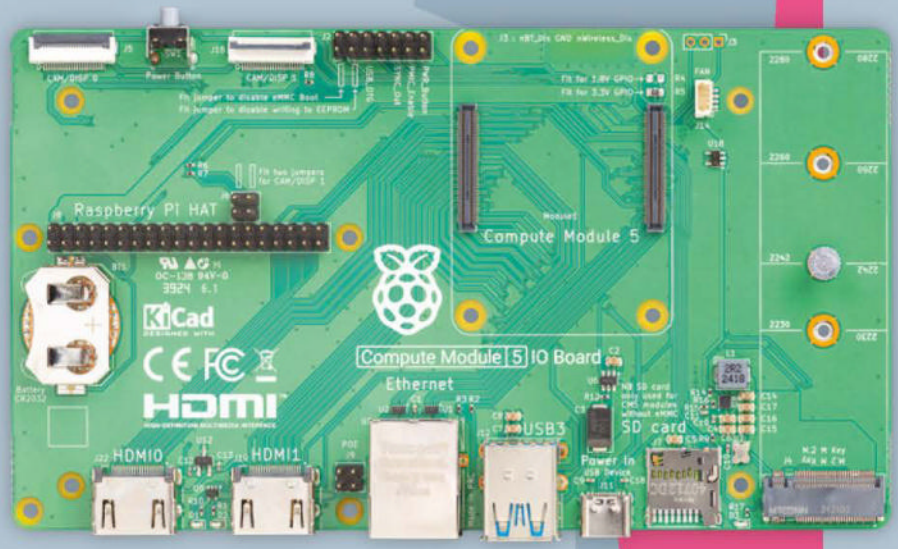
ACCESSORIES

Accessorise your Compute Module 5

Compute Module 5 is only part of the story. Alongside it, we're offering a range of new accessories to help you get the most out of our new modular platform.



IO BOARD



Every generation of Compute Module has been accompanied by an IO board, and Compute Module 5 is no exception. Raspberry Pi Compute Module 5 IO Board (**magpi.cc/cm5ioboard**) breaks out every interface from a Compute Module 5. It serves both as a development platform and as reference baseboard (with design files in KiCad format), reducing the time to market for your Compute Module 5-based designs.

The IO Board features

- A standard 40-pin GPIO connector
- 2 × full-size HDMI 2.0 connectors
- 2 × 4-lane MIPI DSI/CSI-2 FPC connectors (22-pin, 0.5 mm pitch cable)
- 2 × USB 3.0 connectors
- A Gigabit Ethernet jack with PoE+ support (requires a separate Raspberry Pi PoE+ HAT+)
- An M.2 M-key PCIe socket (for 2230, 2242, 2260, and 2280 modules)
- A microSD card socket (for use with Lite modules)
- An RTC battery socket
- A 4-pin fan connector

Power is provided by a USB-C power supply (sold separately).

IO CASE

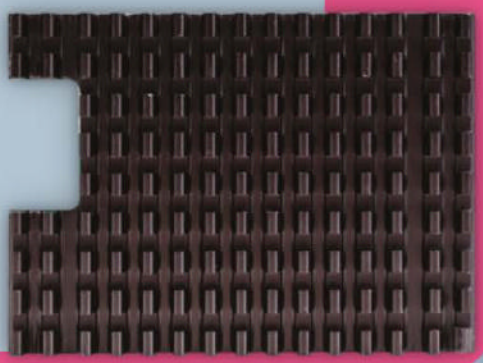
As in previous generations, we expect some users to deploy the IO Board and Compute Module combination as a finished product in its own right: effectively an alternative Raspberry Pi form factor with all the connectors on one side. To support this, we are offering a metal case which turns the IO Board into a complete encapsulated industrial-grade computer. Raspberry Pi IO Case for Raspberry Pi Compute Module 5 (**magpi.cc/cm5iocase**) includes an integrated fan, which can be connected to the 4-pin fan connector on the IO Board to improve thermal performance.

ANTENNA KIT

Wireless-enabled variants of Compute Module 5 provide both an on-board PCB antenna, and a UFL connector for an external antenna. Use of a Raspberry Pi Antenna Kit (identical to that already offered for use with Compute Module 4) with Compute Module 5 is covered by our FCC modular compliance (**magpi.cc/cm4antenna**).

COOLER

While Compute Module 5 is our most efficient modular product yet in terms of energy consumed per instruction executed, like all electronic products it gets warm under load. Raspberry Pi Cooler for Raspberry Pi Compute Module 5 (**magpi.cc/cm5cooler**) is a finned aluminium heatsink, designed to fit on a Compute Module 5, and including thermal pads to optimise heat transfer from the CPU, memory, wireless module, and eMMC.



DEVELOPMENT KIT

Raspberry Pi Development Kit for Raspberry Pi Compute Module 5 (magpi.cc/cm5devkit) comprises a Compute Module 5, an IO Board, and all the other accessories you need to start building your own design:

- CM5104032 (Compute Module 5, with wireless, 4GB RAM, 32GB eMMC storage)
- IO Case for Compute Module 5
- Compute Module 5 IO Board
- Cooler for Compute Module 5
- Raspberry Pi 27W USB-C PD Power Supply (local variant as applicable)
- Antenna Kit
- 2 × Raspberry Pi standard HDMI to HDMI Cable
- Raspberry Pi USB-A to USB-C Cable

Documentation, Compliance, and Obsolescence

Extensive documentation for Compute Module 5 is available on the Raspberry Pi website:

- Raspberry Pi Compute Module 5 product brief (**magpi.cc/cm5brief**)
- Raspberry Pi Compute Module 5 datasheet (**magpi.cc/cm5datasheet**)
- Raspberry Pi Compute Module 5 design files (`magpi.cc/cm5designfiles`)

Raspberry Pi Compute Module 5 has undergone extensive compliance testing and meets a number of regional and international standards.

View and download relevant certificates and conformity documents on the Raspberry Pi Product Information Portal (**pip.raspberrypi.com**).

If you require any further information regarding compliance, please contact Raspberry Pi at **compliance@raspberrypi.com**.

Raspberry Pi Compute Module 5 will remain in production until at least January 2036.

> **RASPBERRY PI DEVELOPMENT KIT CONTAINS ALL YOU NEED TO START BUILDING YOUR OWN DESIGN**

MEET THE ENGINEER

DOMINIC PLUNKETT

How the pieces of the CM5 puzzle came together

SENIOR PRINCIPAL HARDWARE ENGINEER

The MagPi: What's changed between CM4 and CM5?

Dominic Plunkett: CM5 takes all of the goodness of Raspberry Pi 5 and puts it on the Compute Module. So we've got the BCM2712 Broadcom processor used on Raspberry Pi 5. We've got our IO processor, the RP1. That's a whole extra chip on the board compared with CM4, and so that required a lot of effort to get it on there.

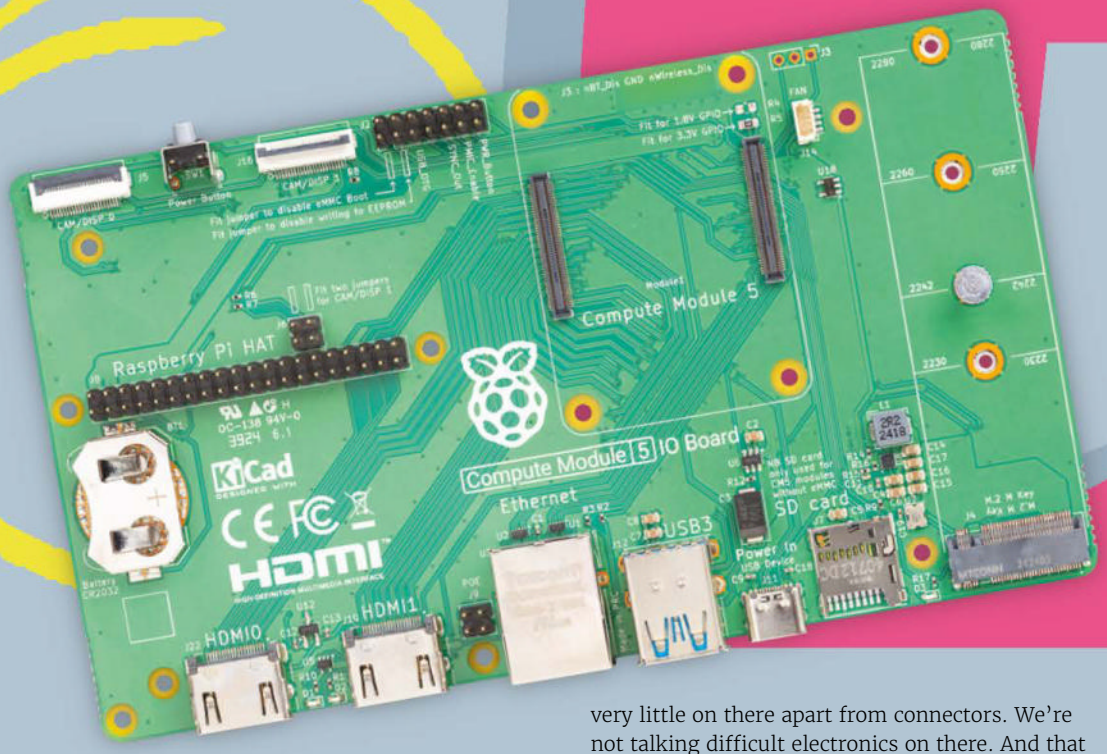
I'd set myself the challenge that the central processor wouldn't move, so that anyone who has used a CM4 with any sort of heatsinking would be able to use the same setup with CM5. That gave me a huge challenge to try and get the RP1 on the board – for weeks it was hanging off the edge of the board, but eventually I managed to squeeze up the bits and get all the electronics on there correctly.

MP: Compute Module 5 is basically a Raspberry Pi 5 without the connectors, so what's stopping you from just taking Raspberry Pi 5 and sort of snipping off the bits of the PCB with the connectors on?

DP: I can do exactly that, but it won't be as small. Compute Module is significantly smaller than Raspberry Pi 5, and what we also wanted to add things like on-board eMMC, so there's extra technology to squeeze into the same area as Compute Module 4. In theory, yes, all you're doing is cutting off the connectors, but there's a lot of work to make that happen correctly.

MP: So the challenge is to keep the same form factor as CM4?

DP: Yes. It was possible to change the form factor, but that was something that I didn't want to do, because that potentially affects backward compatibility. You could probably change form factor in small ways that won't affect many people, but the second you make a change, you're going to affect somebody.



Want to make your own modified CM5 IO board? Install KiCad, download the design files, and get cracking!

Apart from the physical change in the shape of the heatsinking of the main processor, it is basically the same form factor. Some of the parts have moved on the board, but they shouldn't affect end users.

But electrically, there have had to be some changes, because you're trying to add new features. So there are some differences with means that it's not 100% compatible. But for most people it will be a drop-in replacement, and we're already seeing that people are using it within setups that were designed for CM4 with no problems.

We've added new features such as USB 3.0 that won't work when the CM5 is plugged into a carrier board designed for CM4, because the CM4 didn't have USB 3.0. That's life.

If you want something 100% compatible, stay with CM4; CM4 is still in production and will remain in production for a number of years – 2030-something, and it may well be that we extend it beyond that so it remains available.

MP: So if a manufacturer wants to get the USB 3.0 functionality out of the CM5, they either have to upgrade to the new carrier board, or design their own electronics, right?

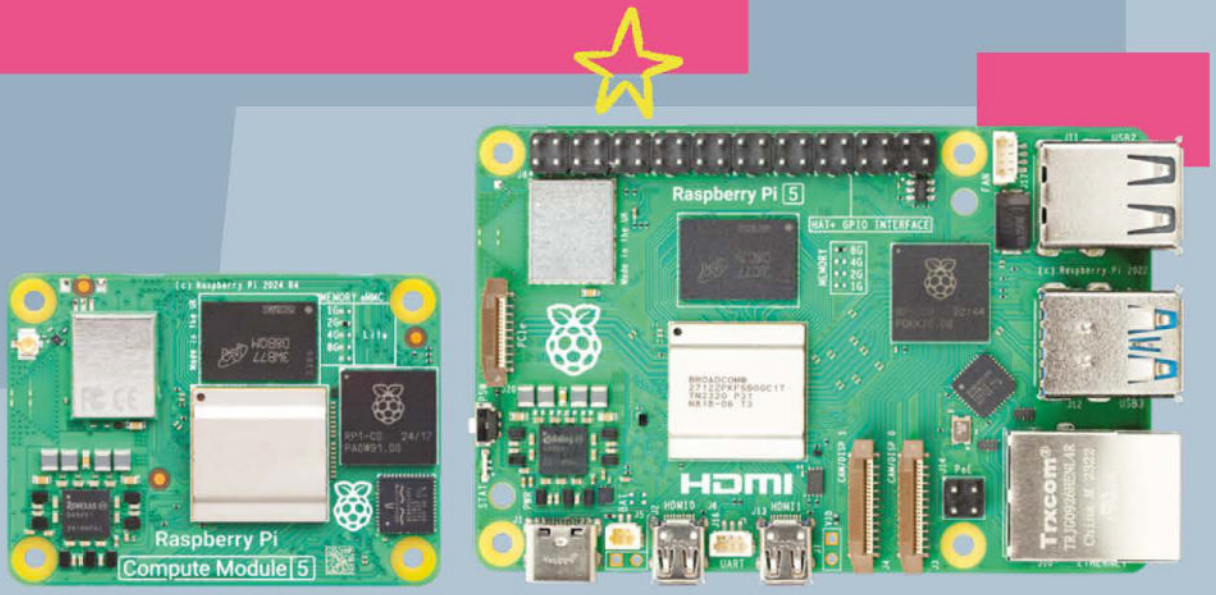
DP: Indeed. The Compute Module is designed for people who want to design their own board. My main aim for both CM4 and CM5 was to absorb as many of the bits that you need into the CM module, so all you need to do is put connectors on your board. So if you look at the CM5 IO board, there is very little on there apart from connectors. We're not talking difficult electronics on there. And that was the whole aim. We do the CM5 IO board in KiCad, which is a freely downloadable CAD system, and the design files for the CM5 IO board are freely available, so you can take the files, delete the bits you don't want, move things around however you want, and design your own board.

MP: What were the challenges in shrinking the functionality of Raspberry Pi 5 onto the CM5 shape?

DP: It was the density, and it was getting RP1 on to the board – RP1 is actually a small chip, but as a proportion of the board, it's made [the electronics] quite a bit denser.

> **THE CM5 ITSELF IS NOW A TEN-LAYER CIRCUIT BOARD – RASPBERRY PI 5 HAS SIX LAYERS**

So getting it onto the board sensibly was hard because there's a lot of IO – it's our IO chip, so there's the USB 3.0 pairs that come out of there. There's the MIPI pairs; the Ethernet comes out of it via a PHY. And then there's all the PCIe to get into it, and all the GPIO to come out of it. So that area of the board is very dense, and it took a long time to be able to work out how to make it all fit.



To fit all of Raspberry Pi 5's goodness in a much smaller footprint, the CM5 PCB has had to go to ten copper layers rather than the six on Raspberry Pi 5

The CM5 itself is now a ten-layer circuit board (Raspberry Pi 5 has six layers). So there's ten layers of copper inside it, with quite a lot of ground planes, because all of these high-speed signals like USB 3.0 and PCIe have to be electrically matched on the circuit board. So you've got to do some quite accurate routing of the traces to make sure you get good signal integrity across the board.

The edge of the RP1 chip, which is on the end of the board, has all the USB 3.0 signals coming off. They can't come out because there's no board space, so they have to go down into the board and then be routed on an inner layer of the board. And so that's quite dense at that corner of the board. And then you're routing them on the inner layers.

> **YOU'VE GOT MORE USB OVERALL AVAILABLE THAN YOU HAD ON THE COMPUTE MODULE 4**

And you've also got the MIPI pairs in another layer, and then you've got Ethernet on the bottom layer. So there are a lot of signals trying to cross each other and route out and take up the same sort of space, and so you're just trying to keep everything in three dimensions correctly spaced apart with the correct copper reference planes in the board there.

It took a while to work out with our board manufacturers just how it was going to work. And in the end, we actually made the circuit board 40 microns thicker than the CM4 to make all the electric impedances correct. That extra thickness then allowed me to get the next part of the puzzle solved.

It's a big puzzle-solving exercise that just requires a lot of juggling and a lot of looking at and working on it. It's quite a dense little circuit board, this; it's complex, but once you've sat at it for a couple of weeks, you start to you get a feel of where things are happening, where things are dense… I usually concentrate on the hard bits first, so I'll do a bit, then I'll get to a point where I think, 'Oh, I'm pretty sure I know how that area is going to route out now.' So then I'll go and do the next hardest bit, and I'll come and finish that off once I'm sure I can get all the hard bits done, because if I can't get the hard bits done, then I have to make a decision of what to change.

MP: Was there anything that you were forced to leave off in the process of shrinking the goodness of Raspberry Pi 5 into the smaller size of the CM5?

DP: Very early on, we had an internal discussion about some of the signals, because we've got the 200 pin connectors and we knew we were going to have to change some signals there, as some of the signals don't exist in the new world. So that freed up some pins. But then we had more signals that we wanted to put on the pins than there were pins available, and we had to decide what the features were going to be included. So Raspberry Pi 5 has two USB 2.0 ports on the right-hand side, and they got left off. There was no signal space for those two USB 2.0 ports, so they don't exist on CM5.

Some people will find that they would like some extra USB ports, but we have to balance and try and get a good product for everybody, and not just one person or one group of people. So the key thing is to make sure it's good for a number of people, and there was a good level of backwards compatibility for our main customers as well.

You've got more USB overall available than you had on the CM4. So CM4 had four MIPI ports, but

Raspberry Pi 5 onwards only supports two MIPI ports. So that frees up two MIPI ports that we could reallocate for USB 3.0. And that's exactly what we did.

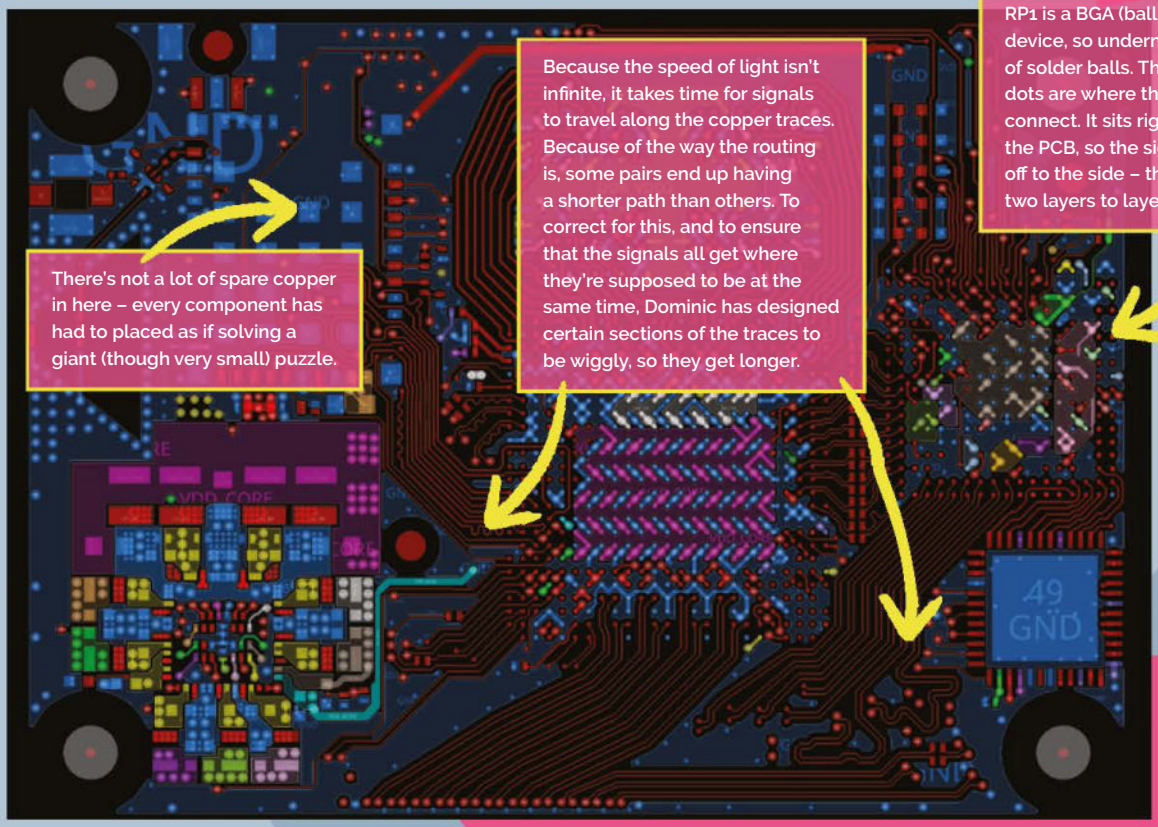
So if you do plug a CM5 into a CM4 board, and you use one of the MIPI ports, then that can no longer be used for one of the cameras and one of the displays. But that's life. We have to make some choices. And yes, so those choices will be hard for some people, and I fully acknowledge that some people will find the choices that we made were not right for them. But as I say, CM4 is still available, and CM4 was obviously the right product when they designed their product around the CM4. It's not going to become obsolete. But a lot of people will find that they can just drop in CM5 and get more processing performance.

If you have the on-board eMMC, that is significantly faster. So that's faster than an SD card, and that's significantly faster than the on-board eMMC that CM4 had. So we've made some other improvements as well. There's more memory available – in future there'll be a 16 gig version.

There's no 1GB version any more – if someone came along with an order for a few million of them I'm sure we'd consider it, but at the moment there isn't going to be a 1GB version. In part that's the inevitable march of progress. It's also that we already have loads of products on the books, and we have to be rational and not overload ourselves with loads of different products that are just going to sit in inventory.

MP: Where are Compute Modules turning up? What sort of products are companies building with them?

DP: They get into all sorts of places because they are small, efficient compute power for people. And it becomes easy just to add your own IO to your system, and you get all the goodness of Raspberry Pi. And because it uses the same software, you can do all your development on a Raspberry Pi 5 in advance of creating your custom board.



COMPUTE MODULE CASE STUDIES

Success stories from companies using the most versatile Raspberry Pi

KORG SYNTHESIZERS

SIZE OF BUSINESS: LARGE ENTERPRISE

INDUSTRY: MUSIC TECHNOLOGY

TECHNOLOGY: COMPUTE MODULE 3

URL: MAGPI.CC/KORGCS

Korg is one of the most recognisable names in synths – in fact, it made Japan's first synthesizer. Since the 2000s, Korg has been using Linux to run on its high-end keyboards powered by the kind of chips you used to get in the netbooks of the era – most recently though, the firm has been using Compute Module 3 in some of its synths; specifically the wavestate, modwave, and opsix models.

This move to Raspberry Pi Compute Module came while Korg R&D was trying to reach a sub-$1000 price point while still maintaining quality, and also fixing persistent technical issues along the way. Korg hoped this was the way to reach more musicians, and after using more traditional desktop and laptop-style solutions for over a decade, it realised Raspberry Pi Compute Module was the logical step to help bring that price down.

This resulted in wavestate, a successor to the 30-year-old Wavestation that uses a combination of two boards – one for the actual physical synth controls, and another that has audio subsystems and power – both of which connect to CM3.

"Not everyone understands that Raspberry Pi is actually making the sound – many people assume that it's not," Dan Phillips from Korg told Raspberry Pi. "We use the CM3 because it's very powerful, which makes it possible to create deep, compelling instruments."

iPourIt

After waiting in line so long for a specific beer only for it to be sold out by the time he got to the bar, Brett Jones, CTO of iPourIt, thought there had to be a better way. So he designed an automated system that lets customers choose their beer and pay using an RFID device linked to their tab. It's very popular with businesses, as it allows for faster service, less wastage, and even saves space. In fact, you can find 5800 iPourIt taps in 220 locations across North America.

By 2019, some of the first iPourIt terminals were reaching eight years old and maintenance and refurbishment was becoming costly. Until now they'd been based on various Android devices over the years, and it was time for more consistent and reliable technology to replace them. Enter, Compute Module 3+, with the help of a Raspberry Pi 4.

The whole system went from wireless to PoE (Power-over-Ethernet), simplifying the wiring in the process. Each touchscreen includes a CM3+ to control it, and every twelve taps are then controlled by one Raspberry Pi 4. The system allows for extremely accurate dispensing, and now includes spirit and liquor dispensing.

"Right now we are probably 20% less expensive than our nearest competitor, so price-wise, how [Compute Module] has been designed has really allowed us to reduce the acquisition cost for our operators," Darren Nicholson, CMO of iPourIt, told Raspberry Pi.

SIZE OF BUSINESS: SMALL TO MEDIUM

INDUSTRY: HOSPITALITY (FOOD AND BEVERAGE)

TECHNOLOGY: COMPUTE MODULE 3+ AND RASPBERRY PI 4

URL: MAGPI.CC/IPOURITCS

Bio Business

In 2009, Mostafa Elwakeel along with two colleagues set up Bio Business, recognising the potential of Internet of Things-based monitoring products. As part of this they started creating ECG machines, ventilators, and other critical medical equipment. The devices took off, and before long they were making medical equipment for large companies such as Philips, Siemens, and GE.

Bio Business began manufacturing more kinds of IoT devices, including ones that shared imaging data such as ultrasounds, radiation, x-rays, and MRIs. The next step was creating IoT monitoring devices on an OEM basis that provided detailed environmental information, such as temperature, humidity, air quality readings, etc. Connecting everything to the cloud complicated things, especially when a lot of the equipment could be mobile. Bio Business also needed to be able to secure components that would easily scale up as its client base/product demand increased.

Raspberry Pi Compute Module 4 and RP2040 ended up being the solution as the company otherwise started to struggle to keep up with demand. Its CPAP machines use RP2040 to measure oxygen levels, and Bio Business also sells Raspberry Pi-based oxygen concentrators with manual control and power monitoring.

SIZE OF BUSINESS: SME

INDUSTRY: MEDICAL TECHNOLOGY

TECHNOLOGY: COMPUTE MODULE 4, RP2040

URL: MAGPI.CC/BIOBIZCS

TBS MINI MEDIA SERVER

SIZE OF BUSINESS: SME

INDUSTRY: TV, HOSPITALITY

TECHNOLOGY: COMPUTE MODULE 4, RP2040

URL: MAGPI.CC/TBSSERVERCS

While TBS supports the television industry in a lot of ways, it also supplies hotel chains with special systems that run the televisions in their rooms. These can stream channels and provide digital signage as well. While developing its new OBP-24 mini-server, one of the main requirements was the ability for customers to be able to add their own tuner card as well: "So we will be able to stream DVB channels, satellite, terrestrial, or cable through the whole local network," managing director Christian Kingler told Raspberry Pi.

Maintaining a standard form factor was very important, but adding flexibility to adapt the device for different users was also a requirement. In early tests of the design, TBS used a Raspberry Pi 4 and everything was working just fine. After that, the firm started using Compute Module 4 and developed the PCB for the final product from there.

"It was quite attractive to have the CM4 IO board available… We were also able to test with this first, and then we made our own adaptation [for] what we needed in terms of form factor and PoE," added Kingler. RP2040 was then used for the little LCD control panel at the front of the OBP-24, thanks to further testing at an early stage using existing hardware, before being adapted and made according to the company's needs.

HOMEY PRO SMART HOME HUB

SIZE OF BUSINESS: SME

INDUSTRY: SMART HOME

TECHNOLOGY: COMPUTE MODULE 4

URL: MAGPI.CC/HOMEYPROCS

Homey started life in 2014 as a smart speaker and home hub from the Dutch company Athom. Over the years, the firm has released more powerful devices with more advanced features. This included Homey Bridge, to add local wireless connectivity to earlier models.

While designing the recent Homey Pro, Athom wanted it to work with as many communication systems as possible – including Zigbee, Z-Wave, Wi-Fi, Bluetooth, 433MHz RF, infrared, and Thread, without needing the extra Bridge. It became a challenge to fit everything into the device.

"We didn't want it to look like a gaming router with all these antennas sticking out," said Emile Nijssen of Athom. "So getting that right took a long time. And we also wanted to profit from the development we did on Homey Bridge. So actually while designing Homey Bridge, which is sort of a light version of Homey Pro, even if you look at it from the outside, we already were thinking about how later on we could put our own carrier board on top of it that could carry, for example, a Compute Module."

Choosing a Compute Module 4 allowed Athom to get to market faster, as it didn't need to "reinvent the wheel" to get a small Linux computer working. Integration was straightforward thanks to the documentation and robust software support.

SETTING THE PACE

NOW AVAILABLE

RevPi Connect 5

powered by Compute Module 5

The Gold Standard for Industrial Raspberry Pi in IIoT and Automation since 2016.

revolutionpi.com

REVOLUTION PI
a KUNBUS brand

PiFi

▶ PiFi ▶ **pifi.org** ▶ £35 / $35

Solving a newer issue for an older problem, **Rob Zwetsloot** tests the paces of this mobile wireless access point converter

SPECS

WIRELESS:
802.11ac, dual-band, 1300Mbps

RASPBERRY PI COMPATIBILITY:
Raspberry Pi 4 and Raspberry Pi 5

KIT CONTENTS:
Preloaded 32GB SD card, Cat 6 cable, PiFi USB 3.0 wireless adapter

Wi-Fi is just about everywhere now. Classic locations for complimentary Wi-Fi such as hotels and coffee shops have been joined by pubs, restaurants, theme parks, coaches, and aircraft. Back in the day, though, even hotels would just have an Ethernet port for connectivity. When Raspberry Pi first launched in 2012, creating mobile access points and/or Tor routers to take to hotels was quite popular, and you can see similar technology utilised today with the popular Pi-hole system protecting home networks.

Quantity doesn't always make up for quality, though. A lot of these wireless networks can be very slow, especially when you're used to full fibre speeds or even decent 5G. And we can't tell you the number of Airbnbs we've been in where Wi-Fi only works in one corner of the property.

Enter, PiFi, a simple kit that allows you to easily create a fast and secure wireless network with just a Raspberry Pi.

The kit comes with just three items: a microSD card with the software preloaded, an Ethernet cable to plug into the nearest router, and the all-important Wi-Fi dongle that handles a lot of the heavy lifting for the wireless.

External vs internal

When plugged into a USB 3.0 socket, the wireless dongle is actually faster than the internal wireless on Raspberry Pi 4 when utilised as an access point – PiFi reckons it's up to eight times faster, and in our tests it was definitely running noticeably faster for internal speeds.

▶ You can use PiFi with WireGuard or OpenVPN

PiFi can provide far faster wireless speeds

Set up is a doddle – you literally just plug everything in and turn Raspberry Pi on. You can then connect via the smartphone app, set up a new admin password, and you're done. There's extra settings you can start digging around in,

> It's definitely coming with us to all future Airbnbs

and you can even tunnel through a VPN if you have one. By default, WireGuard is available for connecting to a VPN; however, OpenVPN can be selected in the VPN tab of the app.

Plug and play

While PiFi is still fairly new, the documentation is very robust. Access to the latter is made available straight from the app if you fancy diving deeper into the configuration – and there's quite a lot of depth to it, to the point where you might break some stuff. Luckily, there's a clever hardware reset involving unplugging the dongle and waiting a minute or so before plugging it back in.

The range is fine. You won't be replacing your home router with something like this, but it can easily work to bring better Wi-Fi to a room or corner of the house if you have a spare LAN port available. And, as we said before, it's definitely coming with us to all future Airbnbs.

A smartphone app is used to configure it

Verdict

A very good piece of kit that simplifies portable access points, with good enough wireless range to boot.

9/10

10 Amazing:

Raspberry Pi Pico 2 builds

What are people making with the brand new microcontroller

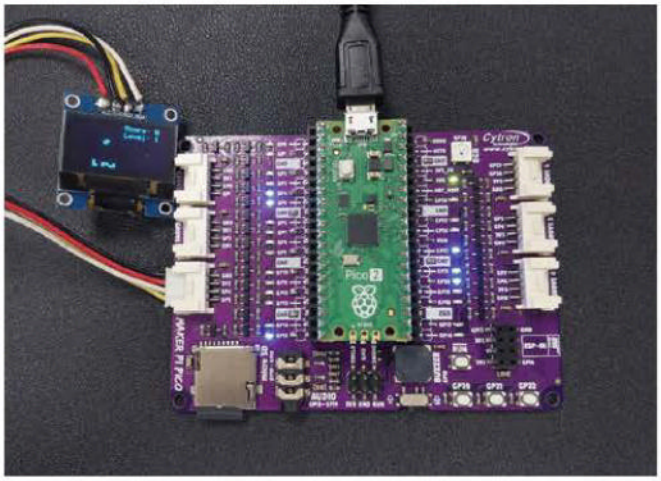
Raspberry Pi Pico 2 W has just recently been announced, but the original Pico 2 has been out long enough for plenty of folks to put it through its paces. There's even some cool products that will help you make great projects of your own! We can't wait to see what folks are making with Pico 2 W in the new year, though...

Pimoroni Explorer

Experiment with Pico

This complete board includes an RP2350 chip, the same one that powers Raspberry Pi Pico 2, allowing you to really experiment with different circuits and code.

magpi.cc/explorer | £34 / $43



Tetris recreation

Rotating tiny pieces

A little OLED display is attached to Pico 2 to recreate the classic Tetris game, which only requires three buttons to begin with.

magpi.cc/pico2tetris

Pico 2 Groovebox

Amen Break to that

Play samples, sounds, and your own tunes with practice with this very DIY piece of kit that can handle loops and recording too.

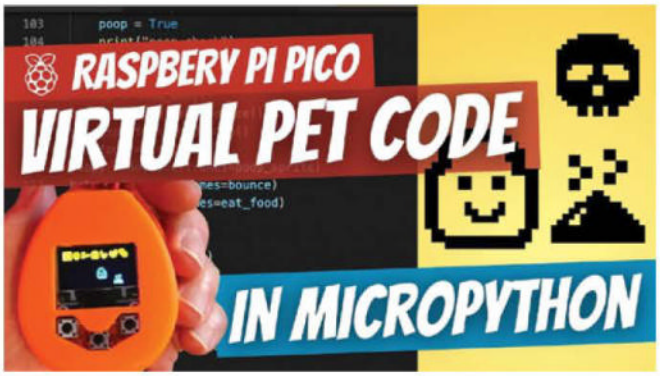
magpi.cc/pico2groove

Plasma 2350

Lights, Pico, action

This RP2350-powered board is purpose-built to drive NeoPixel LEDs so you can create your own amazing light displays. All it requires is a USB-C power supply.

magpi.cc/plasma2350 | £12 / $15



Picotamachibi 2

DIY virtual pet

The upgraded version of the original Picotamachibi includes more complex interactions and animations thanks to the power of Pico 2.

magpi.cc/picotama2

Thumby Color

Tiny game development

This tiny handheld game system is a great way to learn about game development and have fun doing it – on the go!

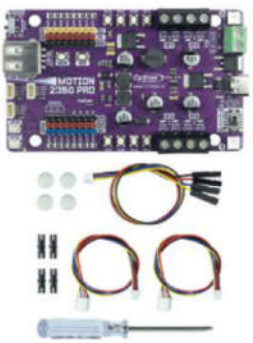
magpi.cc/thumbycolor | £39 / $49

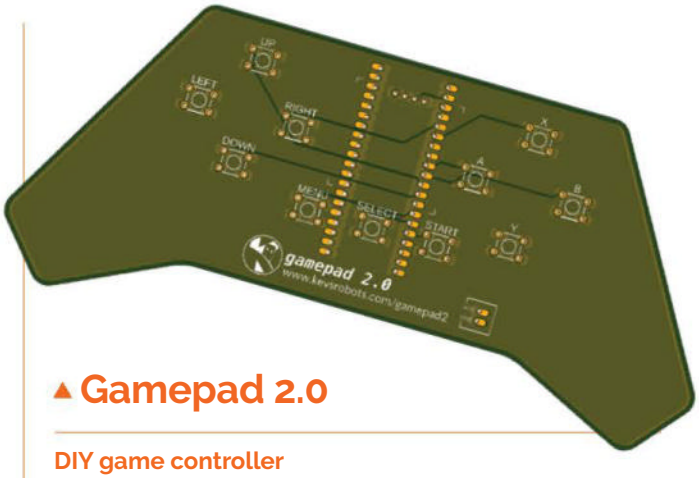
MOTION 2350 Pro

Make a robot

Power up your robot builds with this incredible RP2350 robotics controller featuring a four-channel motor driver and connections for up to eight servos.

magpi.cc/motion2350 | £20/ $25



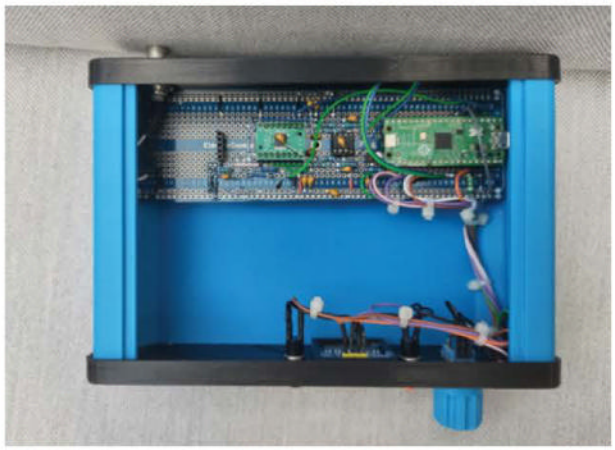


Gamepad 2.0

DIY game controller

Turn your Pico 2 into a gamepad with this custom PCB that also supports using an OLED screen for gaming on the go.

magpi.cc/gamepad2



Pico software-defined radio

Capture the airwaves

This project was started in the previous issue of *The MagPi*, continued in this one, and allows you to construct a radio receiver with a Pico, or Pico 2, and some simple circuits.

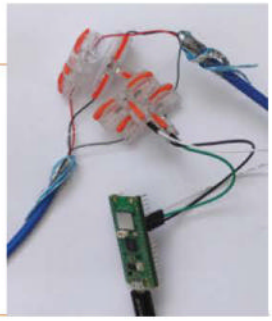
magpi.cc/148

Pico USB sniffer

Inexpensive USB testing

A tutorial from issue 147 of *The MagPi*, this is a cheap and simple way to catch and analyse data packets being transferred via USB – perfect for developers.

magpi.cc/147



GurgleApps

Three young YouTubers who make videos on STEM, creating projects and products

> Name Amélie, Caleb, and Ziva | > Occupation Students
> Community role YouTuber | > URL gurgleapps.com | youtube.com/gurgleapps

We've been covering projects from the team of siblings that make up GurgleApps for a long time – most recently their Colour Word Clock (magpi.cc/colwordclock) – and they themselves have been using a Raspberry Pi since the year it came out. In fact, it helped turn them into the makers they are today.

"Making became a part of our lives largely due to the influence of our parents, who filled our home with electronics, science, and coding projects," the GurgleApps trio tell us.

"Funnily enough, we weren't hooked immediately – we had all this amazing equipment and knowledge at home, but took it for granted. The real spark came when Caleb received his first Raspberry Pi in 2012. Our dad playfully 'forgot' to tell us about the startx command, so we spent the first month working solely in the terminal, using simple commands like top and programming in Vi (a text editor) to create quiz and adventure games – without realising there was a graphical interface! It was rather frustrating for us at the time, but as our dad reminded us, it was nothing compared to his old ZX Spectrum."

▼ The Word Clock is getting an update – it's likely hit their shop by the time you read this

How did you start making videos together?

We started making videos together somewhat accidentally in 2015. It all kicked off with a prank on our dad where we used a Raspberry Pi to SSH into his computer and close the app he was working on. Amélie demonstrated the prank using simple shell commands, while Caleb handled the filming. Since we were too young for social media, we posted the video on our parents' account. Unexpectedly, it went viral, gathering 1.4 million views! The overwhelming support inspired us to create more content, leading to the birth of our channel, GurgleApps.

During the COVID-19 pandemic, we noticed that many students – including us – were missing out on hands-on science experiments. We started recreating school physics experiments at home and sharing tutorials on our channel. This allowed others to keep learning and exploring STEM subjects despite the circumstances. We're dedicated

This Pico Piano uses touch capacitive keys and was custom-made by the team

to making STEM education accessible and fun for everyone.

What was your first group maker project?
Our first significant group project was creating the Pico Piano. We built it using a Raspberry Pi Pico microcontroller and designed our own circuit board right at home. To make the circuit board, we used a DIY method: drawing the circuit design on a copper board with Sharpies and then etching it using ferric chloride. This hands-on process was both challenging and exciting, as it combined electronics, coding, and a bit of chemistry.

How has the channel affected your lives?
Running our YouTube channel has taught us a wide range of skills – from presenting and video editing to live-streaming and valuable maker and business skills. Live streaming helped us handle mistakes on the fly and build confidence. We've also been guests on podcasts and other live streams, which allowed us to meet lots of fun and interesting people in the maker community.

Our STEM knowledge has deepened significantly.

> Our YouTube channel has taught us a wide range of skills – from presenting and video editing to business skills

Supportive viewers often share their expertise; for example, one viewer spent hours teaching us about PCB manufacturing, and another pointed out an inaccuracy in our light gate calculations, helping us learn and improve.

What's your favourite thing you've made together?
Our favourite project we've made together is definitely the Word Clock! It's special to us because it was inspired by our very first word clock project with a tiny 8×8 display over ten years ago. We've evolved it into a kit that you can now buy, and we've made everything open source – even the 3D print files for the case are available. We spent months perfecting it and putting everything we've learned into making it something we're really proud of. What's even more exciting is seeing people hack it to do things we never dreamed of. Watching others take our creation, build upon it, and share their own versions has been incredibly rewarding. We've recently updated our custom-made RGB LED matrix display – a key component of our word clock – and hopefully it will be ready for purchase from our shop very soon!

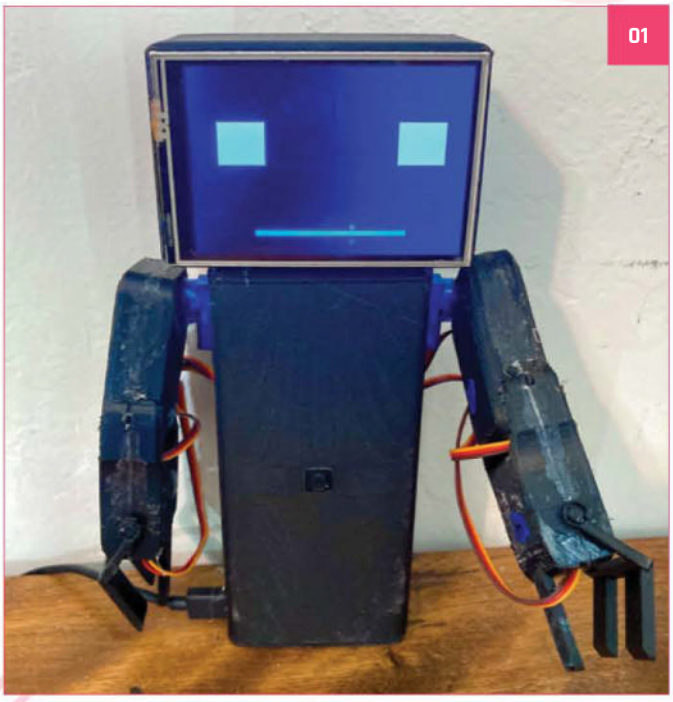
Ziva has coded on a Speccy on live stream, recreating the first program their grandparents wrote

MagPi 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.

Here's a selection of some of the awesome things we got sent this month – and remember to follow along at the hashtag #MagPiMonday!



01. This is a robot called Robert, with face detection and the ability to talk, sent to us via email

02. This arcade machine is very tiny but at leasts seems to have Blast Processing abilities

03. It's been very fun to follow along with this project! Now we can ride the model train virtually

04. Today we learned what an oud is – maybe we need this script too

05. These kinds of photo booths always go down well at weddings

06. This is a great Pico project for learning about making and code

07. This was originally powered by a Raspberry Pi computer! It sat on the GPIO pins, so it's very cool to see it working on Pico

08. Aki once again back with a cool tiny little project using Pico 2

09. Some very serious enterprise Raspberry Pi stuff going on here

03

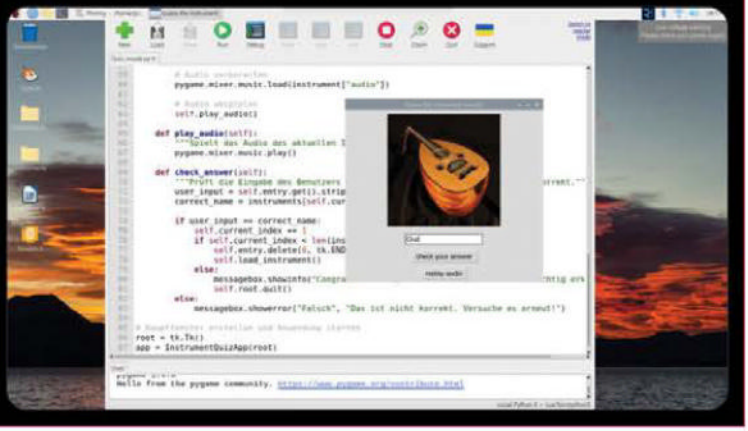
Pater Practicus
@PaterPracticus

Video-equipped model inspection train now fully operational, with almost completed bodywork conversion. Part 1 of the how-to video also finished: youtu.be/aizuPh6pryo?si... #MagPiMonday

04

Roland Schulz
@r_schulz_maker

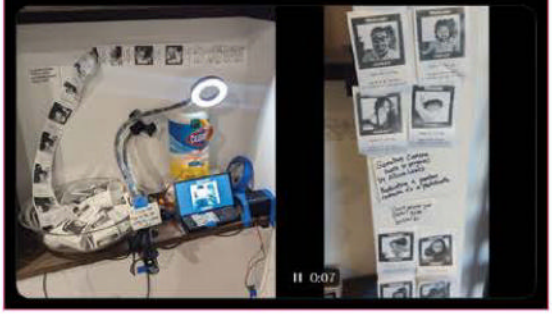
Hi @TheMagPi , I wrote a #python script supported by GUI and @pygame_org on a @Raspberry_Pi 400 to help my daughter with her homework, so that she can recognize different instruments by sound and image. #MagPiMonday #maker



05

Alicen Lewis
@alicen_lewis

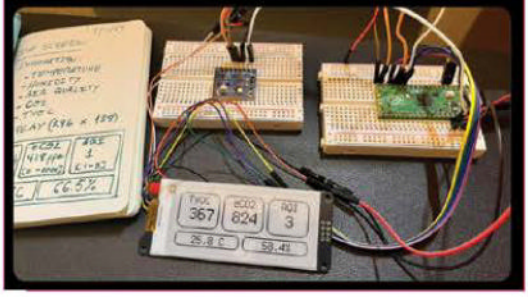
Work in progress, but created a photobooth inspired by Gameboy Camera #magpimonday



06

jvlobo
@jvlob

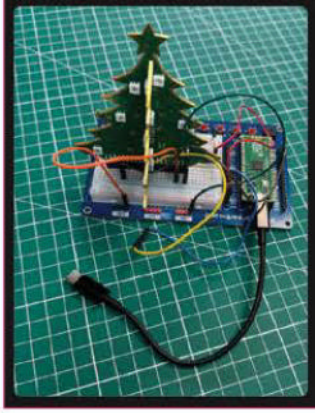
Building a TVOC, CO2, temperature, and humidity monitor with an ink screen on the Pico—learning so much, and it's super cool! Still need to refine the interface and design a 3D printed enclosure.



07

jhmcaleely 19h

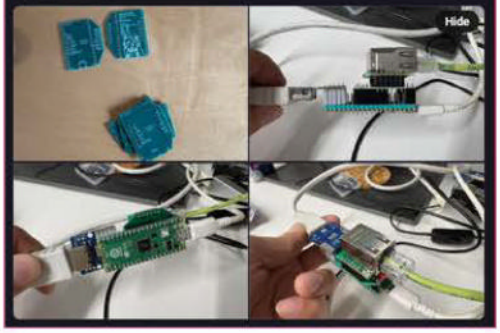
@themagpimag is it MagPiMonday ? Here's a prototype of a @thepihut 3D Xmas Tree being driven from a Pico. A fun little reverse engineering project!



08

あっきぃ@C105月曜西2い-19a
@akkiesoft@social.mikutter.hachune.net

@themagpi I made an adapter board to use WIZnet W5500 module and PicoDVI together with Raspberry Pi Pico 2. I'll create a signage using a wired network to exhibit at Ogaki Mini Maker Fair 2024 ! #MagPiMonday



09

OpenEmbed
@Open_Embed

Start to arrange first batch of the RaspberryPi PLC

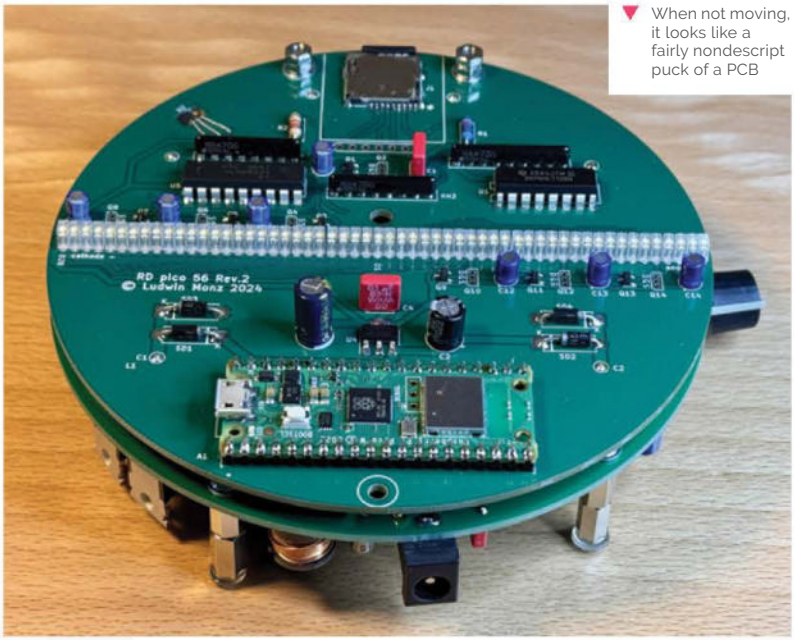
Rotating Display – persistence of vision

A Pico-powered rotating display using 56 LEDs

As ever, we get emails from people with projects that end up being showcased throughout the magazine. This POV (persistence of vision, not point of view) project is one we wanted to highlight here in the community section. It's by maker Ludwin Monz.

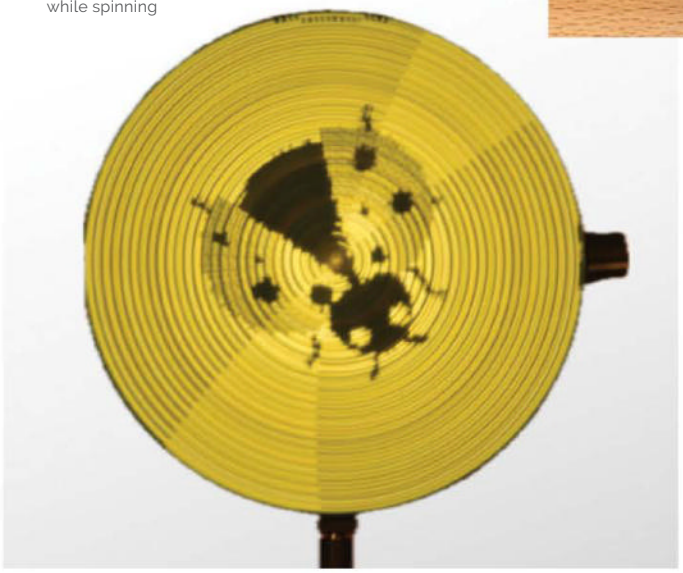
"I have developed a persistence of vision rotating display which is controlled by a Raspberry Pi Pico W," Ludwin writes. "It makes use of the RP2040 PIO for fast multiplexing of 56 LEDs. The device is easy to replicate and might be a fun project for your readers. All technical documentation (circuit diagrams, PCBs, software) is open source and free for non-commercial use."

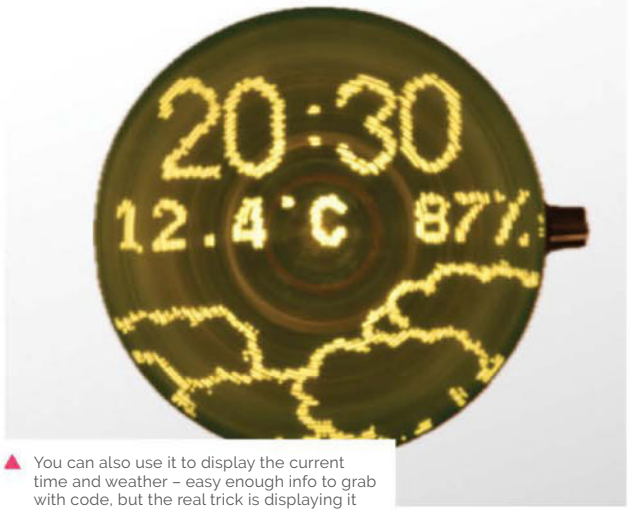
You can check out the full build on Instructables (**magpi.cc/povpicoinst**), and see a video of it in action over on YouTube (**magpi.cc/povpicoyt**).



When not moving, it looks like a fairly nondescript puck of a PCB

The device can display still images and animations while spinning





You can also use it to display the current time and weather – easy enough info to grab with code, but the real trick is displaying it

Best of the rest!

Other cool Raspberry Pi things we saw this month

'SPOTTED AT CANCUN AIRPORT'

One of our favourite games – spot the digital signage powered by Raspberry Pi at an airport. Sightings seem rarer these days, though...

magpi.cc/cancun

AUTOMATED CHEESSBOARD

'Mechanical Turks' have come a very long way since putting a guy in a box to play chess. We love the implementation of this.

magpi.cc/autochess

Your Letters

Errata 1 – AI in issue 141

Any errata found are posted to the issue page on our website at **magpi.cc/issues**

I tried to get the image creator working.

Is it correct that the end of step 7 is the same as step 8?

When starting step 9, 'python mitsua_app.py', I only get the ModuleNotFoundError: No module named 'diffusers'.

I had a look in the following *MagPi* issues but didn't find a correction of step 8 at all.

Jürgen via email

Yes, there was unfortunately an error with that tutorial – we put errata on the website for each issue (**magpi.cc/issues**). In this case, it reads:

On page 39 as part of the 'Build an artist-respecting image diffuser' tutorial, the last code block on step 07 should read:

```
$ pip install diffusers
$ pip install transformers
$ pip install torch torchvision torchaudio –
index-url https://download.pytorch.org/whl/cpu
$ pip install accelerate
```

If you try step 09 again, it should now work fine.

Send us your projects with a photo and they may end up in the magazine – wherever you send it to

#MagPiMonday via email

I don't have social media, but I would like to share my project, so would it be alright if I emailed in my pictures for MagPi Monday?

Nathanael via email

Absolutely – in fact, Nathanael sent us his project and we've featured it in This Month in Raspberry Pi, which you can find on page 118! If anyone wishes to submit a project, whether for #MagPiMonday or elsewhere in the magazine, you can always email us.

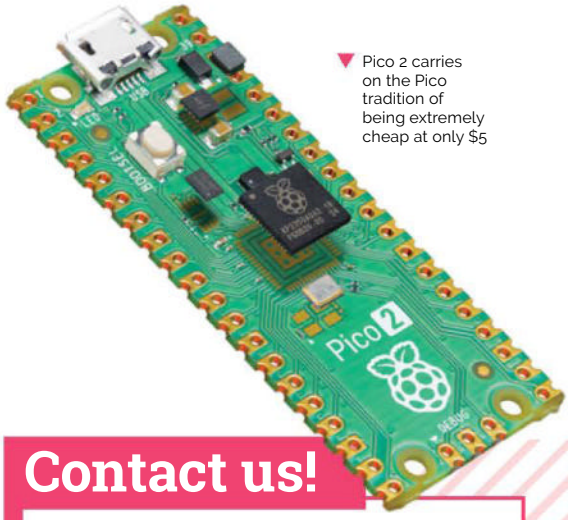
Errata 2 – Pico 2 price

I would just like to point out that on page 39 of the Gear Guide 2025 (#148), the Raspberry Pi Pico 2 pictured says 'From: £67 / $70'. If I'm not mistaken, this is not the real price of the Pico 2. Thanks, and have a great day!

Elouan via Facebook

Yes, Raspberry Pi Pico 2 is a fair bit cheaper than that! It looks like the info for Raspberry Pi 400 was put there by mistake.

A standard Pico 2 will set you back £5 / $5, while a Pico 2 W (newly announced since our Gear Guide was released) is £7 / $7, and you can find out more about both at **magpi.cc/pico2**.



▼ Pico 2 carries on the Pico tradition of being extremely cheap at only $5

Contact us!

- Mastodon **magpi.cc/mastodon**
- Threads **@themagpimag**
- Facebook **magpi.cc/facebook**
- Email **magpi@raspberrypi.com**
- Online **forums.raspberrypi.com**

Community Events Calendar

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

01. Southend Raspberry Jam Maker Meetup

- Thursday 19 December
- The Board Game Hut, Southend on Sea, UK
- magpi.cc/srjmm149

Southend Raspberry Jam Maker Meetup is a monthly meetup for those who are interested in building hardware and software projects using Raspberry Pi hardware and want to join a friendly group of enthusiasts and makers. We welcome beginners to professionals. If you have any ideas for projects, talks or demos, we're especially keen to hear from you.

02. Raspberry Pint

- Tuesday 28 January
- Online
- magpi.cc/pint149

This is Raspberry Pint, where we share our digital making experiences. Most of our presentations are about building personal or professional projects with Raspberry Pi boards, Arduinos, ESP32s, micro:bits, etc. We also welcome presentations about skills and techniques such as website design, PCB design, SW development, 3D printing, soldering, etc. Occasionally, we have had presentations about deep learning, big data, IoT, etc. and would love to hear about what you do in your hobby or professional life. All makers and all digital making welcome. The quirkier, the better.

03. PLUG/Perth Open Source Hacking afternoon

- Sunday 12 January
- Perth Artifactory, Perth, Australia
- magpi.cc/plug149

The monthly PLUG + POSH Hack Afternoon is a language/platform-agnostic hack session. Bring your favourite or interesting project and a love of code, or any other tech project that you're interested in. We'll be hosting it in person at the Artifactory, as well as online.

04. PLUG Annual General Meeting 2025

- Tuesday 14 January
- Riff/Spacecubed, Perth, Australia
- magpi.cc/plug2025

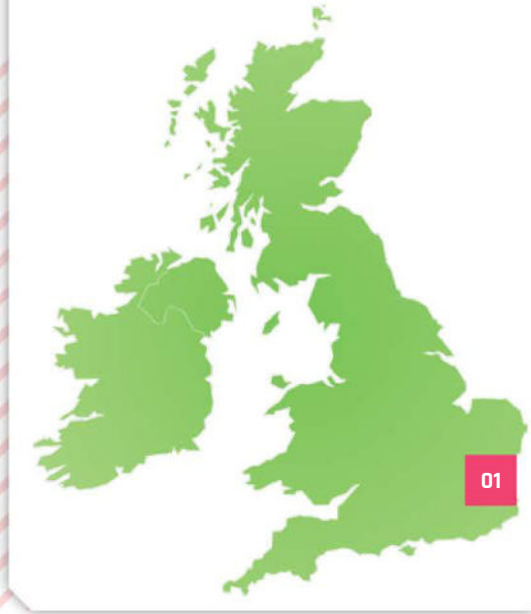
PLUG Annual General Meeting 2025. Light refreshments from 18:30, meeting starts 19:00 (doors are locked at 18:00 so please call the number on the door if arriving later).

FULL CALENDAR

Get a full list of upcoming community events here:

magpi.cc/events

SOUTHEND RASPBERRY JAM MAKER MEETUP



New year, new events

- Where Around the world
- When 2025

Nothing has been announced just yet for Raspberry Pi events in 2025, but expect the usual selection of maker event appearances, online talks, and maybe some pop-up stores (but don't quote us on that last one). See you in 2025!

magpi.cc/events

WIN ONE OF FIVE RASPBERRY PI MONITORS

The brand new Raspberry Pi Monitor has been in the making for ages, and it's finally out to help you create the perfect Raspberry Pi setup when paired with a Raspberry Pi 500. We have five – read it, five! – to give away.

Head here to enter: magpi.cc/win | Learn more: magpi.cc/monitor

Terms & Conditions

Competition opens on **18 December 2024** and closes on **30 January 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 The MagPi 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 or any other companies used to promote the service.

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150

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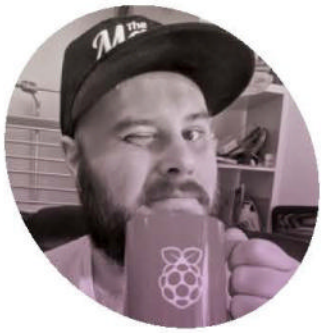

The big One-Five-Oh

The MagPi is getting to a big number, and **Rob Zwetsloot** is excited for it

Next month will be the 150th issue of *The MagPi*. Starting from humble beginnings as a fanzine (which I didn't work on but I did read), to this 119-issue long stint (as of this issue) as the official Raspberry Pi magazine, I feel like the mag has come a very long way in the last twelve or so years. There's even been change in the last year with the addition of the excellent HackSpace section to the magazine.

Like Raspberry Pi itself, the magazine has just been going from strength to strength – although we'd have not got anywhere without the wonderful community we get to highlight, and the readers who pick up a copy at the shops or get it delivered to their door every month. Thank you all!

Ten years official

Next year will also coincide with ten years of the magazine being official, which means I'll have worked on the magazine for ten years. At an old job, someone told me about how they change careers every ten years, and it's something I think about often. I don't mean because I'm thinking about leaving *The MagPi* – as a career I've been a magazine writer for about 13 years, so I'm long past due that anyway – but because ten years is a long time. It also probably feels especially longer because since 2015 a lot of major things have happened around the world.

In my first year at Raspberry Pi, we put Raspberry Pi Zero on the cover – that was 2015! In fact when I joined, several months before the famous issue 40 came out, it was already on the cards. We were working up to it happening, building up the magazine with that issue as the goal. While issue 150 won't be that grand (unfortunately we cannot put Raspberry Pi 500 on the cover, sorry), it will still be just as important. We'll even have a fancy cover! We don't know what kind of fancy cover yet but mark my words, fancy.

> "We'd have not got anywhere without the wonderful community we get to highlight"

Beyond 150

As you may have noticed, a huge number of Raspberry Pi products have been released over the last few months and I am very excited to get to play with them more in 2025. The X00 series of Raspberry Pi are my fave, so I'm looking forward to getting my 500 shortly (it's not even been announced as I write this) and upgrading my little workstation. I still have an AI Camera waiting to be used as well and I'm excited to get started with that – computer vision is one of my favourite uses of machine learning.

So I hope you'll join us for issue 150 and for the rest of 2025. While I may not be a spry 20-something anymore like when I started on it, the magazine is not slowing down one bit.

AUTHOR

Rob Zwetsloot

Rob is as old as *Star Trek: The Next Generation*, but it's best not to let the Gen Xers know this; it upsets them.

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