YOUR OFFICIAL RASPBERRY PI MAGAZINE

The MagPi

Issue 135 | November 2023 | magpi.cc

The official Raspberry Pi magazine

Raspberry Pi 5 LAUNCH SPECIAL!

Quickstart setup • Build ideas • Accessories guide

50 Raspberry Pi Projects

XGO robot dog

PicoTouch Synth

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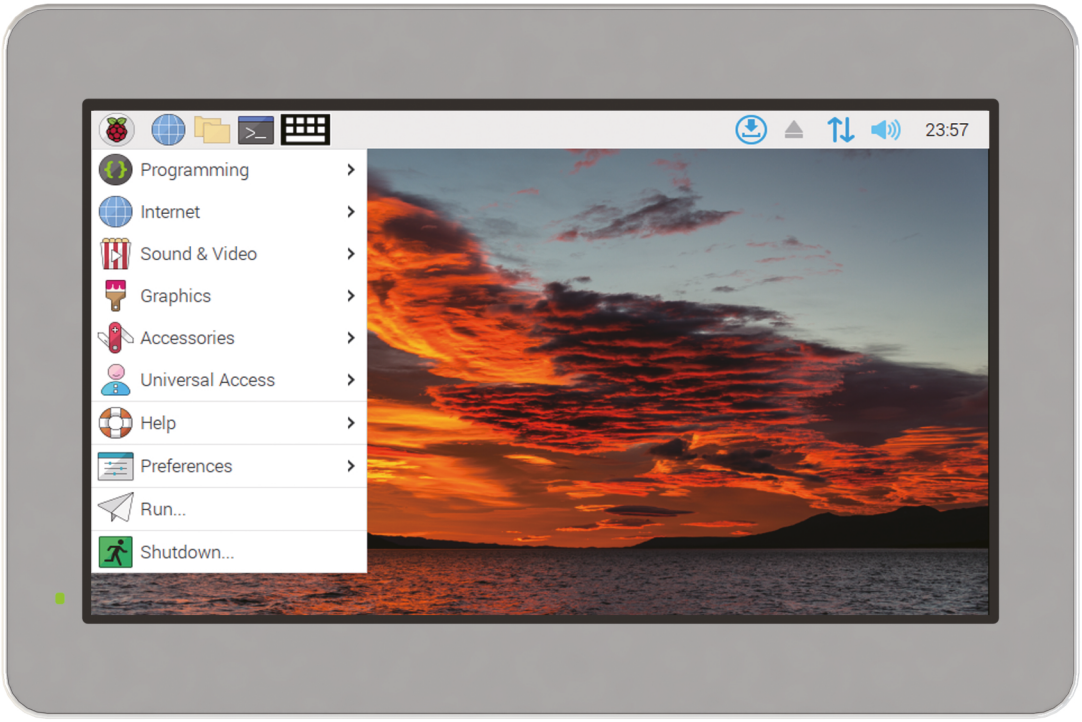
Raspberry Pi PRESS

WIN! OFFICIAL RASPBERRY PI 5 CASE

UL LISTED

Industrial Raspberry Pi

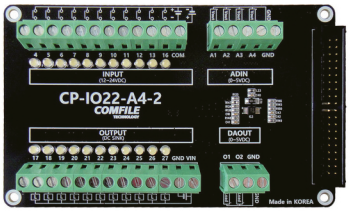


ComfilePi

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.

POWERED BY Raspberry Pi



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COMFILE TECHNOLOGY

WELCOME
to The MagPi 135

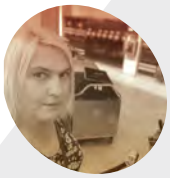
Raspberry Pi 5 is out now! This is a landmark event for Raspberry Pi as it brings speed parity with traditional desktop computers.

That you get all that speed and power in a tiny single-board computer is nothing short of miraculous. And we can't wait to see what you make with it. Our Launch Special starts on page 36.

We've also got 50 Raspberry Pi project ideas starting on page 70. If you're thinking of something to make with your shiny new Raspberry Pi 5, this feature is sure to fire some brain cells.

We can't wait to see what you make with Raspberry Pi 5. So please remember to share your creations (big or small) with us using #MagPiMonday on social media. Or, email us directly: **magpi@raspberrypi.com**. We always love to hear from you!

Lucy Hattersley Editor



EDITOR

Lucy Hattersley

Lucy is editor of *The MagPi* and has been making retro synthpop in the Welsh countryside for the last few weeks. Ideas for her synthpop band name on a postcard, please!

magpi.cc

GET RASPBERRY PI 5 *FIRST!*
Priority Boarding
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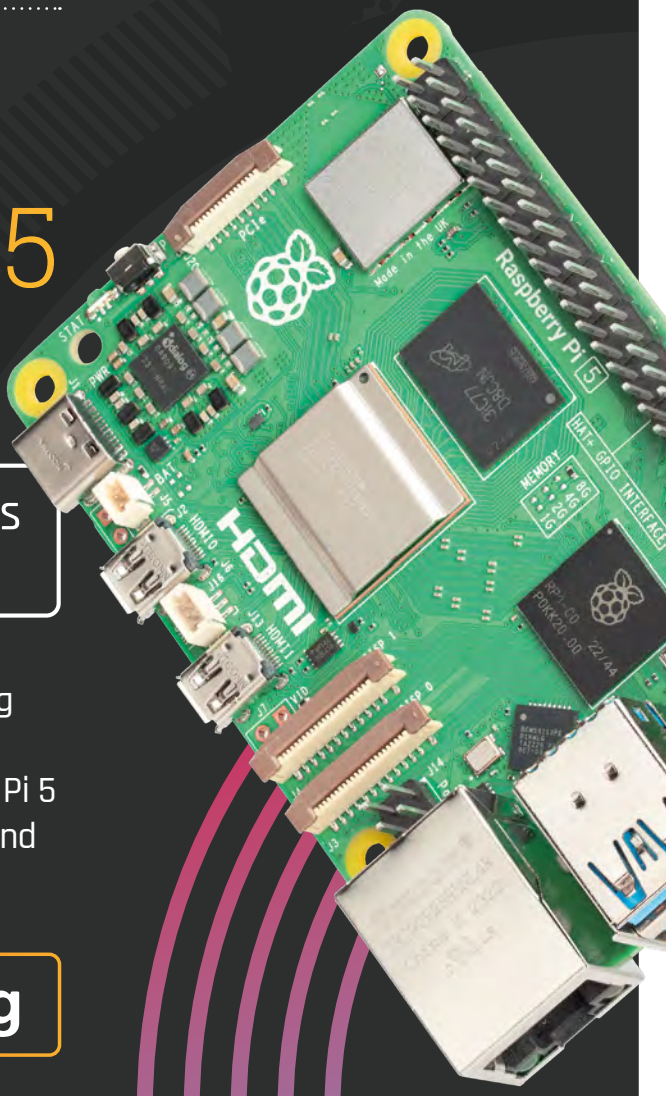
Raspberry Pi 5

PRIORITY BOARDING

GET YOUR RASPBERRY PI 5 *FIRST!*



We've reserved Raspberry Pi 5 boards
for The MagPi subscribers

New subscribers to The MagPi will get a Priority Boarding code when they sign up. So don't delay. Take out a subscription today! You'll be able to buy your Raspberry Pi 5 first and get incredible Raspberry Pi tutorials, projects, and community events every month.

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TERMS & CONDITIONS A Priority Boarding code will be emailed to everybody who takes out a print subscription to The MagPi or HackSpace magazine. People who subscribe to both magazines will get two codes. Print subs only! Priority Boarding does not apply to people with App Store, Google Play, Zinio, PDF contributions, or other paid-for subscriptions. Each code will entitle you to purchase 1x (one) Raspberry Pi 5 model (either 4 GB or 8 GB) for the standard retail price and delivery. Multiple codes need to be used individually. This is a limited offer and is subject to change or withdrawal at any time.

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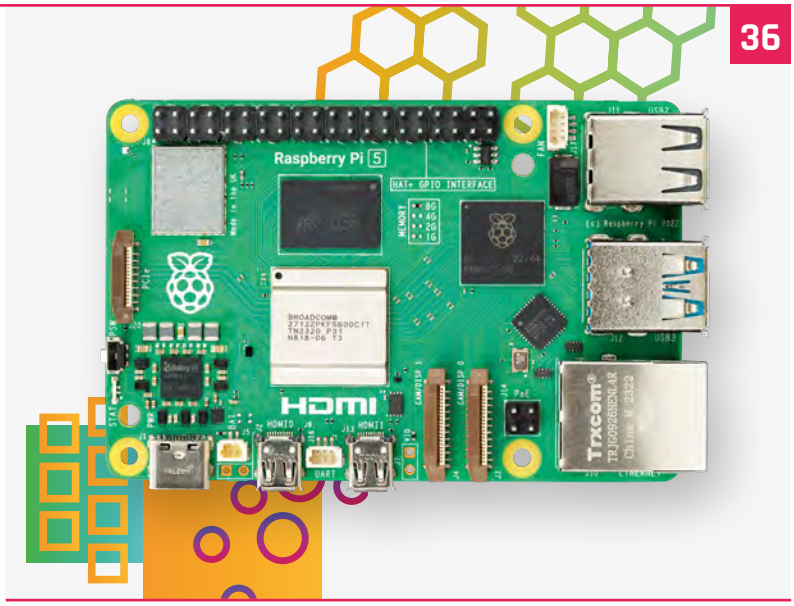

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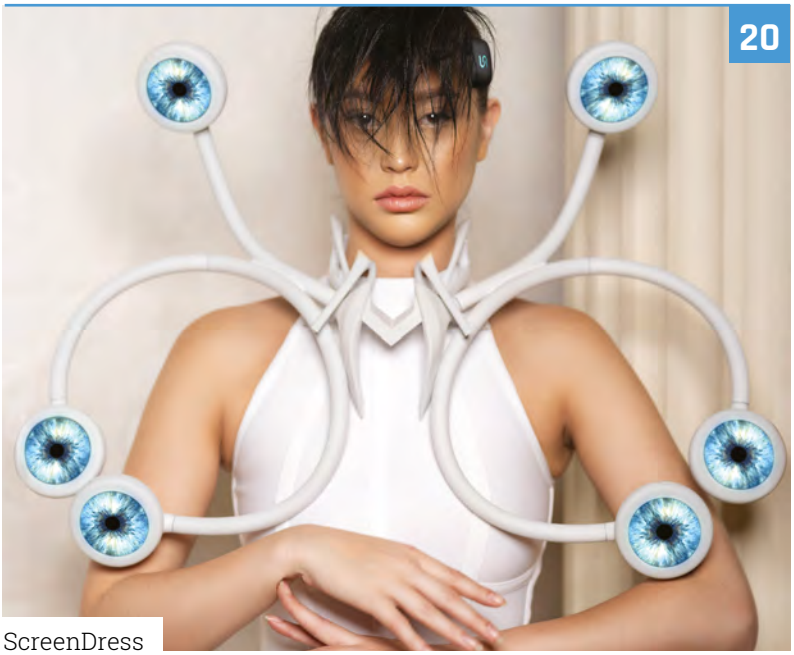

ScreenDress

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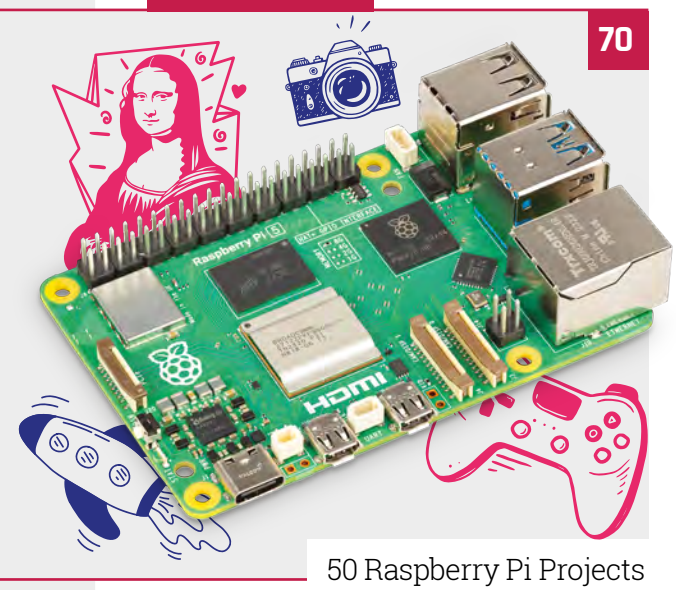

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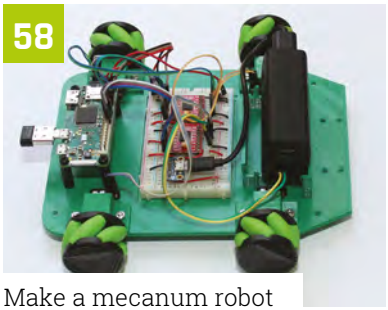

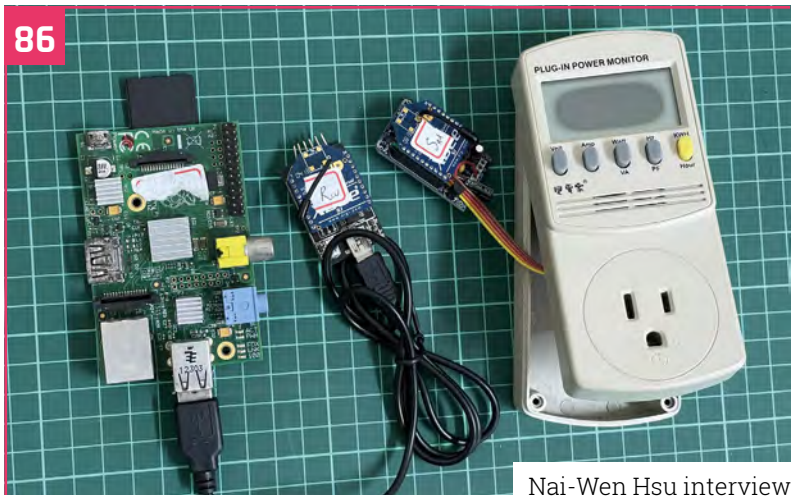

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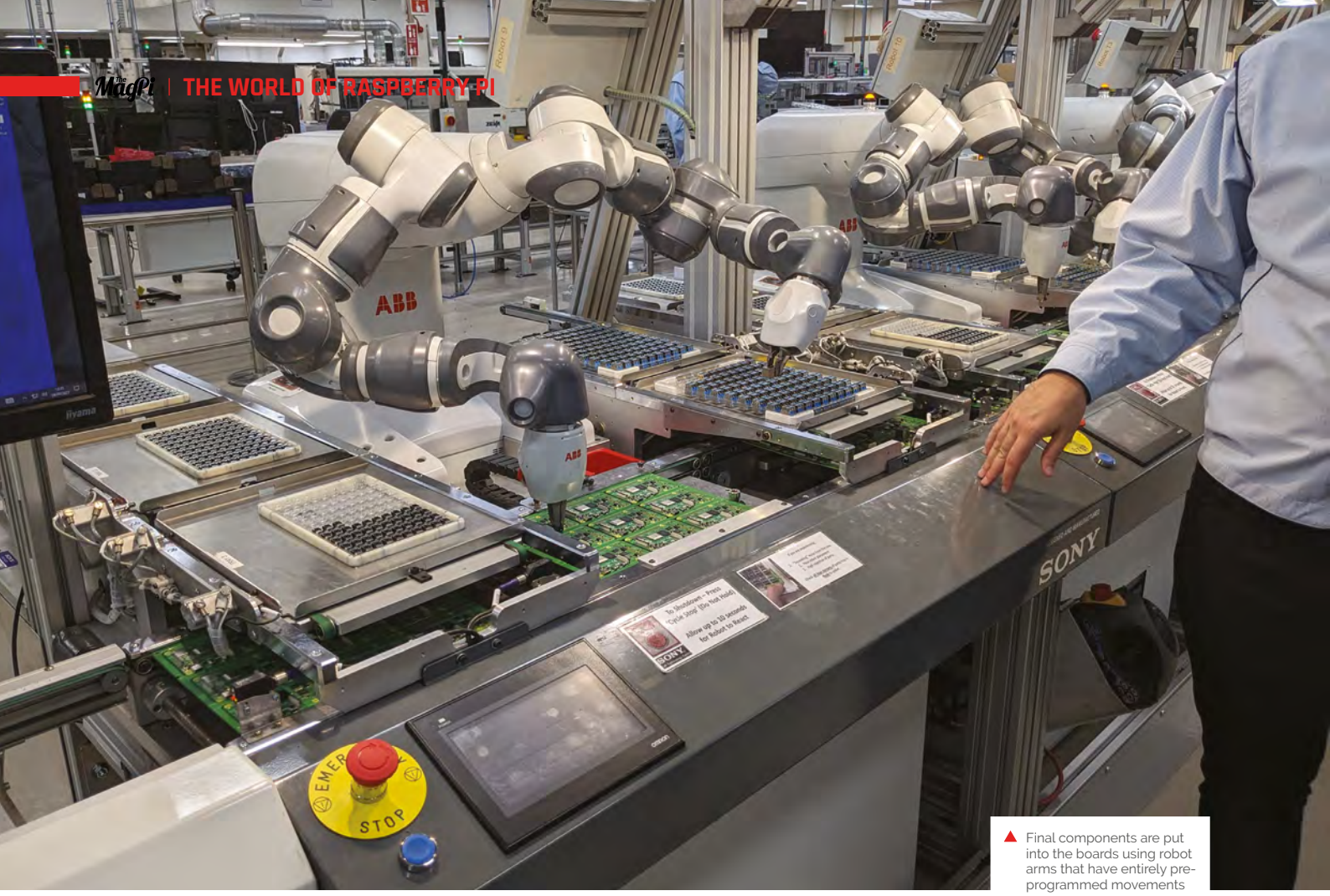


▲ Final components are put into the boards using robot arms that have entirely pre-programmed movements

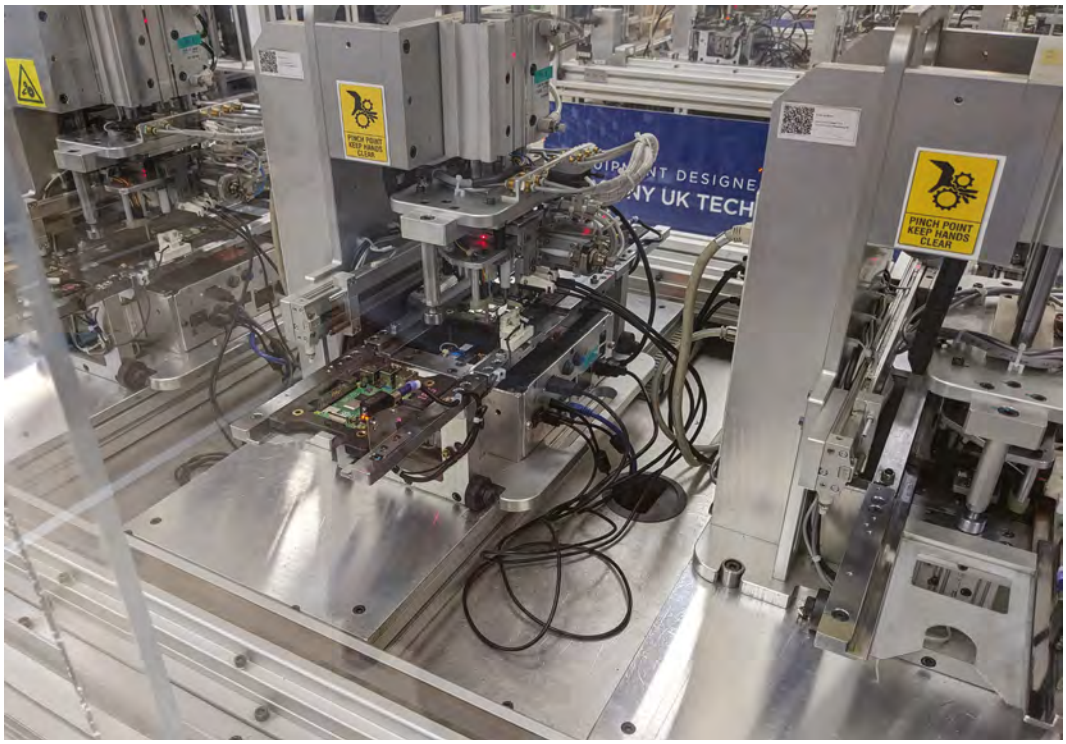
Where Raspberry Pis are made

The Sony factory in Wales is where Raspberry Pi and its accessories come to life. **By Rob Zwetsloot**

▲ Sheets of naked Raspberry Pi 4, ready to be assembled

Pencoed is not a big town, having a population of under 10,000. However, big things come out of there. It's where you'll find the Sony UK Technology Centre, one part factory where the vast majority of Raspberry Pis are made, alongside other products such as Sony broadcast cameras, and also where Sony supports tech startups, prototyping, and code clubs.

We were lucky to be given a tour of the facilities where machines, robot arms, and real people make 250,000 Raspberry Pi computers a week – from board to box. Have you ever seen a machine put a little computer in a box? It's very cute, and the mechanism to fold the lid is a very simple angled piece of metal that runs along the line,



Each board is tested before being packed using this fantastic Sony machine

maintaining the key engineering philosophy of KISS (keep it super-simple, as our friends at the Raspberry Pi Foundation like to say it).

Eco friendly

A (rightful) concern of many people is the environmental impact of manufacturing products, and a key part of the operation of the Pencoed site is meeting sustainability targets which are set every five years. From using more green energy to reducing waste of all kinds, Sony is taking active steps towards reducing its environmental impact.

You can see this along the lines, with (human-supervised) automated checks to make sure all chips are installed correctly. Misaligned chips can usually be reset which cuts down on waste and overall improve yield, and the reflow soldering methods (described in our engineering interview in *The MagPi* 134: **magpi.cc/134**) in the new Raspberry Pi 5 manufacturing process (referred to by a codename of Hydrogen in the factory) that also improve the number of working boards.

The factory floor itself is divided up into areas with clear signs on what section is which. On one station you'll have someone building a broadcast camera from scratch, with two a week going out the doors, and in another section you'll have people snapping boards off runners to be fed into the boxing machine. The complexity is impressive to behold, with a lot of custom machines built and maintained by Sony to make the humble Raspberry Pi.

> We were lucky to be given a tour of the facilities where machines, robot arms, and real people make 250,000 Raspberry Pi computers a week

Factory tour video

Want to see the factory for yourself? Jeff Geerling has a great video of his tour of the factory with even more excellent visuals: **magpi.cc/tour.**

People are trained on how to make Raspberry Pi thoroughly before heading to the factory floor

Blackberry Pi

The BlackBerry is back – or at least that's what **David Crookes** thought until he looked more closely at Zhou Xu's amazing creation

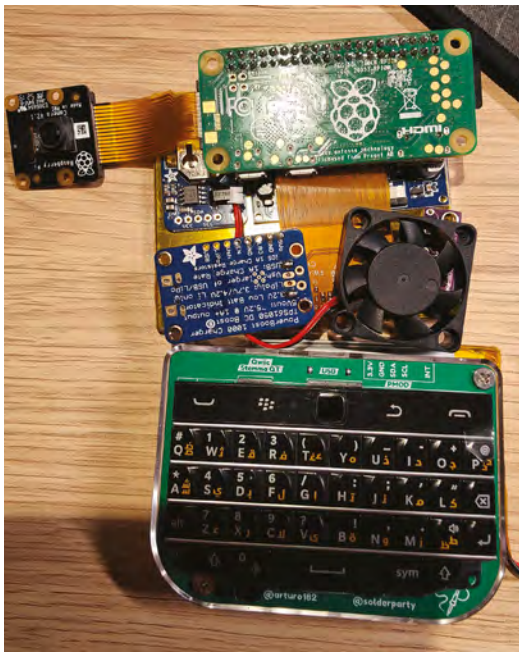
MAKER

Zhou Xu

Zhou is an electron microscope scientist working at Monash University in Australia. He also describes himself as a maker, 3D printing nerd, and LEGO MOCer.

magpi.cc/bbpi

There was a time, before Apple and Google entered the fray, when BlackBerry smartphones were all the rage. They were introduced in 1999 and, at their peak in 2011, attracted more than 85 million users. From that point on, however, it was all downhill as BlackBerry's big selling points – the physical keyboard and email service – gave way to touchscreens and rival alternatives.



Zhou gathered all of the components together before considering the design of the case

Even so, there's still something rather charming about BlackBerry handsets and, for anyone wanting to do some serious computing on-the-go, tapping away on physical keys remains more comfortable. For those reasons, it's hard not to be enthused about Zhou Xu's amazing project. It allows Linux software to run via a Raspberry Pi Zero W computer on a 320×240 LCD screen and it's controllable using a BlackBerry-style keyboard.

"The idea started from my Game Boy Zero Plus build that was based on a stripped Raspberry Pi 3A computer," Zhou explains, referring to a project in which a new Game Boy handheld was built by inserting a thinned-down Raspberry Pi 3A into an original case. "After completing it, I decided that I would then love to make use of Raspberry Pi in a handheld format for testing and debugging in the field. But I did not have a clear plan for the keyboard design until I recently found the BBQ20KBD from Solder Party."

Key components

The BBQ20KBD is a QWERTY keyboard and optical track pad device powered by an RP2040 microcontroller. Identical to the BB Q20 used in the BlackBerry Classic released in 2014, the tiny set of keys is placed onto a custom-printed circuit board and, because it has a USB Type-C socket, it's easy to hook up to Raspberry Pi.

The keyboard gave Zhou's Blackberry Pi a strong direction. "The design was heavily inspired

Look above the screen and you can see that all of the GPIOs are available for easy connection

The overall design is a mash-up of a BlackBerry phone, a Game Boy handheld console and, as a nod to the more distant past, a ZX Spectrum!

Running Raspberry Pi OS, the device boots in the command-line interface by default

▲ The case was designed in SolidWorks, a 3D CAD package for Windows that dates back to 1995!

by many other Raspberry Pi handheld projects, such as Beepy and ClockworkPi," he adds. There were some other requirements. "One of the aims for this design was to test an SDR radio antenna in my backyard. A battery-powered handheld is so much easier for this job," he says.

Zhou chose a 2500 mAh LiPo battery, as well as an Adafruit PowerBoost 1000C power supply. He also took a GearBest 3.5 composite LCD display out of his Game Boy Zero Plus build, and added a Raspberry Pi Camera Module 2 NoIR. Of all the components, though, selecting to use a Raspberry Pi Zero W was the easiest decision.

"I started playing with Raspberry Pi with the original version so I'm very comfortable tinkering with the config files and soldering the pins," Zhou says. "Even though many Raspberry Pi

Quick FACTS

- The project uses an upcycled BlackBerry keyboard
- The NNQ20KBD keyboards cost just £30/$30
- BlackBerry Pi is designed for potential future expansion
- External devices may need an add-on battery pack
- The STL and STEP files are at: **magpi.cc/bbpi3D**

▲ The main components sit behind the screen. There is a 5V fan for cooling too

models were still out of stock at the time when I started this project, I still wanted to use one (and I'll be upgrading to Raspberry Pi Zero 2 W). I find the comprehensive documentation provided by Raspberry Pi is so much more useful than starting from scratch on the other counterparts."

Mod man

Rather than use an existing case to fit the components, Zhou felt he would have much more control if he designed his own. As such, he drafted a case using the 3D CAD package SolidWorks, with the aim of outputting the design to his Creality Ender-3 3D printer.

"Ever since my Game Boy project, I find it so much easier to build things from the ground up," he explains. "Modding an existing enclosure can take quite some extra effort and I'm now getting more confident in CADing.

"Besides, if I'd have used an existing BlackBerry case, squeezing the components in there would be very challenging. That said, recently I've started to teach myself to use KiCad for designing customised PCBs. Perhaps it would be possible to make one that fits in a BlackBerry case using a [Raspberry] Pi Compute Module 4."

Not that the project is any worse for having a freshly designed case. In fact, it looks amazing, made all the prettier by having the classic rainbow stripes as seen on the Sinclair ZX Spectrum from 1982. "That was a bit of a random decision," Zhou says. "ZX matches my initials and I've always liked retro-style designs."

Clever case

A lot of thought went into the case. "I'm pretty proud to point out that all the GPIO pins are accessible from the top of the screen and I have added a few peripheral mounting points around the enclosure for future add-ons such as [Raspberry] Pi HATs," Zhou adds. "I'm also very excited about the outcome of the enclosure printing. This was the first time I have ever played with the six-colour manual change on my Klipperised Ender-3 printer."

> "Ever since my Game Boy project, I find it so much easier to build things from the ground up"

It nevertheless proved very challenging. "I spent quite some time trying to optimise the arrangement of different components, especially the position of the GPIO pins and other connection ports so that they can be easily accessible," he continues. "It was also very tricky to squeeze all the components into such a tight space. But I guess one thing that differentiates this project from the others is that all of the components can be purchased off-the-shelf, and it does not require any PCB design experience."

The end result is a stunning, expandable machine that boots, by default, into the command-line interface. The frame buffer is enabled in the **/boot/config.txt** file to display

320×240 resolution and, as well as being great for entering code, the Blackberry Pi is able to capture photos. It's proving to be quite a useful Linux handheld.

But Zhou is not yet finished. "As I mentioned earlier, I'll be adding a Sense HAT and an SDR dongle. I also recently added a light guide to the USB charging port using translucent 3D-printing filament, so that the Adafruit PowerBoost status LED lights can be visible from outside the enclosure (green being fully charged, orange charging, and red showing low battery).

"Unfortunately, the progress has been slow lately because there are a few other projects which have been keeping me busy, including using a Raspberry Pi to remote-control an electron microscope and optical filters, but everything seems to be working very well."

▲ The back of the Blackberry Pi makes use of a Raspberry Pi Camera Module 2 – the night-vision-enabled NoIR version

A bit of BlackBerry magic

01 Zhou Xu dropped the USB port because Raspberry Pi and the LCD screen were pretty much drawing the power supply's capacity. But he used an I2C connection for the keyboard so added it again!

02 Frustrated that the BBQ20KBD keyboard does not have **ESC** and **CTRL** keys, Zhou sought help. He said he was able to get the BBQ20KBD I2C driver (**magpi.cc/bbq20kbd**) working, which allowed the function keys to be mapped.

03 Using translucent 3D printing filament has allowed Zhou to add a great-looking power-status light to the USB charging port. When it is orange, as shown, here it is charging. It'll turn green when full, and red when it needs charging.

Drill Press Camera

A desire for absolute precision was this maker's driving force. **Nicola King** admires the microscopic details

MAKER

John McNelly

A tinkerer who is fond of making and breaking new things with electronics, software, and mechanical engineering. John lives in Campbell, CA, and works as an electrical engineer.

johnmcnelly.com

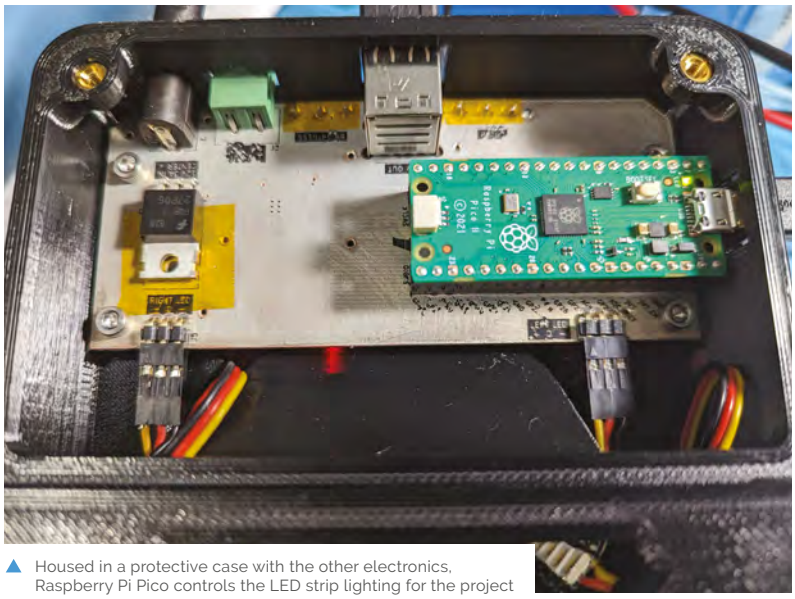
Experienced at etching PCBs in his garage, John McNelly found that one of the most frustrating and time-consuming parts of fabricating two-sided boards was drilling the through-holes. Keen to speed up the process, he created the Drill Press Camera, a clever piece of kit that makes his life so much easier.

"I got tired of squinting at a teeny-tiny drill bit attached to a benchtop drill press," John explains, "so I built this project so that I can squint at a teeny-tiny screen attached to a benchtop drill press instead. The microscope camera has an HDMI output that I've been meaning to hook up to a larger display, but even with the small built-in screen, the magnified image has made drilling much faster and more accurate."

Practicalities

John's project works by using an angled, mirrored periscope to point a microscope camera at the underside of a drilling platform. "The position of the Drill Press Camera is adjusted until the crosshairs on its screen are lined up with the centre of the drill bit," he says. "Once a PCB is placed on top of the drilling platform, the user can see a magnified view of the traces and intended drilling location." Since the position where the drill bit will make a hole is indicated by the crosshairs on the camera screen, "lining up holes with the centre of the drill bit is about as easy as point and shoot."

A Raspberry Pi Pico is used to control the LED strips that illuminate the underside of the PCB, and John has written a simple MicroPython script that "reads brightness and hue values from two potentiometers on the control board, and sends the corresponding NeoPixel commands to the high-density LED strips embedded in the periscope." John wanted the ability to dim the LEDs and also added colour control: "With some experimentation, I found out that controlling the colour of the LEDs was a cool way to improve contrast on some material types."



▲ Housed in a protective case with the other electronics, Raspberry Pi Pico controls the LED strip lighting for the project

Reviving concepts

John estimates that he is now twice as fast at drilling holes than when he was aligning by eye, and "my holes are also much more accurate." Unsurprisingly, the project has garnered a good deal of enthusiastic reaction, especially regarding the periscope configuration. "One [Hackaday] user pointed out that I had pretty much reinvented something from the 1970s called a 'Target Drill', which is pretty cool."

John is more than happy to have reintroduced a drilling concept to a new generation: "There's a lot of really neat fabrication equipment from the good old days, when people made PCBs by hand, that has since faded away." After taking this project to Open Sauce in San Francisco earlier this year, he found that "lots of maker types were curious about it, and then quite enthusiastic about the concept once they saw how it worked! Drilling precise holes in flat things is apparently not a problem that is unique to PCB fabrication."

The drill press platform includes Pico-controlled LED lighting, adjustable with two rotary potentiometers at the rear

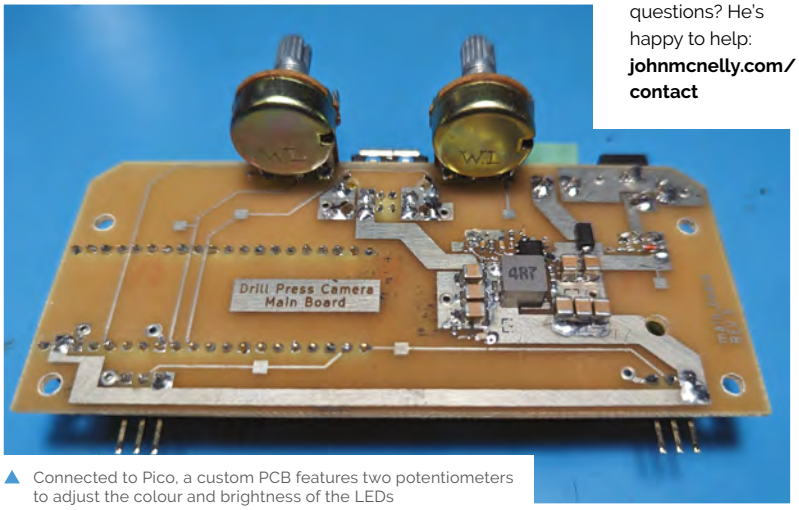
A periscope-style section features an angled mirror to enable the camera to see the underside of the platform

The LCD camera view features crosshairs to aid precision alignment of the drill with the hole

Quick FACTS

- John spent around 50 hours on the project…
- …including 20–30 hours on the CAD model
- The total cost of the build came in at under $300
- See John's GitHub for full details: **magpi.cc/drillpressgh**
- Have any questions? He's happy to help: **johnmcnelly.com/contact**

If you'd like to build your own, John is more than encouraging, claiming this design is easy to build if you have access to a 3D printer and some soldering supplies. "Most of the stuff is pretty easy to get, but I've only been able to find one supplier for 2-inch glass circles of the right thickness. Since the microscope camera's field of view passes almost entirely through the hole drilled in the glass disc, I think that a 3D-printed disc with a hole in it could substitute for the custom glass part just fine." Go forth and create, as John would love to see what you come up with.



▲ Connected to Pico, a custom PCB features two potentiometers to adjust the colour and brightness of the LEDs

TouchCam camera

A love of making shines through in this Raspberry Pi 4-based TouchCam project, finds **Rosie Hattersley**

MAKER

Mukesh Sankhla

Siemens India software and IoT developer Mukesh loves making and documenting electronic, mechanical, and software projects.

magpi.cc/touchcamins

Mukesh Sankhla's enthusiasm for tech jumps off the page. His responses to *The MagPi*'s questions about his TouchCam camera project are packed with words such as 'inspire', 'love' and the absolute joy he's found in sharing his roster of makes over the past three years. Having completed his studies only a year ago, the computer science graduate was quickly snapped up by Siemens India, where Mukesh works as a software engineer with an Internet of Things focus, and spends his spare time creating and sharing technology-based designs. The TouchCam has gone through several iterations, which Mukesh has shared as an Instructable: **magpi.cc/touchcamins**. Its design is loosely based on Adafruit's 3D printer camera case for Raspberry Pi HQ Camera (**magpi.cc/hqcam3d**). Mukesh's initial version, the PiCam, added remote access options and was pitched as a means of monitoring, as well as offering on-demand photography and remote printing. He used Fusion 360 to come up with his own camera case design, and NextPCB for the bespoke printed circuit board. Both the Linux-based PiCam and the TouchCam have Raspberry Pi 4 at their core and Remote.It and SSH, so the HQ camera can be triggered from anywhere.

The TouchCam's screen provides instant video and time-lapse playback

> "My goal was to blend my love for creating things with my technical knowledge"

Iterate and improve

Designing the TouchCam gave Mukesh a chance to combine his skills as a maker and a computer science enthusiast. "My goal was to blend my love for creating things with my technical knowledge," he enthuses of the versatile device "that can even work as a server for my test applications and database."

Perhaps it's no surprise that, as a computer engineer and developer, Mukesh works in a process of continuously improving successive designs. Mukesh says many of the design updates and improvements he made when moving on from the PiCam and developing TouchCam were directly influenced by the feedback he got from the design of the PiCam. It is also an apposite demonstration of how far his Fusion 360 computer-aided design

A DFRobot touchscreen on the rear allows for on-body camera controls, while Remote.It software means it can also be used remotely

Raspberry Pi HQ camera and 8GB Raspberry Pi 4 power the TouchCam and provide time-lapse photos and HD video footage

Mukesh is justifiably proud of his Fusion 360 CAD skills, resulting in this gorgeous 3D-printed camera case

Quick **FACTS**

- The TouchCam took about a week to print and build
- It cost around $170, but has no running costs
- Mukesh has used it as the 'eyes' of his robot
- A strength of being able to control it remotely

▲ A sample photo taken using the TouchCam triggered remotely

▶ Raspberry Pi HQ Camera offers high-quality photography using its 12.3 megapixel Sony IMX477 sensor

skills have developed and was used to showcase his design prowess for his BSc.

With the TouchCam, Mukesh was keen to design a system that is compact and easy to carry and that would appeal to multitaskers who enjoy activities such as 3D printing, time-lapse photography, electronics, robotics, programming, and machine learning. He also thinks the TouchCam could be used for software development, low-cost personal servers, and similar uses.

> "I chose the Raspberry Pi because it's affordable, powerful, and has an internet full of resources"

Fine new features

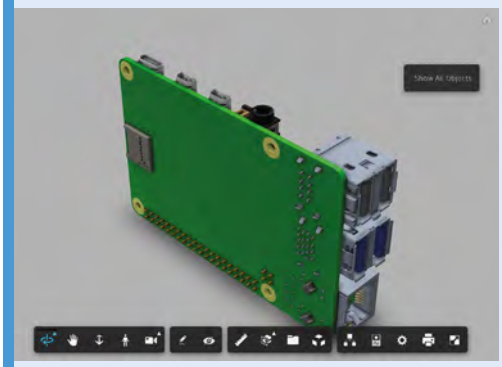
The TouchCam builds on the PiCam by integrating a high-definition touchscreen display and has a touch sensor that is used for live view, to access the photo gallery, and to switch between still, time-lapse, and video capture modes. The

▲ TouchCam is an evolution of the PiCam Mukesh designed and built

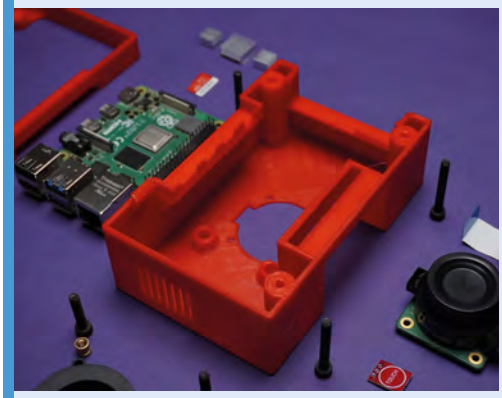
HQ Camera remote server also gained more prominence. "I chose the Raspberry Pi because it's affordable, powerful, and has an internet full of resources. I am using the Raspberry Pi 4 8GB variant." The components were sourced online, with standard items such as the HQ Camera paired with a DFRobot Raspberry Pi Touchscreen, cooling from a 5V fan, and open-source software libraries such as Imager, and Silvan Melchior's Raspberry Pi Camera Web Interface (**magpi.cc/rpicamwebint**).

Having already got the basics down pat with the PiCam, the case design and touchscreen integration were the real challenges for this build. Only three 3D-printed versions were needed, and even these were simply to fix minor fit issues to accommodate the screws. Overall, Mukesh was pleased with the way the TouchCam turned out: "Everything from the outer shell that feels good to hold, to the special mounts that hold the camera perfectly. Each piece came from my careful design work, making sure they look good and work just right."

TouchCam tips



01 You'll need a Raspberry Pi 3B+, 4, or 5, a Raspberry Pi HQ Camera, and a touchscreen display. Design or reuse an existing case or use Mukesh's STL files at: **magpi.cc/touchcam360**.



02 Assemble the camera case, adding a heatsink for Raspberry Pi 4. Follow the instructions at: **magpi.cc/touchcamins**.

03 Use Remote.It to run the camera remotely. All the code you need to program the TouchCam is at: **magpi.cc/touchcamgit**.

ScreenDress

We'd definitely say yes to this dress – a stunning creation by Anouk Wipprecht that is proving to be an eye-opener, as **David Crookes** discovers

MAKER

Anouk Wipprecht

Anouk Wipprecht is a Dutch FashionTech designer and innovator who works and travels between San Francisco, Los Angeles, Miami, and Amsterdam.

anoukwipprecht.nl

It's fair to say that clothing fashion and computing don't always go hand-in-hand. But bring amazing talent such as Anouk Wipprecht on board and all eyes are definitely going to be on the wearer – as this striking ScreenDress shows to great effect.

As well as fitting snugly around the body, the 3D-printed dress includes a set of circular LCD screens, each of which looks like an eye. Connected to an EEG sensor – a four-channel BCI headset developed by neurotechnology company g.tec – they change according to how the wearer feels by reading brainwaves and working out a person's cognitive load.

To that end, the screens can show signs of stress, fatigue, and frustration. The more a person subconsciously feels their mental load is increasing, the wider the iris and pupils dilate. By making changes in real-time, Anouk, a Dutch FashionTech designer, says the dress is able show a direct correlation between a person's actions and their brain's reaction. One thing's for sure, it's certainly eye-catching.

> "The 3D-printed dress includes a set of circular LCD screens"

Dress to impress

ScreenDress was created from scratch. As well as the headset – called the Unicorn Headband – the dress was designed in Onshape (**magpi.cc/onshape**), a free, cloud-based CAD app. Anouk said it helped her to understand the look and feel of the possible embedded LEDs and how light reflected back on the body and space around it. "I used various Onshape design capabilities including mixed modelling, generative design, render studio, and in-context design to reference hardware elements," she adds.

The dress was outputted to an HP Jet Fusion 5420W 3D printer using a form of nylon. "This material is ideal for engineering-grade, white, quality functional production parts," Anouk continues, pointing to the components being light – an important factor when being worn.

Behind each of the HyperPixel 2.1 round hi-res screens that display the eyes are Raspberry Pi Zero 2 W computers. "There are six of them," Anouk says. They take information from the sensor that has been analysed in real-time and determine how the animated eyes appear on the screen.

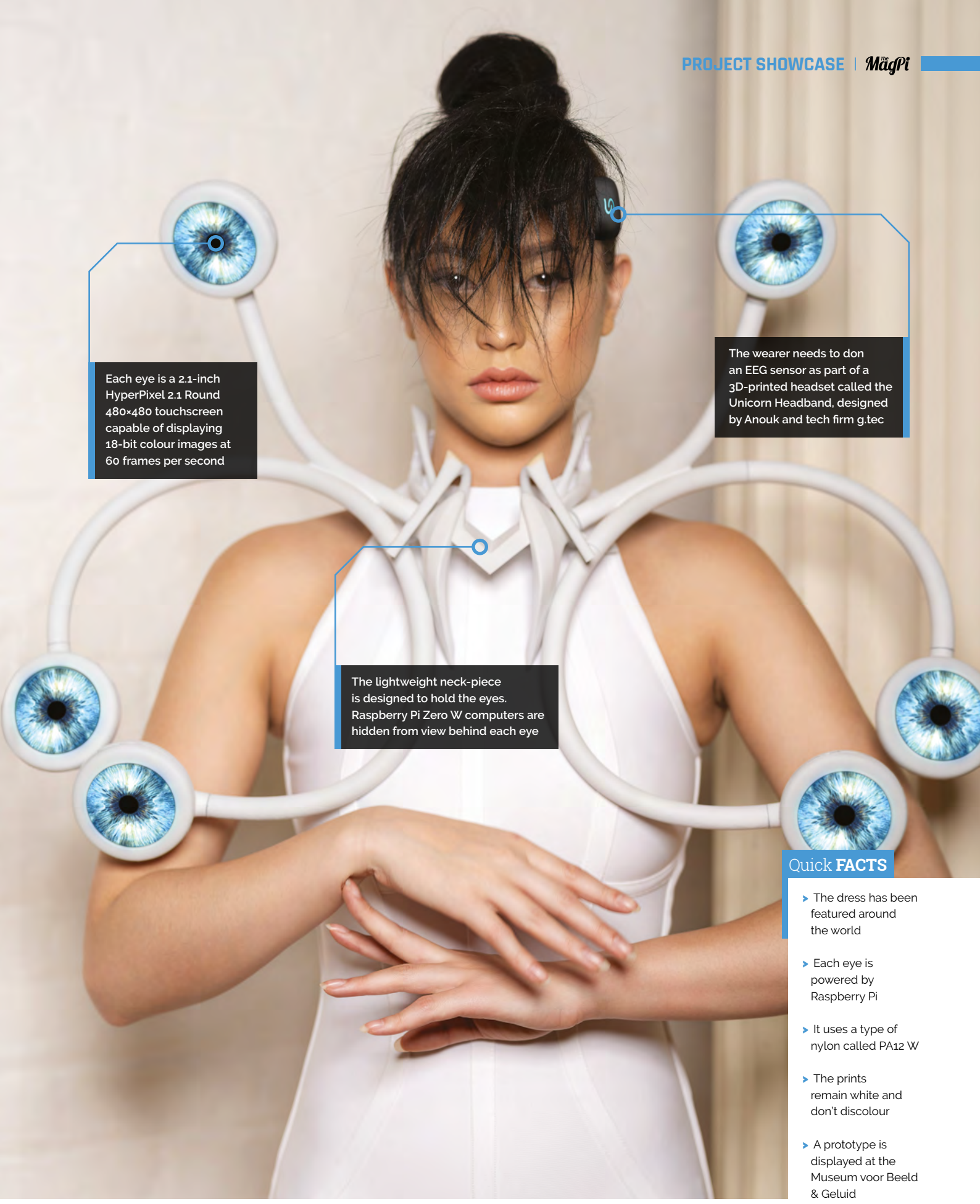
Got the look

To ensure the ScreenDress is in-tune with the wearer's brain, anyone wearing the clothing, which has the eyes flaring out from a sculpted neck-piece, has to undergo a two-minute training session. Machine learning then begins to understand the wearer's mental workload so that the eyes work as accurately as possible.

"Our fortunes turned when Raspberry Pi Zero 2 W, equipped with a quad-core Cortex A53 processor, was released," Anouk says. "This upgrade significantly enhanced the processing capabilities [over Raspberry Pi Zero W], allowing us to manage data seamlessly and achieve the desired performance."

ScreenDress is certainly cool and it turned a lot of heads when it was first put on show at the ARS Electronica Festival in Linz, Austria in September before being presented in Budapest, Hungary and Eindhoven, Netherlands. It has also posed a lot of questions.

"What does it mean when we can connect technological-expressive garments to our bodies, body signals, and even emotions? What dialogues can we trigger? This is what I am exploring with designs like these," Anouk explains. It also means that Raspberry Pi computers can be seen as a fashion accessory, potentially inspiring many other makers.



Each eye is a 2.1-inch HyperPixel 2.1 Round 480×480 touchscreen capable of displaying 18-bit colour images at 60 frames per second

The wearer needs to don an EEG sensor as part of a 3D-printed headset called the Unicorn Headband, designed by Anouk and tech firm g.tec

The lightweight neck-piece is designed to hold the eyes. Raspberry Pi Zero W computers are hidden from view behind each eye

Quick **FACTS**

- The dress has been featured around the world
- Each eye is powered by Raspberry Pi
- It uses a type of nylon called PA12 W
- The prints remain white and don't discolour
- A prototype is displayed at the Museum voor Beeld & Geluid

Instant Framed Camera

A little tinkering has given this classic camera a second shot. **Nicola King** focuses on the facts

MAKER

Max van Leeuwen

Max studied at the Netherlands Film Academy. After working in visual effects for film, he now develops augmented reality and interactive installations.

maxvanleeuwen.com

A broken Polaroid Land Camera may, for some people, not prove particularly inspiring. However, Max van Leeuwen's grandfather had given him the antiquated object, and Max was determined to give it a new impetus. "I really wanted to hide a Raspberry Pi in there and bring this vintage object back to life in some way," he tells us. "I loved the idea of adding some mysticism to it. At first, I wasn't sure what to make with it, though…"

When Max came up with the idea of adding an e-paper display module to the mix, he knew he was on the right track. "I wanted to make a live picture frame right away… This idea felt right because, now, I could give the picture frame to my grandma and keep her posted (it lives in her bookcase now)."

Raspberry Pi is equipped with a Waveshare Li-ion Battery HAT, enabling a 14500 battery to be recharged via USB-C

A Raspberry Pi 3A+ with a Li-ion Battery HAT is secreted in the body of the old Polaroid camera

A flash of inspiration

Using a Raspberry Pi Camera Module 3, a couple of Raspberry Pi 3 Model A+ boards, and some Python code, along with the other required bits of hardware, Max has essentially created a camera within a camera here, as a digital camera is hidden within the body of the original shell. "When the camera's button is pressed, it makes a hidden digital camera take a picture," he explains. "This picture is sent to a server, for the display frame to show."

Interestingly, Max decided that he wanted the picture to then be deleted from the camera itself and, once the frame has downloaded this picture to display it, it is deleted from its storage as well. "I really like the idea of having only one copy of the picture baked into the e-ink display. It makes the picture feel important, and it fits with the essence of Polaroid photos," declares Max. When

The original lens was replaced with a Raspberry Pi Camera Module to take digital images

With the image uploaded to a server, the e-paper photo frame can download and display it

a new picture is taken, the old one disappears from the frame.

The e-paper display module was a key inspiration to Max to make the photo frame: "I really like the look of a display that doesn't emit any light, so it's more like an e-book instead of a screen. It's really fun to see the individual dots on it; it looks just like a real print." When he found a type of e-paper that could do colours, there was no stopping him. "The slow drawing speed of the e-paper module (~1 minute) fits with the idea of mimicking developing film, which was a happy accident," he enthuses.

Max was determined that the camera should send pictures to a server, instead of directly to the other device, so that it works "even if both devices are on opposite sides of the planet." Deciding against using a SIM card in the camera and frame, he instead opted for Wi-Fi, and the camera simply

▲ Max considered using a Pico in the camera, but eventually opted for a Raspberry Pi 3A+ for its extra RAM

Quick FACTS

- The hardware cost Max around €200
- The parts list is in the GitHub repo: **magpi.cc/instantcamgh**
- This was one of Max's very first Raspberry Pi projects
- Although time-consuming, he thinks it's straightforward…
- "Anyone with an affinity for coding can pick this up and improve it!"

▲ Comprising another Raspberry Pi 3A+ and e-paper display, the digital photo frame downloads each image from the server

connects to Wi-Fi networks by taking a picture of a QR code.

Shooting the snags

Max found that the physical build was the hardest element of the project, and many hours of work went into the venture. "At first, I only made little steps at a time for a couple hours a week but, once it started taking shape, I dedicated a few days to it to make some real progress," he reveals. Most of his time went into the physical photo frame and the camera body. "Breaking the camera open on the inside without breaking it on the outside was a bit of a tedious task. And the photo frame needed a wooden shape on the back to fit the computer and wires, so that became a little arts-and-crafts-session."

Max's father was on hand to help him with the woodwork for the frame, but "I was scared I'd break the camera when drilling a hole through the top for an LED light," he shares. Also, making the real camera's button trigger a signal necessitated some good old-fashioned trial and error. "I ended up using a metal spring with aluminium foil on it, and the ends touch when the button is pressed to make a closed circuit."

> "I really like the idea of having only one copy of the picture baked into the e-ink display"

Finally, deciding on power options for the camera demanded some further head-scratching – "I ended up using a battery HAT that works for about an hour on this setup and can be recharged with USB-C." The end-product was well worth the labour and troubleshooting required en route, however. As long as there is Wi-Fi available, "the

photos you take with the camera appear instantly on the display frame, no matter where in the world each of them is."

No negatives here

Understandably, many people have enjoyed reading about Max's camerawork. "There were a lot of positive reactions online! I really loved reading them. All the individual steps to making this project are nothing new, but bringing them together into this simple idea is what people seemed to appreciate the most."

Significantly, he has had messages from a number of people who are keen to replicate his endeavours using similar vintage cameras. Describing this as "super-cool", Max is very keen that people make their own variations and, indeed, improvements to the project. "One possible variation someone told me about was to make multiple photo frames and connect them to the same camera, so you can update a whole group at once! That could be fun."

Max handcrafted a wooden back for the photo frame to fit in Raspberry Pi and the wiring

From camera to frame

01 Protected by a Perspex cover, the Camera Module is connected to a Raspberry Pi 3A+ inside the Polaroid camera body, powered by a Li-ion Battery HAT.

02 When the camera's button is pressed, a circuit is completed, sending a signal to Raspberry Pi's Python program to light the flash LED and take a picture.

03 The image is then uploaded via Wi-Fi to a server. From there, it can be downloaded to the e-paper display frame, no matter where it is located.

Gutter Probe

Trying to discover the cause of a blockage, Peter Anderton invented an ingenious solution that resulted in a twist ending. **Rob Zwetsloot** listens to the tale

MAKER

Peter Anderton

A civil engineer with a background in computer science who eventually became a software developer before semi-retiring, and now does a lot of making and puzzle-solving for fun.

Raspberry Pi is used for a lot of things – some more surprising than others. When Peter Anderton emailed us about a very unique use of Raspberry Pi to solve a conundrum, we decided we had to share it in the magazine.

"My wife and I had noticed that, whenever it rained hard, we were getting a serious overspill from one of our house gutters onto our conservatory," Peter says in his email. "Unhelpfully, the overspill appeared to originate from an inner-corner joint of the gutter, over 15 feet up and directly over the conservatory, so virtually impossible to reach without scaffolding or a cherry-picker, either of which would be extremely expensive if it turned out there were no alternatives. We first thought the cause might just be a leaky joint, but one day we spotted a suspicious growth poking out above the gutter itself."

With a bit of deductive reasoning, Peter figured out that the plant was blocking the joint, so the rainwater would just overflow. He didn't want to hire expensive equipment to confirm this theory, though.

"I then had the bright idea of mounting a Raspberry Pi Camera on the end of a long pole to get a view of the plant itself," Peter mentions. "The sticking-point here was how to connect the camera to Raspberry Pi whilst still being at the far end of the pole. At first, I considered having Raspberry Pi and camera both mounted at the far end, but this would have required much longer power and display cables than I had available; the obvious alternative was just to have the camera at the far end of the pole but, at the time, I only had to hand the short ribbon cable that came with the camera, and had no idea whether longer cables were even available. However, after discovering that cables up to 2m in length existed – thank you, The Pi Hut! – I had at least solved the connectivity issue."

▲ The original mount used to take a peek at the gutter

Printed solution

Peter turned to Fusion 360 to design and then 3D-print a mount that would allow the Camera Module to slot inside a bike lamp bracket, which was then mounted to a pole. After taking a peek, Peter found the true culprit – a plant growing in a big clump of soil.

"I now had a much clearer idea of what exactly we were dealing with, but there was still the matter of how to get the offending plant out," Peter continues. "It was unlikely any cherry-picker would be able to fit through either of our side gates to reach the rear of the house where this gutter was, so it would have to operate from the adjacent road, with all the safety and other implications that would entail. However, to go down the scaffolding route would be equally

▲ The culprit causing the rainwater to spill over

> The success of this venture has opened my eyes to the potential for remote-viewing generally

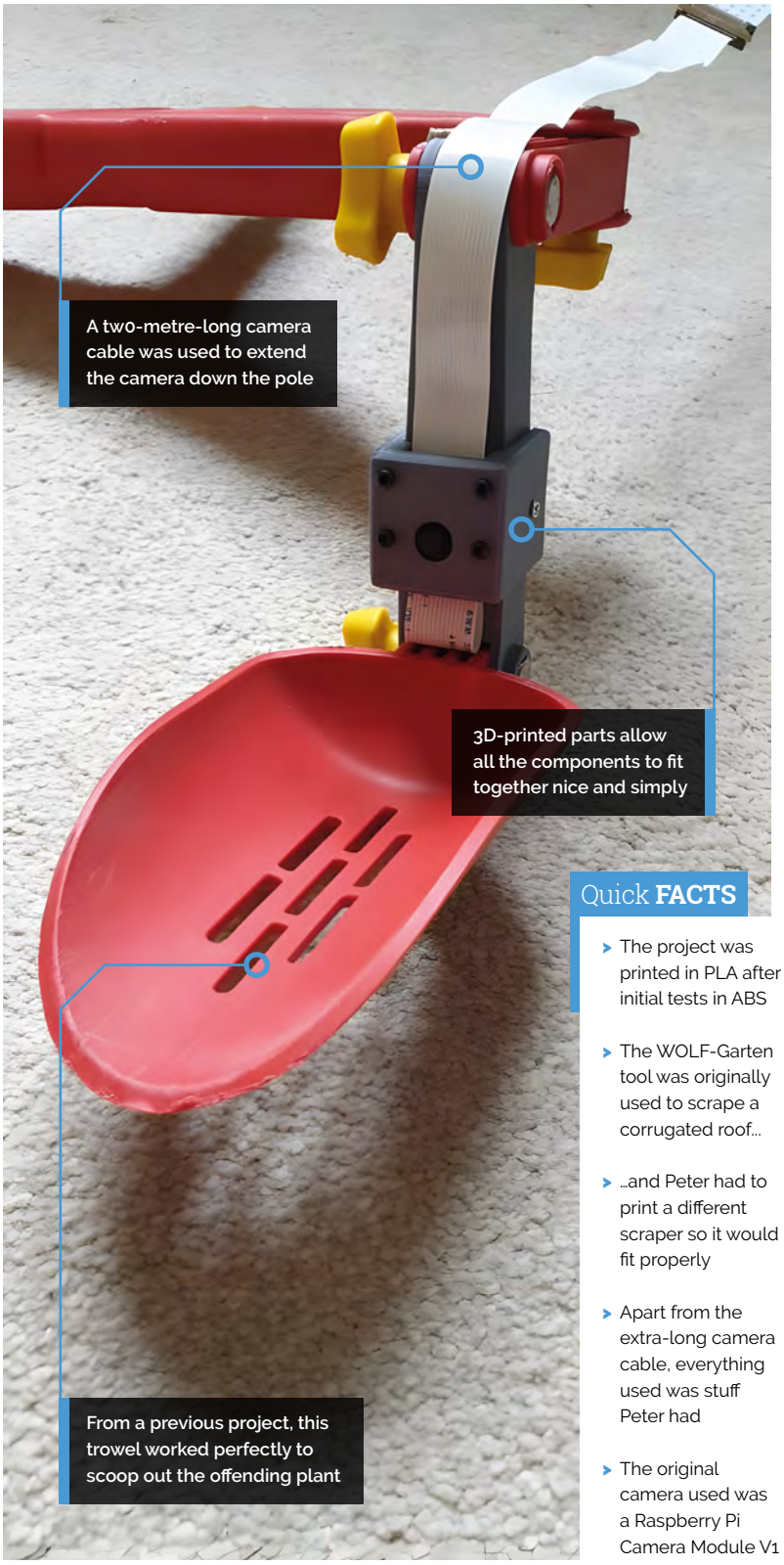
problematic, not least because it would have to bridge over the conservatory to get to the gutter in the corner, with no obvious way to support it."

For one small plant, this was a bit overkill. However, he did have a pole that could reach the plant, so he began Phase 2 of the operation: attaching a trowel. He already had a WOLF-Garten system that he'd 3D-printed parts for, so he made a further extension to fit the trowel on.

Remote gardening

After digging up a bit of the soil, the plant was removed and the gutter stoppage fixed. It worked so well, it's inspired him to do more.

"I would be the first to admit that I produce more things using my 3D printer than I do using a Raspberry Pi," Peter says. "However, the success of this venture has opened my eyes (no pun intended!) to the potential for remote-viewing generally using Raspberry Pi / camera combination and, to this end, I have bought a second 2m camera cable and connector, as well as a new Raspberry Pi Camera Module 3."



Quick FACTS

- The project was printed in PLA after initial tests in ABS
- The WOLF-Garten tool was originally used to scrape a corrugated roof...
- ...and Peter had to print a different scraper so it would fit properly
- Apart from the extra-long camera cable, everything used was stuff Peter had
- The original camera used was a Raspberry Pi Camera Module V1

PicoSynth

One maker has turned PicoTouch capacitive board into a wave synthesiser. **Lucy Hattersley** channels her inner Kraftwerk

MAKER

Tod Kurt

Tod is a maker from Pasadena CA. He runs ThingM, is co-founder of CrashSpaceLA hackerspace.

mastodon.social/@todbot

Tod Kurt is a maker with a love of musical synths and his latest creation is PicoSynth, a MIDI synthesizer based on the PicoTouch board.

PicoTouch is a thin capacitive touch platform, and Tod's software turns Raspberry Pi Pico into a MIDI synthesizer that he can use to play sounds directly, or connect to another computer to control audio software (**magpi.cc/picotouch**).

The PicoTouch CapSense MIDI keyboard is a slim plastic board with 22 touch pads and 19 RGB LEDs. "It's one of the thinnest MIDI controllers at about 6 millimetres when Raspberry Pi Pico is installed," says Tod.

The ten pads on the bottom are note triggers for the C major scale, while the two pads on the right shift the octave up and down. The top row of pads controls wave and filter functions. Finally, three 'patch select' buttons on the right move between different waveforms. You can pick the board up from Tindie for $11, although it will need a Raspberry Pi Pico soldering inside.

"It's not too bad!" says Tod. "It's a pretty easy first-time, surface-mount device soldering project." Tod has created a video showing how to solder Pico to the board (**magpi.cc/picotouchsolder**).

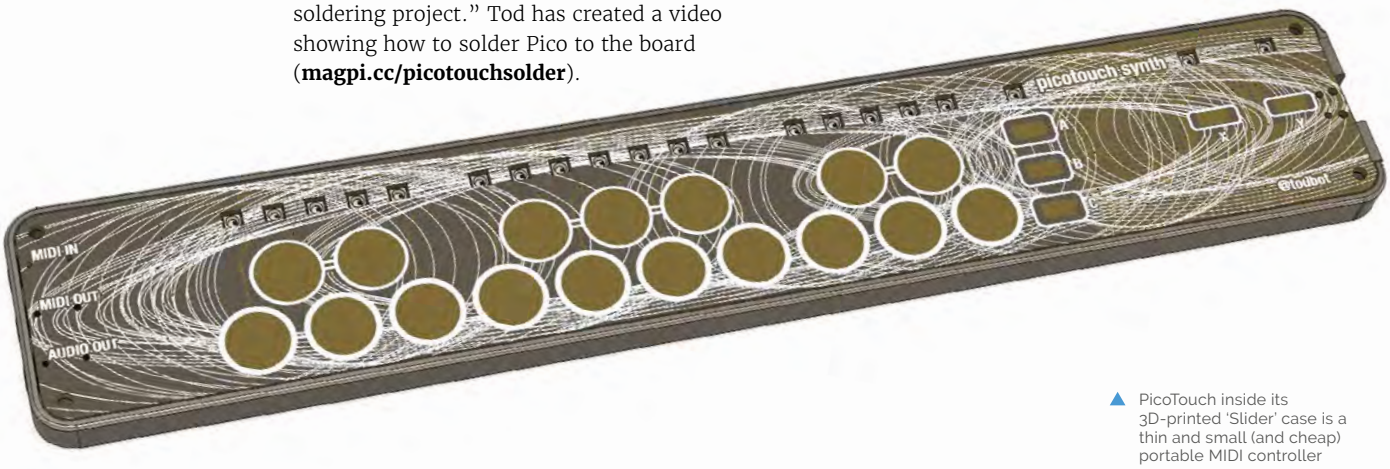
There is also a PicoTouch Slidercase that is "a simple 3D-printable protective enclosure for the PicoTouch USB MIDI / HID controller board."

"The result is still very thin and helps prevent false triggers or bad calibration if touching the back on power up," explains Tod. You print it in two pieces, and no supports are required. Snap the top piece around the PicoTouch board, then slide the combo into the bottom piece. A third 'picocap' piece can be printed and glued to the top piece to protect the Pico.

The PicoTouch Synth software is installed on Pico as a ready-made U2F file (**magpi.cc/picosynthgit**). The source code is also available.

MIDI sound

Once up and running, PicoSynth is powered by a USB-C socket on the right, and to the left sit three 3.5mm audio jack connections that provide audio out, MIDI in, and MIDI out. The device can be connected directly via USB-C to a computer running audio software, such as Ableton. You can also use Reaper if you want something that works natively on Raspberry Pi



▲ PicoTouch inside its 3D-printed 'Slider' case is a thin and small (and cheap) portable MIDI controller

The capacitive pads act as buttons with the bottom row used as a scale of notes, and the top row adjusting the waveform pattern

Pico needs to be soldered onto the PicoTouch board which makes it an easy and fun soldering project

The sound is generated by Raspberry Pi Pico which also acts as a MIDI connection when connected to a MIDI device or computer

Quick FACTS

- Tod needed a MIDI controller for his computer
- It's hackable, cheap, and thin
- The source code is available
- It's designed for MIDI but you could code the pads for anything
- The board costs just $11

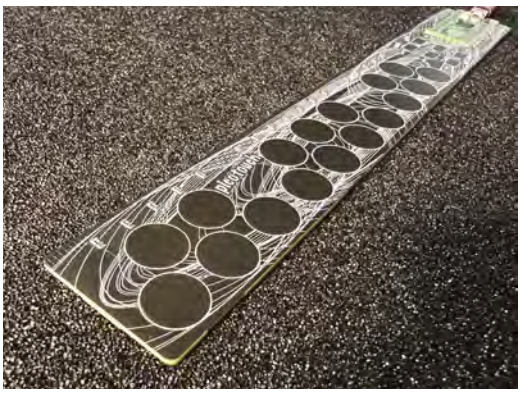
> "It's currently running CircuitPython and talking MIDI to my computer"

(**reaper.fm/**). The USB-C connection to Raspberry Pi Pico provides power and a MIDI connection in one step. This enables you to use the PicoTouch to play instruments in audio software.

"It's currently running CircuitPython and talking MIDI to my computer which is running Ableton Live so it can do monophonic and polyphonic stuff; you can even play drums with it if you want to," says Tod.

"It's a lot of fun!"

▲ The PicoTouch bare board is available on Tindie if you want to recreate this project at home



◀ PicoTouch can be used for other projects as well as creating PicoSynth

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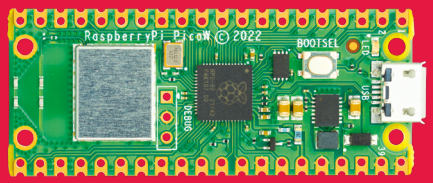

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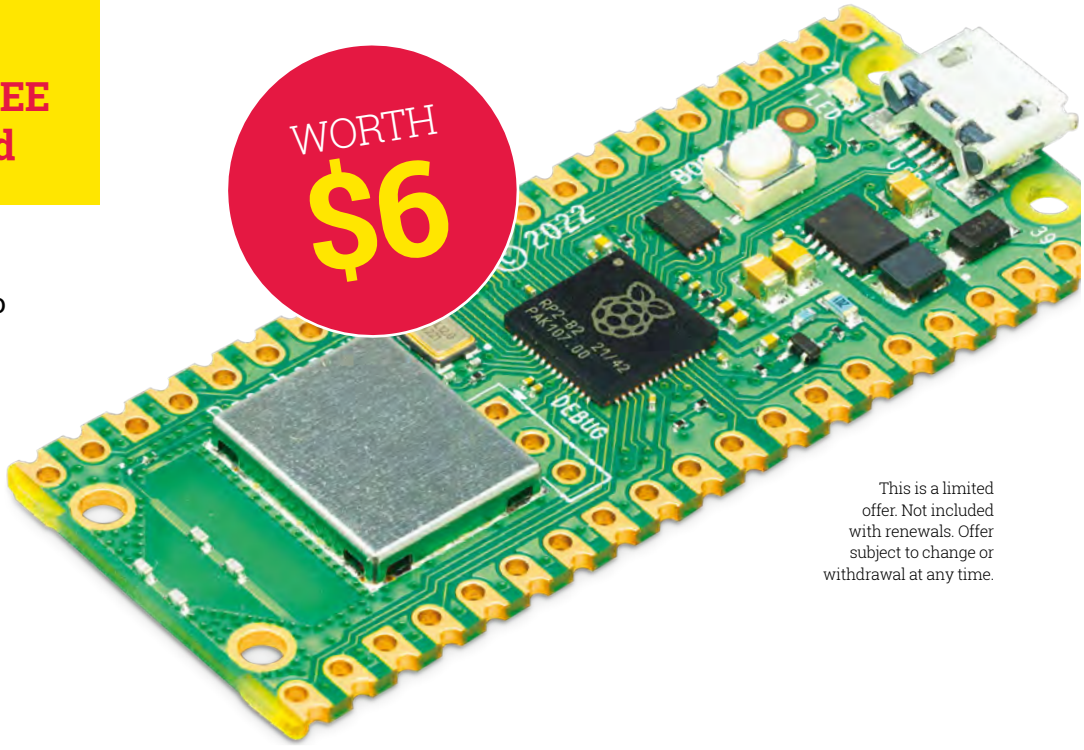

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SUCCESS STORY magpi.cc/success

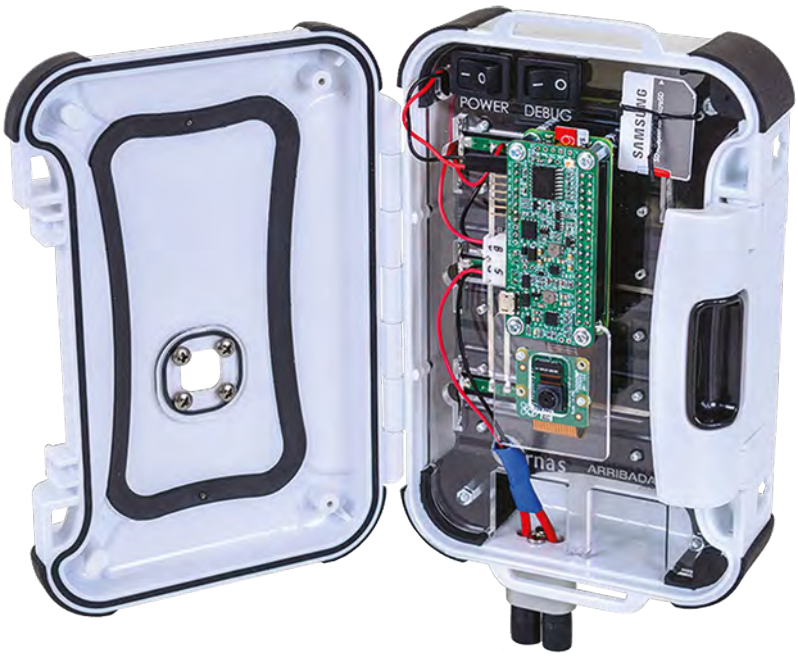
Arribada technology for conservation

Raspberry Pi is key to Arribada's wildlife monitoring projects

By **Rosie Hattersley**

Time-lapse photography and remotely accessible monitoring tools are used routinely in conservation these days, but back in 2017, when Alasdair Davies founded his non-profit organisation Arribada, they were groundbreaking. Keen to draw attention to threats to wildlife in different habitats and locations, he set about developing low-cost monitoring tools, reasoning that equipment costs should not be a barrier to helping critically endangered animals. He produced and designed multiple observation tools, from a camera trap that would wake and detect an animal walking by, to a device that would send back an alert if a particular animal appeared.

Davies founded environmental organisation Arribada (the name, meaning 'arrival', refers to the migration and birth cycles of sea turtles), with the aim of using technology to make a positive environmental contribution.



THE CHALLENGE

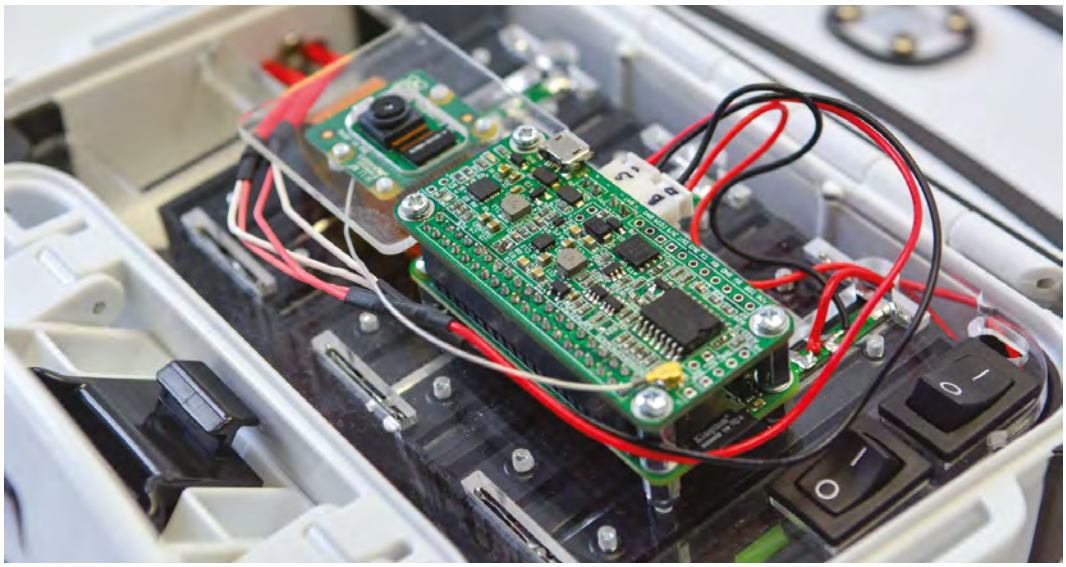
Arribada needed a robust, low-cost kit that could be used in remote locations, often without human intervention. Its first project was a tag to monitor green sea turtles: this tool would show the impact that fishing and human activity were having, and open discussions about what protections might need to be introduced for the endangered species.

To track the turtles, Arribada's solution would need to be waterproof at the depths at which the creatures swim, as well as being able to operate reliably without the possibility of human intervention. It also needed to be both affordable and accessible to local research teams.

THE SOLUTION

A Raspberry Pi Zero and a Raspberry Pi Camera Module were enclosed in a lightweight, waterproof enclosure. This could be attached, harmlessly, to the shell of a sea turtle, to track its journey under the waves. The device captures photos, video, and location data.

"Once the video has been recorded, the tag is released from the shell of the turtle and is then recovered from the water's surface two weeks



later. This lets us capture behaviour footage of both female and male turtles," Davies explains.

A challenge for turtle monitoring is that GPS location tags are only effective when the creature surfaces, which is often for less than two seconds. Waking up the monitoring devices to get a triangulation fix is not instantaneous, so Arribada developed its own Horizon Assisted-GPS tag as a key part of its Raspberry Pi Zero-based kit.

The kit means that turtles' behaviour, as well as their locations, can be discerned. The first turtle tags were developed when AI and machine learning were in their infancy, but, Davies says, we're in a very different space now. "You can imagine the benefit of running AI models on Raspberry Pi devices for the sea turtle: we can wake up [the device], capture a scene, process that scene, we can even [get the device to] make some intelligent decisions to say, is this worth recording? Is it worth going back to sleep, or should I stay on?"

In addition to making decisions about continuing to monitor a site, perhaps going into a sleep cycle and awakening again an hour later to see what's changed, using Raspberry Pi offers machine learning advantages. "We can pull the models off, sit there and go through and train them a little bit more, tweak and review the video content. We can do it all at very little cost, because [Raspberry Pi] is so affordable."

It's an approach that has begun to mark out Arribada as a sophisticated research partner, with conservation organisations showing "a real interest in what Edge ML is going to do. We still use it on the Raspberry Pi. We don't just use it with sea turtles."

Some initiatives need bespoke solutions. This was the case in Cyprus where the Society for the Protection of Turtles (SPoT), one of the country's longest-established conservation charities, was keen to explore the use of LoRa radio communications to monitor fishing activity.

The boat-based LoRaWAN gateway that Arribada set up can provide a detailed overview of local fishing activity, and report any potential encroachment on the five critical turtle breeding sites around the country's coast. Cypriot mobile phone regulations, requiring SIM cards to be registered after four months, made using them for cellular communications troublesome, hence the LoRaWAN setup using a Raspberry Pi 4 with a Raspberry Pi Power-over-Ethernet HAT. This setup also meant there was no cost to the boat owners for having a tracking system on-board. An antenna on an eight-metre pole offered a clear view of any fishing vessels in a 15km radius, providing a robust and visible monitoring system.

> "The Penguin Watch camera units survived three Antarctic winters before the Arribada team made a maintenance visit"

WHY RASPBERRY PI?

Raspberry Pi has become a keystone to almost all of Arribada's projects. Davies explains that it has always been one of the tools he uses "because it is so accessible and affordable for anyone to get involved. You are always partnering with a researcher or a local community member who works with an NGO and has a specific challenge. We get called in to solve it with technology. They'll always say it has to be affordable, it has to be repairable and accessible."

Davies has used Raspberry Pi with various HATs to create whichever tool was needed, but after Raspberry Pi Pico became available in 2021, he found the low-cost microcontroller board often provided a solution.

THE RESULTS

The footage gathered by Arribada's Raspberry Pi-based turtle tags helped quantify the number of sea turtles, as well as revealing their nesting locations, bolstering arguments for specific beaches and coastal areas to be off limits at specific times of the year – a crucial protection for this endangered species.

The low cost of Raspberry Pi hardware had a big impact too. Previously, many of the camera tools conservationists needed had such high price tags that research projects either became unviable or ended up severely limited in scope and impact. Often, the quantity of kits a project really needed could not be funded, or the high cost of repair and replacement meant that monitoring could be undertaken only once rather than repeated to track changes over time.

Reducing the costs with off-the-shelf Raspberry Pi hardware – widely available and easily swapped out for replacement or upgrading – was a game-changer. Instead of a camera costing £500, a sub-£50 Raspberry Pi Camera Module with a Raspberry Pi Zero or Zero W could be used. The ability to deploy many of these much more affordable kits meant it was possible to cover significantly larger territories and provide more accurate population estimates. In most cases, a 3D-printed waterproof case became the most expensive element of each kit. And, as new Raspberry Pi camera hardware became available, Arribada was able to make huge improvements to image and video capture capabilities.

Arribada also won over the Penguin Watch project, a wide-ranging research project monitoring penguin populations in different parts of the world. Arribada's Python-controlled Raspberry Pi camera setup came in at least three times cheaper than the commercial cameras the penguinologists had previously been using. The cost reduction meant the team had far fewer qualms about where monitoring kits were sited, and were more relaxed about leaving equipment in situ for remote monitoring, where some units would inevitably be subject to damage.

In fact, the hardware proved impressively resilient to temperature: the Penguin Watch camera units survived three Antarctic winters before the Arribada team made a maintenance visit. They were able to retrieve three years' worth of photos and found that the Raspberry Pi units had reliably woken to capture a photograph once a day every day, saving every single image. This photographic journal of the changing environment and its effect on penguin populations contributed directly to conversations about climate change and habitat loss.

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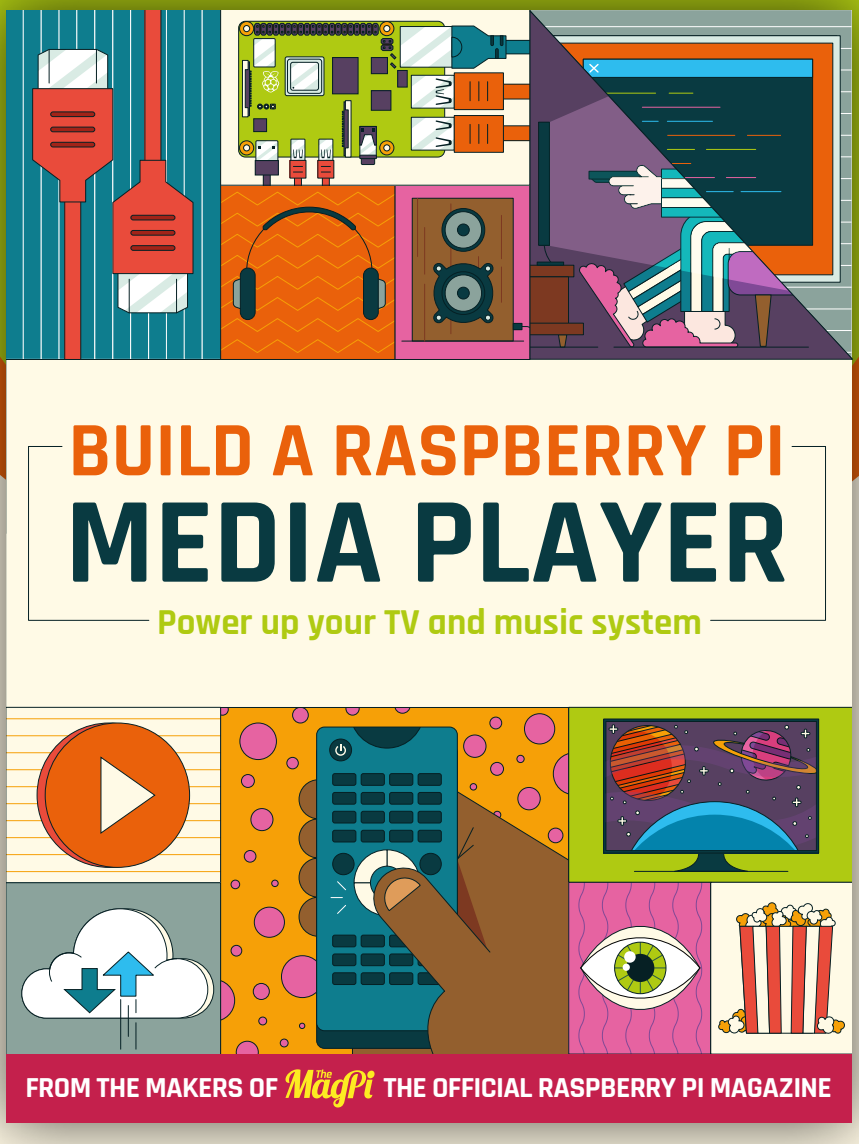

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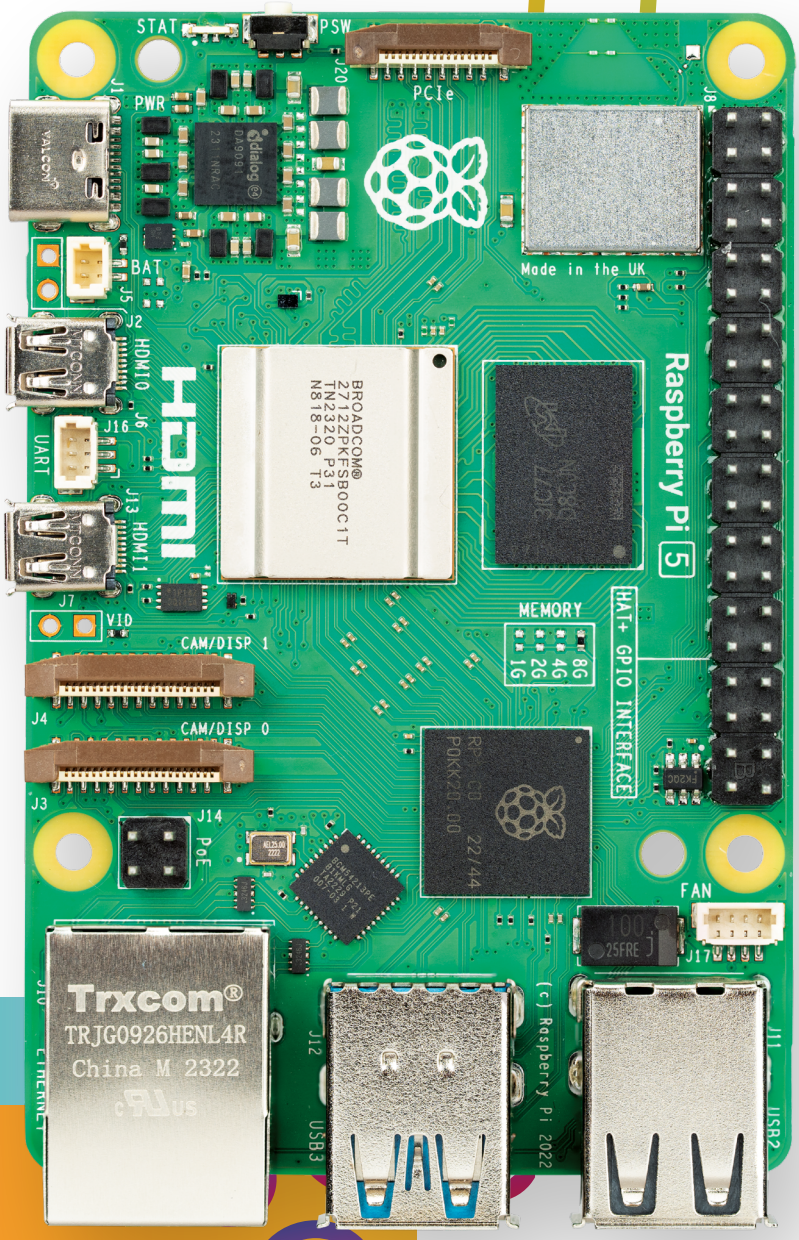
Raspberry Pi 5 LAUNCH SPECIAL!

It's here! Here are some ideas for the latest and greatest Raspberry Pi

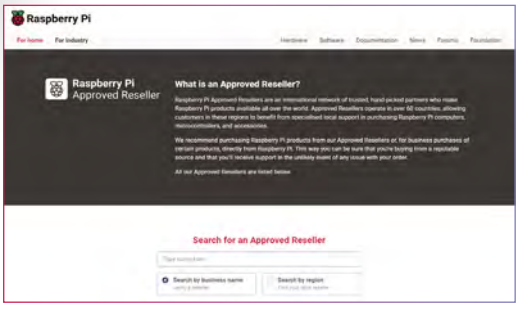
By the time you read this, Raspberry Pi 5 will be out. We've been waiting four years for this and we're very excited to use it ourselves, and see what other people come up with. Which brings us to the age old question: what do you want to do with your Raspberry Pi?

We have some answers for you, and with the new capabilities of Raspberry Pi 5 in mind. So get your brain into gear, and get ready to make.



WHERE TO BUY

The best way to get a Raspberry Pi 5 is via a Raspberry Pi Approved Reseller. Check out **raspberrypi.com/5** for a full list of resellers in your country. The MagPi subscribers get theirs first! **magpi.cc/prioritybording**



For full instructions, head to:
magpi.cc/fileserver

Build a FILE SERVER

Make a better NAS with the new features of Raspberry Pi 5

In *The MagPi* 134 (magpi.cc/134) we talked to Alasdair Allan, Head of Documentation, who mentioned he was excited for the prospect of low-power NAS boxes that made use of the M.2 HAT coming to Raspberry Pi 5 in the future. Here are the basics of setting one up.

An M.2 SSD card will help bring down the power requirements for a file server

01 Software setup

You need to install Samba onto Raspberry Pi OS, usually done with:

```
sudo apt install samba samba-common-bin
```

We like to use NTFS for the shared drive so that other operating systems can use it easily, so we install that with:

```
sudo apt install ntfs-3g
```

02 Storage setup

Usually we use an external hard drive, but using the SSD drive will be very similar – plug it in, make sure it's formatted, and then mount it to Raspberry Pi OS. It will do this automagically when you plug it in once booted, but to automount it on boot (there is a difference) you'll need to edit the **fstab** file with `sudo nano /etc/fstab` and add a line like:

```
/dev/sdb1 /mnt/location ntfs nls-utf8,umask-0222,uid-1000,gid-1000,rw 0 0
```

Example code for your Samba config file

03 Configuration

The magic of the NAS box is in the Samba configuration file – it's like writing a spell to open up the shared storage to the network. Here's one example, and there's another in the screenshot above, but tweak it to your own needs:

```
[share]
Comment = Network share
Path = /mnt/location
Browseable = yes
Writeable = yes
only guest = no
create mask = 0777
directory mask = 0777
Public = yes
Guest ok = yes
```

RAID NAS

PJ Evans shows you a way to create a home file server with redundancies over at **magpi.cc/raidnas**.

3D photos & VIDEO

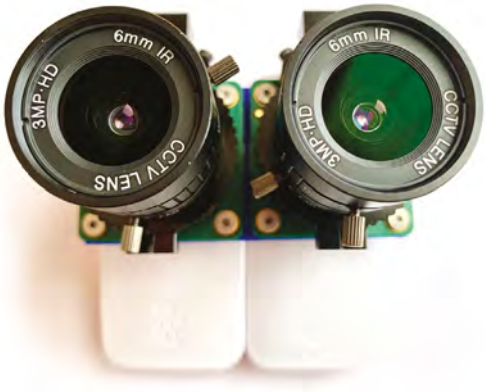
Add an extra dimension to your photography and videography

▲ Create VR and 3D video with two cameras and Raspberry Pi 5

With the ability to add two cameras to one Raspberry Pi 5, it's never been easier to create 3D video or take 3D photos with Raspberry Pi. It can take some tweaking to get it right, but here's how you can get started.

01 VR or movie

There are two distinct ways for doing 3D filming – the kind you see in movies with two slightly overlapping frames that 3D glasses selectively view to make the flat image on the screen have depth, and the VR version which either has two distorted images that a headset can render as a scene in front of you in high quality, or a slightly lower-quality 360° scene all around you. The latter uses two cameras with wide-angle lenses opposite each other, while the former use two cameras facing forwards, and can be a bit easier. Also, with the lack of 3D TVs these days, we'll be looking at using a VR headset.



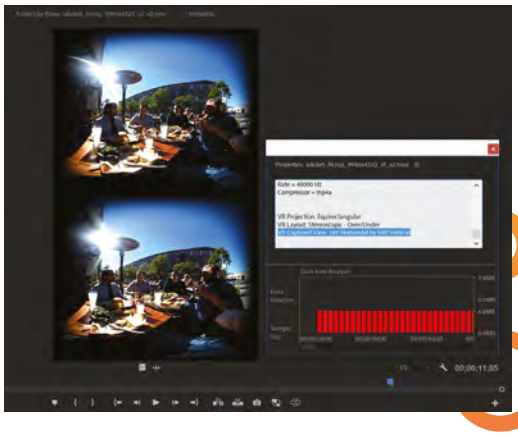
▲ A previous version of 3D photography with Raspberry Pi

02 Timing

The trick to getting the perfect shot is timing the cameras. In a previous tutorial by regular PJ Evans, he linked up to Raspberry Pi Zero with cameras attached and had them shoot images at the same time. This was done with some smart Python code, and you can look at how he did it here: **magpi.cc/make3dcam.**

▼ Editing video together will be necessary

03 Stitching



The images or video, once created, need to be stitched together. For video, we suggest giving each one a look on video editing software to make sure they line up properly. PJ, in his tutorial, created a way for images to be put together for 3D (find the code at **magpi.cc/3dcameragit**). However, you can also do it in video editors like Adobe Premiere.

3D video now

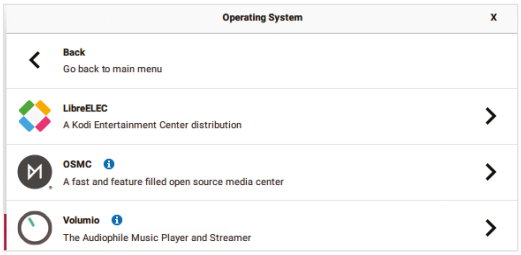
The POPCAM is a 360-degree 3D camera kit that uses Raspberry Pi CM4 – it's not out quite yet, but we've been using a pre-release model and it's very good. If you'd like to skip the DIY, find out more at **magpi.cc/popcamera.**

Media CENTRE

Your media, but better

LibreELEC (in some form or another) and Kodi have been mainstays for Raspberry Pi media centres for a very long time. With the new VideoCore VII GPU on Raspberry Pi 5, while hardware decoding of H.264 is no longer present, the power of the CPU is more than enough to play them and it allows for 4K H.264 media now too. What is exciting is the inclusion of H.265 and VC1 hardware decoding, which is used in a lot of newer media for higher-quality files and audio.

Setting up LibreELEC, our preferred method of using a media centre, is exceptionally easy: on Raspberry Pi Imager (**magpi.cc/imager**), when selecting an operating system, select 'Media player OS' and, from the menu, choose LibreELEC. Setup is simple, and you can check our ultimate media player guide for more info on that: **magpi.cc/mediaplayer**.



There are other media-based OSes you can use with Raspberry Pi too, including audio servers

Retro GAMING

Emulate more consoles than ever before

There are several options depending on your emulation needs

More power from Raspberry Pi means more power to emulate the consoles of yore. We've already seen reports of the GameCube, and even the Wii, being successfully emulated on Raspberry Pi 5. However, you may not be able to quite get it 100% working on day one of Raspberry Pi 5. It likely won't take long, though.

We like to use RetroPie for emulation, which is available as an installation option in Raspberry Pi Imager – find it under 'Emulation and game OS'. Set up is very simple, although you'll have to source your own games. Check out **magpi.cc/legalroms** for how to do that.

Other PROJECTS

Still not inspired? Here are a few more projects you might like...

Portable desktop computer

Raspberry Pi 4 is a good desktop computer – we've used a Raspberry Pi 400 on many occasions for just that – but the extra grunt of Raspberry Pi 5, along with the new Raspberry Pi OS Bookworm, take it to a new level.

To get it set up, you just need a Raspberry Pi 5, a mouse, a keyboard, and an available monitor or TV to plug into. Using the Raspberry Pi OS 'Full' version with recommended software pre-installed means you'll have just about everything you need to get working, making art, or just relaxing with some YouTube.

Other photography

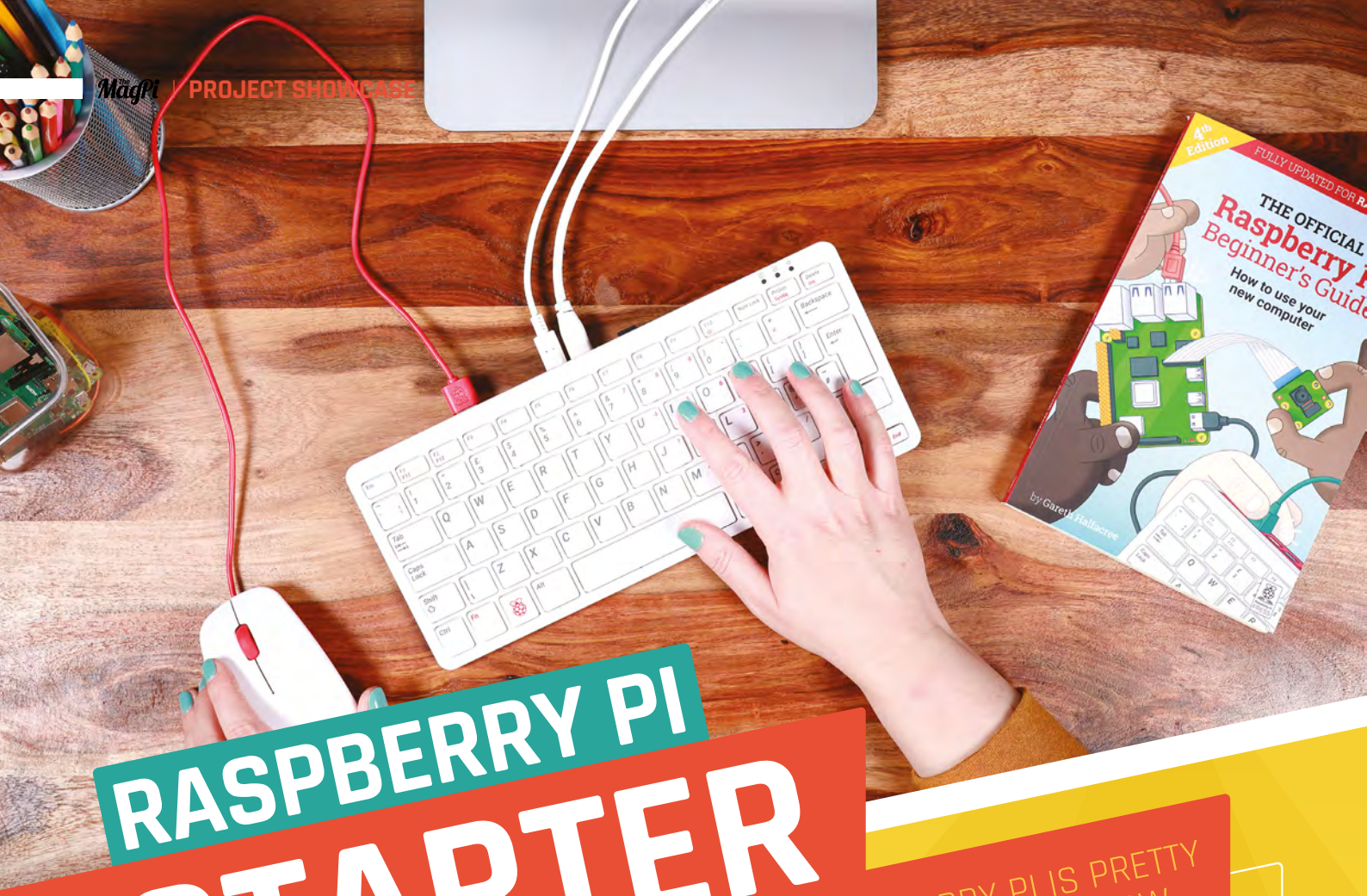
You don't need to take 3D pictures with Raspberry Pi 5; normal photography works just great. Over the years, we've covered many camera projects – from simple photographs to time-lapses, surreal IR photos, motion-sensitive cameras, and even astrophotography.

You can even make use of two cameras similarly to the way smartphones do – two different lenses on two different cameras allowing for macro shots or wide-angle shots alongside regular photos, depending on the situation. With better processing speeds, along with the upcoming M.2 HAT, you'll be able to take a lot more photos as well.

Cluster computing

With more power in Raspberry Pi 5 comes a greater ability to crunch numbers. Whether practical or not, you can get a lot of Raspberry Pi into a small space, and people have created art installations, as well as actual distributed computing setups.

There are kits you can get for previous Raspberry Pi models to help get them into a cluster, and we've seen some people talking about upgrading these on social media – perhaps you could beat them to the punch.



RASPBERRY PI STARTER GUIDE

SETTING UP RASPBERRY PI IS PRETTY STRAIGHTFORWARD, JUST FOLLOW THE ADVICE OF **ROSIE HATTERSLEY**

Congratulations on becoming a Raspberry Pi explorer. We're sure you'll enjoy discovering a whole new world of computing and the chance to handcraft your own games, control your own robots and machines, and share your experiences with other Raspberry Pi fans.

Getting started won't take long: just corral the extra bits and bobs you need on our checklist. Useful additions include some headphones or speakers if you're keen on using Raspberry Pi as a media centre, or a gamepad for use as a retro games console.

To get set up, simply use your pre-written microSD card (or use Raspberry Pi Imager to set up a card) and connect all the cables. This guide will lead you through each step. You'll find the Raspberry Pi OS, including coding programs and office software, all available to use. After that, the world of digital making with Raspberry Pi awaits you.

What you need

All the bits and bobs you need to set up a Raspberry Pi computer

A Raspberry Pi

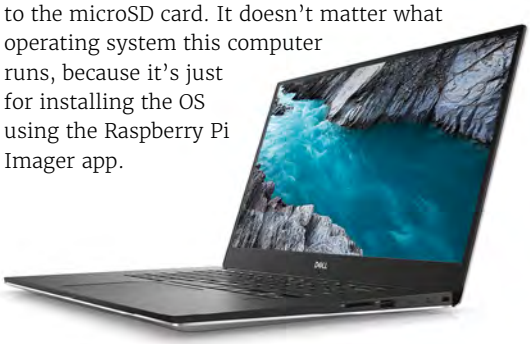
Whether you choose the new Raspberry Pi 5 or a Raspberry Pi 4, 400, 3B+, 3B, Zero or Zero 2 W (or an older model of Raspberry Pi), basic setup is the same. All Raspberry Pi computers run from a microSD card, use a USB power supply, and feature the same operating systems, programs, and games.

8GB microSD card

You'll need a microSD card with a capacity of 8GB or greater. Your Raspberry Pi uses it to store games, programs, and boot the operating system. Many Raspberry Pi computer kits come with a card pre-written with Raspberry Pi OS. If you want to reuse an old card, you'll need a card reader: either USB or a microSD to full-sized SD (pictured).

Windows/Linux PC or Mac computer

You'll need a computer to write Raspberry Pi OS to the microSD card. It doesn't matter what operating system this computer runs, because it's just for installing the OS using the Raspberry Pi Imager app.



USB keyboard

Like any computer, you need a means to enter web addresses, type commands, and otherwise control Raspberry Pi. The Raspberry Pi 400 comes with its own keyboard. Raspberry Pi sells an official Keyboard and Hub (**magpi.cc/keyboard**) for other models.

USB mouse

A tethered mouse that physically attaches to your Raspberry Pi via a USB port is simplest and, unlike a Bluetooth version, is less likely to get lost just when you need it. Like the keyboard, we think it's best to perform the setup with a wired mouse. Raspberry Pi sells an Official Mouse (**magpi.cc/mouse**).

Power supply

Raspberry Pi 5, 4 and 400 need a USB Type-C power supply. Raspberry Pi sells power supplies (**magpi.cc/usbcpower**), which provide a reliable source of power. Raspberry Pi 1, 2, 3, and Zero models need a micro USB power supply (**magpi.cc/universalpower**).

Display and HDMI cable

A standard PC monitor is ideal, as the screen will be large enough to read comfortably. It needs to have an HDMI connection, as that's what's fitted on your Raspberry Pi board. Raspberry Pi 5, 4 and 400 can power two HDMI displays, but require a micro-HDMI to HDMI cable. Raspberry Pi 3B+ and 3A+ both use regular HDMI cables; Raspberry Pi Zero W needs a mini-HDMI to HDMI cable (or adapter).

USB hub

Raspberry Pi Zero and Model A boards have a single USB socket. To attach a keyboard and mouse (and other items), you should get a four-port USB hub (or use the official USB Keyboard and Hub which includes three ports). Instead of standard-size USB ports, Raspberry Pi Zero has a micro USB port (and usually comes with a micro USB to USB-A adapter).

SET UP RASPBERRY PI

Raspberry Pi 5 / 4 / 3B+ / 3 has plenty of connections, making it easy to set up

01 Hook up the keyboard

Connect a regular wired PC (or Mac) keyboard to one of the four larger USB-A sockets on a Raspberry Pi 5 / 4 / 3/3B+. It doesn't matter which USB-A socket you connect it to. It is possible to connect a Bluetooth keyboard, but it's much better to use a wired keyboard to start with.

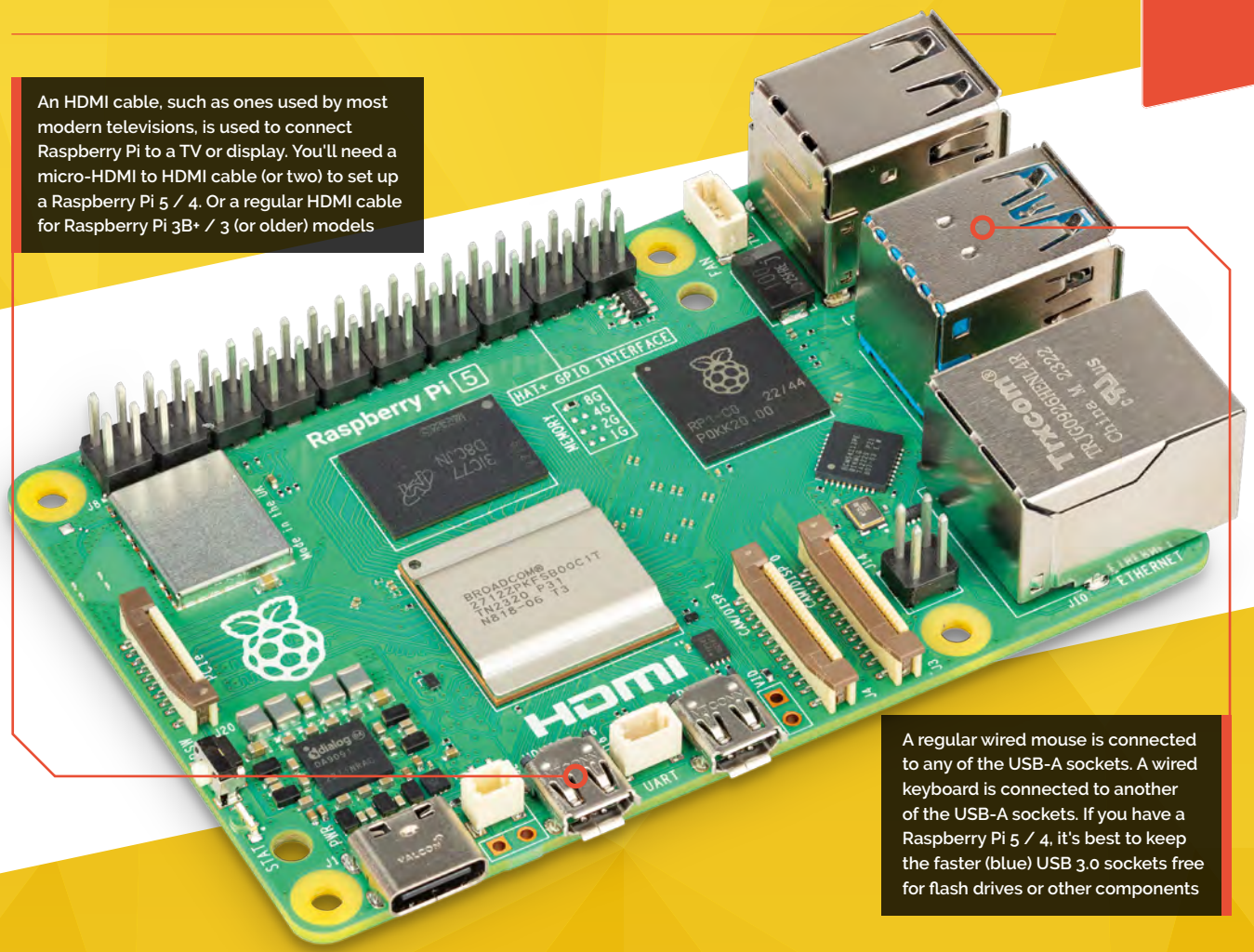
02 Connect a mouse

Connect a USB wired mouse to one of the other larger USB-A sockets on Raspberry Pi. As with the keyboard, it is possible to use a Bluetooth wireless mouse, but setup is much easier with a wired connection.

03 HDMI cable

Next, connect Raspberry Pi to your display using an HDMI cable. This will connect to one of the micro-HDMI sockets on the side of a Raspberry Pi 5 / 4, or full-size HDMI socket on a Raspberry Pi 3 / 3B+. Connect the other end of the HDMI cable to an HDMI monitor or television.

An HDMI cable, such as ones used by most modern televisions, is used to connect Raspberry Pi to a TV or display. You'll need a micro-HDMI to HDMI cable (or two) to set up a Raspberry Pi 5 / 4. Or a regular HDMI cable for Raspberry Pi 3B+ / 3 (or older) models



A regular wired mouse is connected to any of the USB-A sockets. A wired keyboard is connected to another of the USB-A sockets. If you have a Raspberry Pi 5 / 4, it's best to keep the faster (blue) USB 3.0 sockets free for flash drives or other components

The USB-C socket is used to connect power to Raspberry Pi 400. You can use a compatible USB-C power adapter (found on recent mobile phones) or use a bespoke power adapter such as a Raspberry Pi 15.3 W USB-C Power Supply

The Ethernet socket can be used to connect Raspberry Pi 400 directly to a network router (such as a modem/router at home) and get internet access. Alternatively, you can choose a wireless LAN network during the welcome process

SET UP RASPBERRY PI 400

Raspberry Pi 400 has its own keyboard – all you need to connect is the mouse and power

01 Connect a mouse

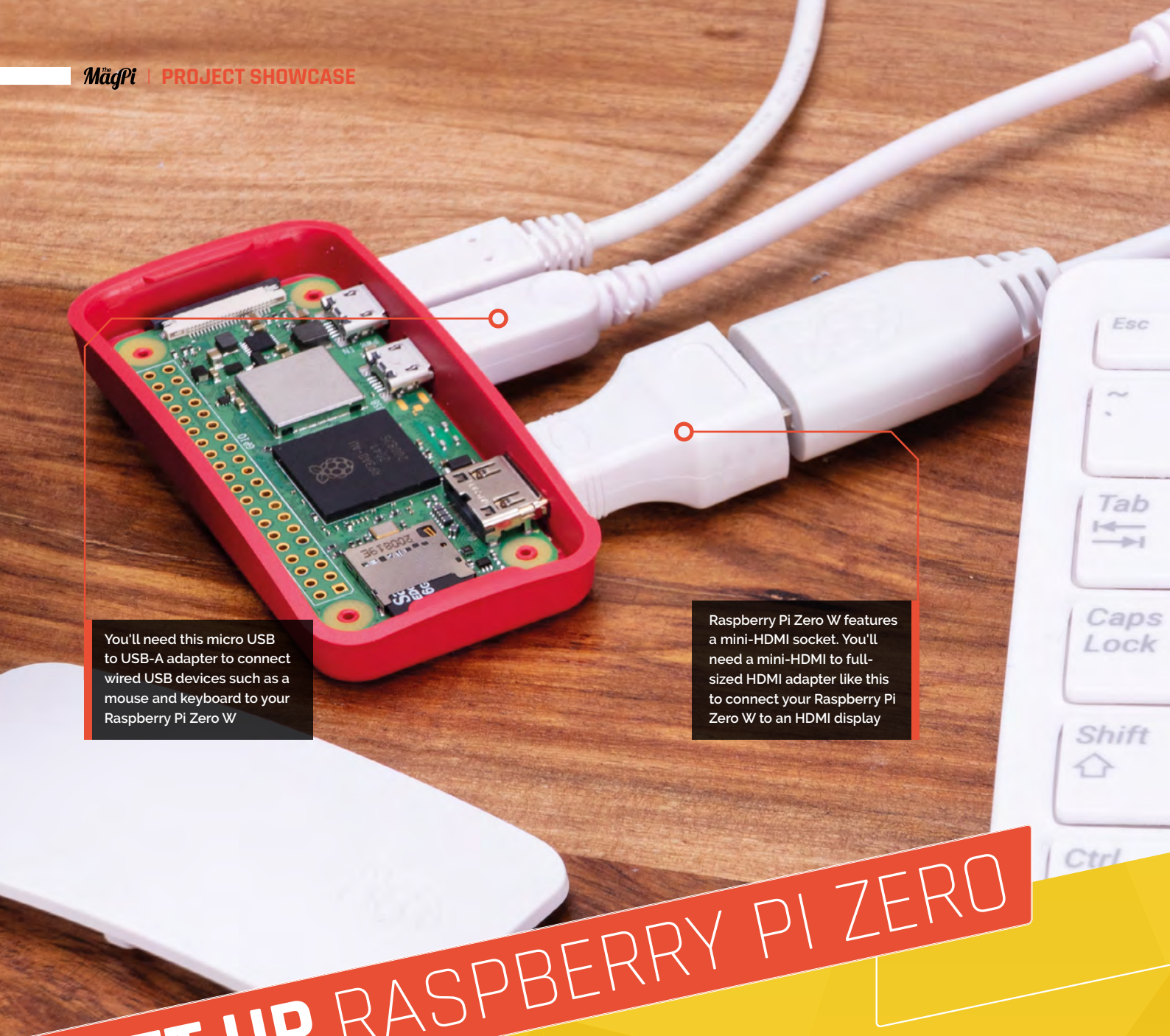
Connect a wired USB mouse to the white USB connection on the rear of Raspberry Pi 400. The two blue USB 3.0 connectors are faster and best reserved for external drives and other equipment that need the speed.

02 Attach the micro-HDMI cable

Next, connect a micro-HDMI cable to one of the micro-HDMI sockets on the rear of Raspberry Pi 400. The one next to the microSD card slot is the first one, but either connection should work. Connect the other end of the HDMI cable to an HDMI monitor or television.

03 The microSD

If you purchased a Raspberry Pi 400 Personal Computer Kit, the microSD card will come with Raspberry Pi OS pre-installed. All you need to do is connect the power and follow the welcome instructions. If you do not have a Raspberry Pi OS pre-installed microSD card, follow the instructions later in 'Set up the software'.



SET UP RASPBERRY PI ZERO

You'll need a couple of adapters to set up Raspberry Pi Zero / Zero 2 W

01 Get it connected

If you're setting up a smaller Raspberry Pi Zero, you'll need to use a micro USB to USB-A adapter cable to connect the keyboard to the smaller connection on the board. Raspberry Pi Zero models only have a single micro USB port for connecting devices, which means you'll need to either get a small USB hub or use an all-in-one mouse and keyboard.

02 Mouse and keyboard

You can either connect your mouse to a USB socket on your keyboard (if one is available), then connect the keyboard to the micro USB socket (via the micro USB to USB-A adapter). Or, you can attach a USB hub to the micro USB to USB-A adapter.

03 More connections

Now connect your full-sized HDMI cable to the mini-HDMI to HDMI adapter, and plug the adapter into the mini-HDMI port in the middle of your Raspberry Pi Zero. Connect the other end of the HDMI cable to an HDMI monitor or television.

First, insert your microSD card into Raspberry Pi

With the microSD card fully inserted, connect your power supply cable to Raspberry Pi. A red light will appear on the board to indicate the presence of power

SET UP THE SOFTWARE

Use Imager to install Raspberry Pi OS on your microSD card and start your Raspberry Pi

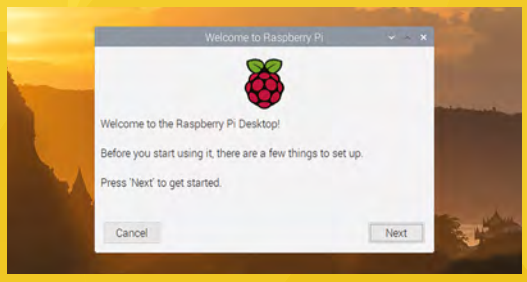
Now you've got all the pieces together, it's time to install an operating system on your Raspberry Pi so you can start using it. Raspberry Pi OS is the official software for Raspberry Pi, and the easiest way to set it up on your Raspberry Pi is to use Raspberry Pi Imager. See the 'You'll Need' box and get your kit together.

01 Download Imager

Raspberry Pi Imager is available for Windows, Mac, and Linux computers. You can also install it on Raspberry Pi computers, to make more microSD cards once you are up-and-running. Open a web browser on your computer and visit **magpi.cc/imager**. Once installed, open Imager and plug your microSD card into your computer.

02 Choose OS

Click on 'Choose OS' in Raspberry Pi Imager and select the recommended Raspberry Pi OS. Click 'Choose SD card' and select the microSD card you just inserted (it should say 8GB or the size of the card next to it). Click on 'Write'. Your computer will take a few minutes to download the Raspberry Pi OS files, copy them to the microSD card, and verify that the data has been copied correctly.



03 Set up Raspberry Pi

When Raspberry Pi Imager has finished verifying the software, you will get a notification window. Remove the microSD card and put it in your Raspberry Pi. Plug in your Raspberry Pi power supply and, after a few seconds, a blue screen will appear with 'Resizing Filesystem'. It will quickly vanish and be replaced by 'Welcome to Raspberry Pi'. Click on Next and follow the on-screen instructions to set up Raspberry Pi OS and start using your new computer.

Top Tip

Advanced options

Click the cog to customise Raspberry Pi OS with options such as Wi-Fi passwords and usernames.

You'll Need

- A Windows/Linux PC or Apple Mac computer
- A microSD card (8GB or larger)
- A microSD to USB adapter (or a microSD to SD adapter and SD card slot on your computer)
- Raspberry Pi Imager **magpi.cc/imager**

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Retro gaming with **Raspberry Pi**

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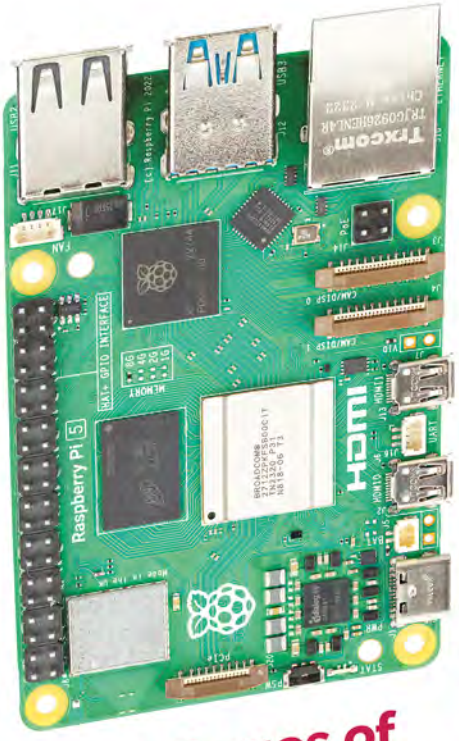

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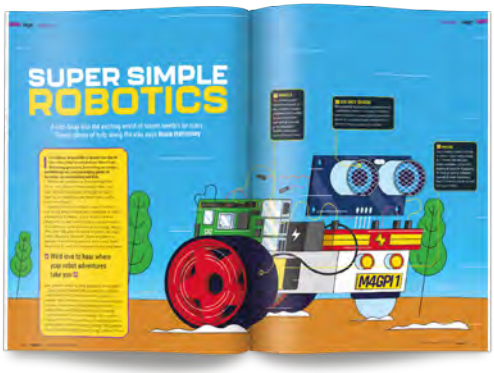

200 PAGES OF RASPBERRY PI

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* Raspberry Pi hardware not included

Part 01

Using Ubuntu on Raspberry Pi

Enjoy a new Raspberry Pi desktop experience by installing Ubuntu Linux

MAKER

Phil King

A long-time contributor to *The MagPi*, Phil is a freelance writer and editor with a focus on technology.

@philkingeditor

While the official Raspberry Pi OS is an excellent, easy-to-use operating system tailored for Raspberry Pi computers, there are numerous alternatives you can use instead – see our feature in issue 111 (magpi.cc/111). The most popular among these is Ubuntu, based on Debian Linux (just like Raspberry Pi OS).

One of the most commonly used Linux distros in general, Ubuntu offers a slick user interface, a wide range of up-to-date software, and the benefit of familiarity for anyone who's already used it on another computer. And Ubuntu 23.10 supports Raspberry Pi 5.

We'll walk you through how to install the Desktop version on Raspberry Pi and make use of some of its key features.

You'll Need

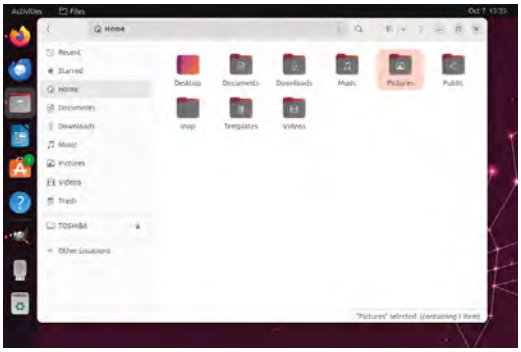
- Raspberry Pi
- 16GB microSD card (or greater)

01 Ubuntu versions

The easiest way to install Ubuntu is to use the official Imager tool **(magpi.cc/imager)**. Click on Choose OS, then 'Other general-purpose OS' > Ubuntu. You'll see a list of different Ubuntu versions. The three main types are Desktop, Server, and Core. The last two of these lack a GUI by default, so we'll stick to Desktop. For this there are two options: the latest version (at the top) and an earlier LTS (long-term support) one which may prove more stable. Choose 23.10 if available and you are using Raspberry Pi 5.

02 Install Ubuntu

Whichever Desktop version you choose in Raspberry Pi Imager, note that – unlike with Raspberry Pi OS – you won't be able to access an advanced options menu in Imager to preconfigure aspects such as the Wi-Fi connection and SSH. As usual, click on Choose Storage and select the microSD card that you have connected to your computer (typically via a USB card reader). You'll need at least a 16GB card for Ubuntu Desktop. Finally, click on Write to flash the OS to the microSD card – it'll take a little while, including verification. When ready, eject the card and insert it into your Raspberry Pi.

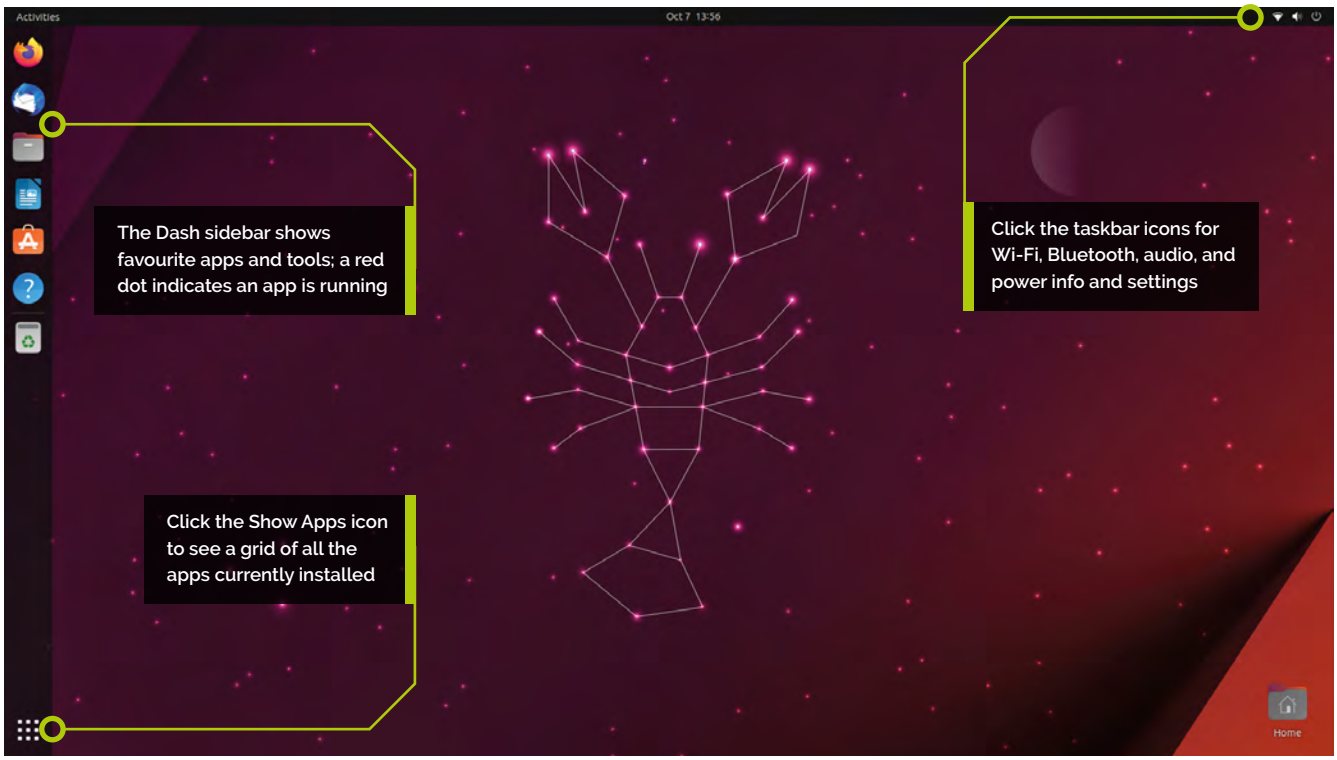


▲ The Files browser is similar to the one in Raspberry Pi OS, except you only have access to your user folders

03 First boot

Before powering it on, make sure Raspberry Pi is connected via HDMI to a monitor or TV. Powering up, the usual colour gradients image will appear briefly before the boot-up process begins. After a few text lines on a black screen, the Ubuntu logo appears, followed by Ubuntu's purple desktop background and a System Configuration window.

This is much like the setup wizard in Raspberry Pi OS: choose the language, keyboard layout (or detect it), connect to a wireless network (or skip



for now), and select your location. Finally, enter your details: name, computer name, username, and password. You can opt to log in automatically or require the password.

A 'Welcome to Ubuntu' screen and progress bar appears while it configures everything, followed by an 'Applying changes' window. It then reboots.

> "The easiest way to install Ubuntu is to use the official Raspberry Pi Imager tool"

04 Final configuration

Following the reboot, you'll see the Ubuntu user selection screen with the username you selected. Click on it; if you opted to require the password to log in, you'll need to enter it.

Finally, the full Ubuntu desktop appears. A window offers you the option to connect to your online accounts – Google, Nextcloud, and/or Microsoft – but you can skip this for now and do it later in the Settings. You're also asked whether to send system info to Canonical, and turn location services on. It then gives you a preview of some of the apps you can use in Ubuntu.

05 Navigate the desktop

Ubuntu's default desktop environment (you can install others) is GNOME, which is fairly easy to navigate once you get used to it. Here are the key areas:

- **Dash:** The left sidebar has shortcut icons for apps and tools – by default, Firefox, Thunderbird Mail, Files, LibreOffice Writer, Ubuntu Software, Help, and Trash.
- **Activities:** This option (top left) brings up an overview of current open windows.
- **Show Apps:** Clicking this icon (bottom left) shows all the installed apps.
- **Home:** Double-clicking this icon (bottom right) takes you to your home folder in the Files browser.
- **Taskbar:** At the top right you'll find Wi-Fi, audio, and power icons; click to see their settings. Or click the time to view a mini calendar, along with any upcoming events on it.

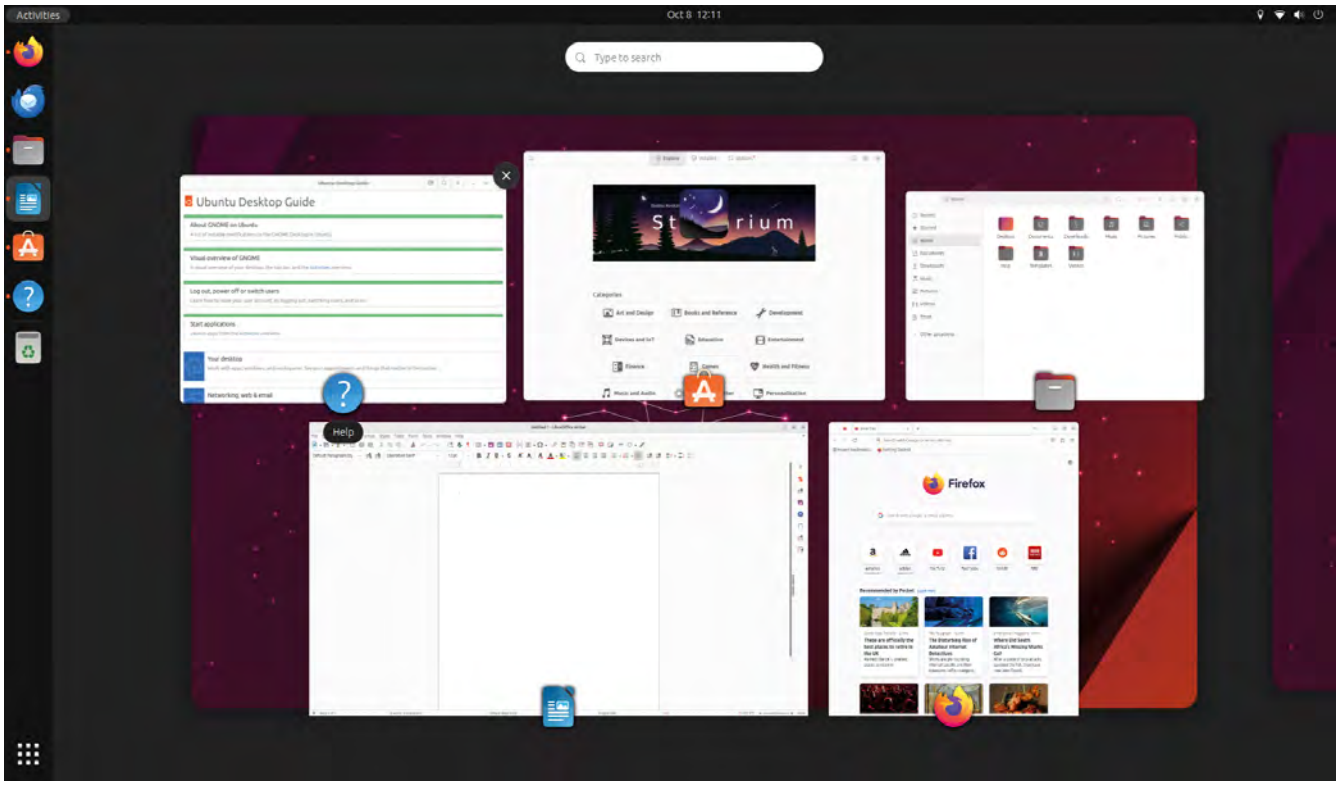
06 Launch an app

After clicking the Show Apps icon at the bottom left, you'll see a grid of icons for installed apps and other tools. Clicking the right-hand

Top Tip

Mount a USB drive

When you insert a USB flash drive, it's automatically detected and its icon appears in the Dash – remember to right-click and Eject before physically removing it.



▲ The Activities overview offers an easy way to switch between windows and workspaces

arrow takes you to a second screen for more apps. In addition, there's a search option at the top; just start typing and relevant app icons will appear.

To launch an app, the Shotwell image organiser for instance, just click on its icon. It will open in a new window on the desktop, and its icon will appear in the Dash sidebar. To keep it in the Dash as a favourite, right-click the icon and select Pin to Dash (to remove, right-click and Unpin).

> By default, there are two desktop workspaces which you can switch between

07 Activities overview

Naturally, you can run several apps at same time. The easiest way to see them all, and switch between them, is to click Activities (top left) to open an overview of all the open windows. Just click on one to select it. You can also search for open apps.

You'll also notice that, by default, there are two desktop workspaces which you can switch between – very handy to avoid clutter when multitasking. In Activities, you can drag and drop an app window from one workspace to another; an extra empty workspace will then be created, so you can have as many as you like!

08 Keyboard shortcuts

Here are just a few of the many handy keyboard shortcuts you can use in Ubuntu. Note that **SUPER** is typically the Windows key, or Raspberry Pi logo key on Raspberry Pi 400.

- **SUPER** – Activities overview
- **SUPER+A** – Show Apps
- **SUPER+↑** – full-screen window
- **SUPER+↓** – revert to standard window size
- **SUPER+←** – move window to left side
- **SUPER+→** – move window to right side
- **SUPER+TAB** – switch between apps
- **ALT+ESC** – switch between windows in current workspace
- **SUPER+ALT+←/→** – switch between workspaces

09 Install more apps

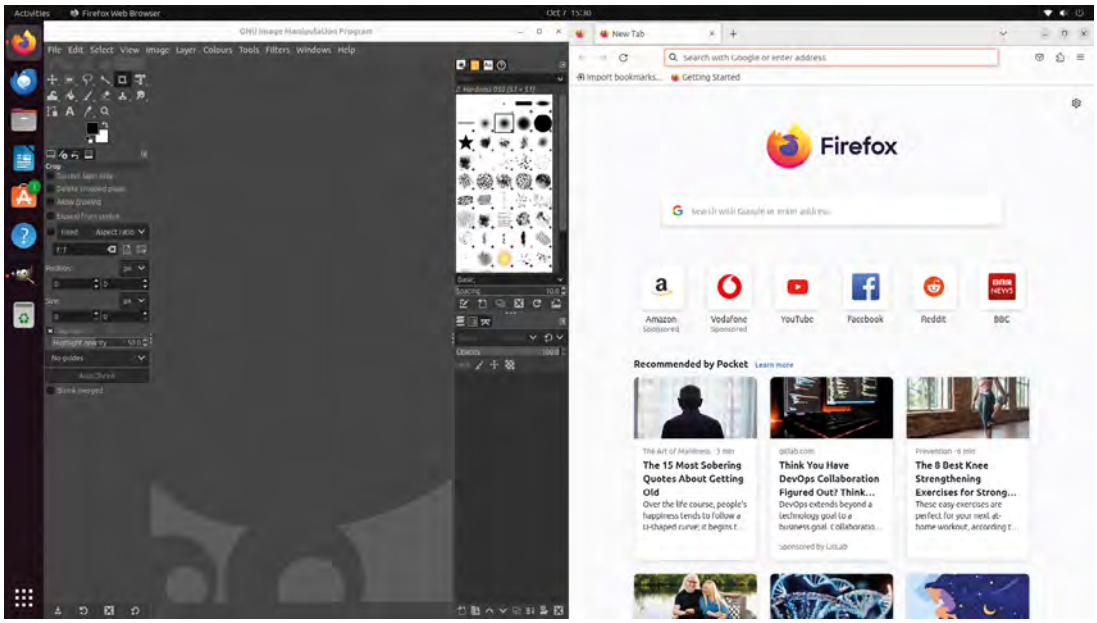
While there are several ways of installing new software in Ubuntu (which we'll explore next time), the easiest is to use Software Centre – akin to an app store. Click on the Ubuntu Software icon (briefcase) in the Dash sidebar to launch it.

In the Explore tab, you'll see a range of app categories including Education, Games, and Productivity; clicking one shows the relevant apps. (The other tabs show installed apps and available updates.) Alternatively, click the search icon (top

Top Tip

Shut down

To shut down the system safely, click the top-right taskbar icons, then the power icon and select Power Down. There are also options to Restart or Log Out.



Open windows can be resized or shifted to the left or right side of the desktop for a neat split-screen view

left) and start typing the name of the app you would like to install.

Clicking an app icon brings up its details screen, including user reviews (at the bottom) and whether it's by a known developer. Click on Install and enter your password to download and install it. Once done, its icon will appear on the Show Apps screen. To uninstall an app, open its details in Ubuntu Software, click the Installed button, and select Uninstall.

10 Change settings

There are several ways to reach the Settings screen: by searching for it in Activities or Show Apps, or by clicking the icons at the top right of the taskbar and then the gear icon.

There are numerous settings categories, including Appearance, Desktop, Notifications, Multitasking, Apps (individual app settings), Power, Displays, and Printers.

In the Appearance section, for instance, you can switch to dark mode and/or select a different backdrop for the desktop – from the selection or by importing your own appropriately sized image.

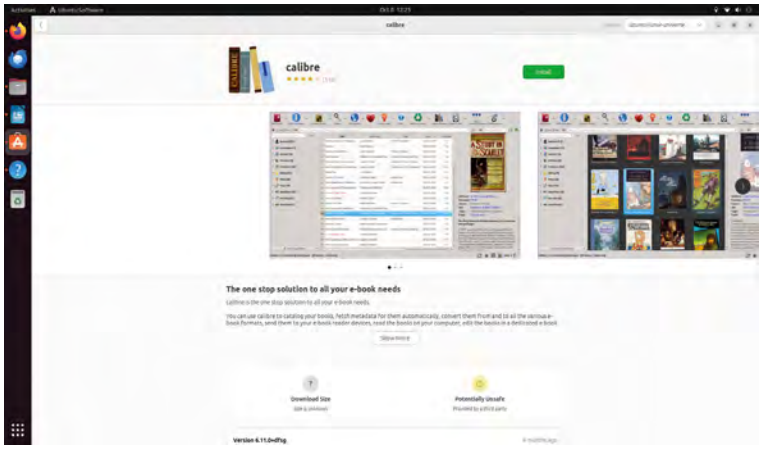
11 System update

From the Show Apps screen, launch Software Updater (not to be confused with Software & Updates). It will then check for firmware and software updates. You then have the option of installing them now or later. If you get a message about Software Updater not responding, click Wait. Enter your password to authenticate and install updates. It may take a while (so go and make a cup of tea). Finally, click Restart Now (or Later) to finish installing the updates.

Taking it further

Next time, we'll cover more advanced Ubuntu aspects such as using the command line, enabling SSH and VNC, installing media codecs, using the GPIO pins, installing software from other sources, and switching to a different desktop environment.

Viewing an app's details in the Ubuntu Software Centre; just click Install to download and install it



An introduction to MQTT

Communication between your devices.

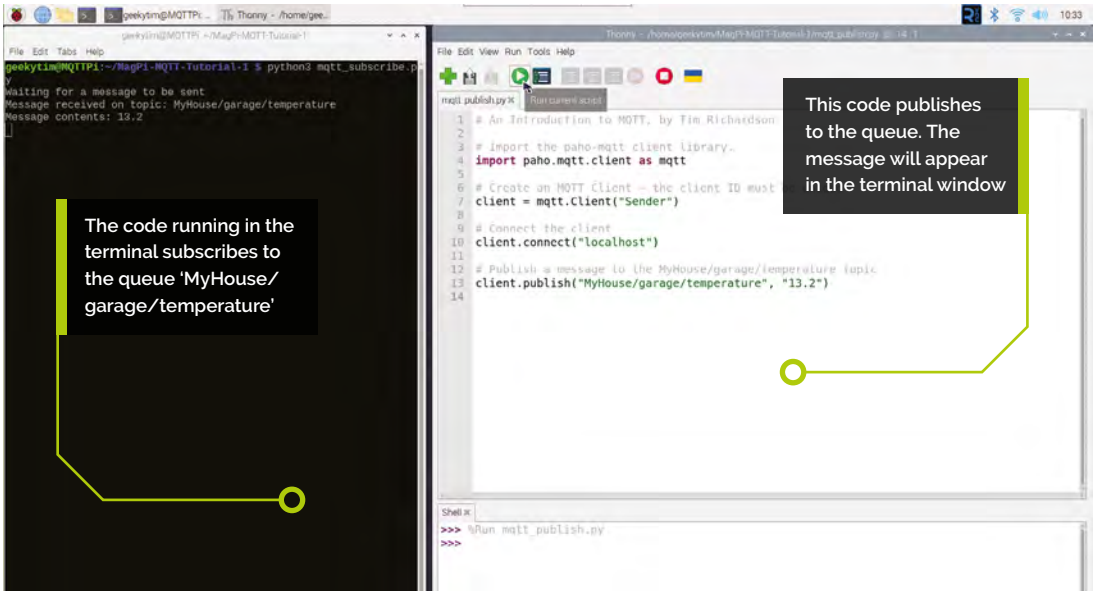
By **Tim Richardson**

MAKER

Tim Richardson

Tim has been involved with Raspberry Pi's community almost from the start. He is part of the Pi Wars organising team and their resident course designer/builder, as well as writing the CamJam EduKit worksheets, former CamJam organiser and current maker.

@Geeky_Tim



Learn how to send messages between Raspberry Pi computers, Raspberry Pi Pico, and lots of other devices using a simple protocol called MQTT.

MQTT (Message Queuing Telemetry Transport) was originally created back in 1999 to be a lightweight way of passing small messages between devices on unreliable or low-bandwidth networks. Its main use is for machine-to-machine communication, or for the Internet of Things. Being lightweight means that it can be used by small, resource-constrained microcontrollers, like Raspberry Pi Pico. That does not mean its use is limited, though. There are plenty of ways you can use it within a home network, across the internet or even on a small cluster of devices that need to talk to each other. Its use is only limited by your imagination.

MQTT works on a publish/subscribe basis. That means a device can either publish (or send) messages or can subscribe to (or listen for) messages. In between the devices is what is known as an MQTT 'message broker'. This is software that runs on a server that receives published messages and sends them out to subscribers. The broker is also lightweight, so any Raspberry Pi computer can run the MQTT broker software.

To explain that with a real-life example, imagine you have a BME280 sensor connected to a Raspberry Pi Pico measuring the temperature, pressure and humidity within your garage or garden cabin. You are going to want to see what is being measured without going out to the garage or cabin or having to log into it remotely to get readings. You can program Pico as an MQTT client which will publish the measurements within

your network. You can then program a Raspberry Pi computer, connected to a display of some description, to subscribe to those MQTT messages, interpret the contents, and display them on screen. That Raspberry Pi can even be running the MQTT broker as well as whatever software you use to display the measurements. **Figure 1** illustrates a possible MQTT network structure.

On topic

MQTT clients publish to and subscribe to topics, which are a hierarchy similar to the folder structure on your computer. Think of the top level as being the home folder on your Raspberry Pi, **/home**. Underneath **/home** are the user folders, like **/home/pi**. And under that are various folders belonging to the user, like the Documents or Downloads folders, **/home/pi/Documents** or **/home/pi/Downloads**. The only difference with MQTT is that there is no '/' at the beginning of the top-level topic.

Let's call our top-level topic **MyHouse**. Subtopics are added using a '/' at the end of the top-level topic followed by the subtopic name. For example, **MyHouse/garage**. You might want to go down one more topic level and have a topic for the temperature only; e.g. **MyHouse/garage/temperature**. This helps you to organise your MQTT into, say, rooms of the house, types of device (e.g. switch, light), what is being measured (e.g.

> If you need to send information around your network then MQTT should be included within your armoury of go-to tools

temperature, humidity), action to be taken (e.g. toggle, turn on, change channel), or anything else you can think of. When publishing a message, it must always be to a specific topic (like **MyHouse/cabin/humidity**), but when subscribing you are able to use wildcards to say 'I want to receive all messages from the garage' by using **MyHouse/garage/#**, or 'I want to receive all temperatures within the home' using **MyHouse/+/temperature**. **Figure 2** shows an example MQTT Topic structure.

There is nothing special about the messages being sent around your network. They are plain text enclosed within the MQTT protocol, so you don't need to understand any complex structures to be able to use MQTT. You just need to decide what text you want to send (publish) and be able to interpret it on the other end (subscribe).

▲ **Figure 1:** An example MQTT network

Using MQTT

MQTT is a well-defined and supported protocol. As such, there are plenty of broker implementations, both commercial as well as open-source. MQTT clients can be written in many languages, such as C, Python, C# or Rust. Lots of tools and software also support MQTT, like Node-RED and OctoPrint (3D printer control software).

In this article, you are going to use an open-source broker called Mosquitto running on a Raspberry Pi. You will use some command-line tools to test your broker and learn to write simple clients with Python using the paho-mqtt library.

Installing Mosquitto

Prepare your Raspberry Pi by writing the latest Desktop Raspberry Pi OS image to a new microSD card and boot up Raspberry Pi. Update the OS to the latest version using:

```
sudo apt update && sudo apt upgrade -y
```

Now install the Mosquitto MQTT server and all of its dependencies, plus some command-line client tools that can be used to test the server:

```
sudo apt install mosquitto mosquitto-clients
-y
```

After installation, the Mosquitto server will be

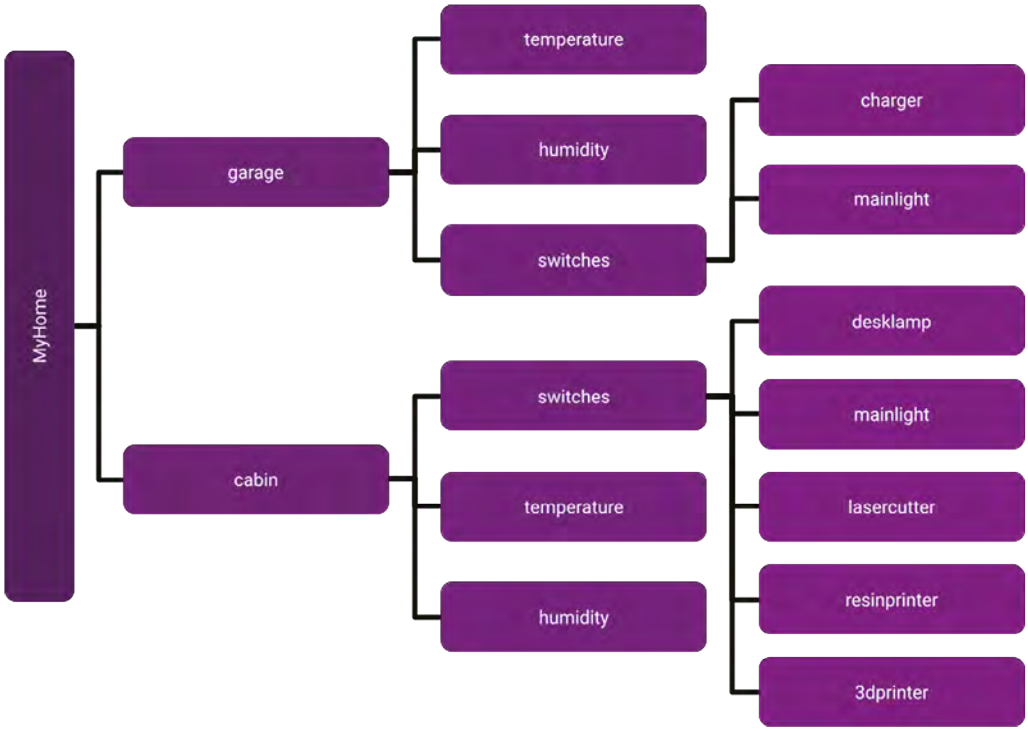


Figure 2: An example topic structure

started via systemd. To check that the server is running, use `systemctl`:

```
sudo systemctl status mosquitto
```

If it is not running for any reason, the service can be restarted using:

```
sudo systemctl restart mosquitto
```

We will be using the default settings in this article, but there are lots of options to secure and otherwise set up your broker which we will be covering here.

Sending messages

First, you need to set up a subscriber to listen for the messages. Without one, anything published to a topic will go nowhere.

On your Raspberry Pi with Mosquitto installed, open a terminal window and enter the following:

```
mosquitto_sub -h localhost -t "MyHouse/garage/temperature"
```

- Here, `mosquitto_sub` is one of the Mosquitto client tools you installed along with the Mosquitto server, providing a way to test the receipt of MQTT messages.
- The `-h` option identifies the hostname or IP address of the MQTT broker. Since the client tool is running on the same Raspberry Pi as the MQTT server, you can use `localhost`.
- The `-t` option identifies the topic you want to subscribe to. In this case, it is `MyHouse/garage/temperature`.

The test client will sit there and wait for a message to be sent on the topic. Leave it running and open a second terminal window and type in the following command to send a message on the chosen topic:

```
mosquitto_pub -h localhost -t "MyHouse/garage/temperature" -m "20.0"
```

- Again, the `-h` and `-t` options identify the broker and topic respectively.
- The `-m` option is the plain text message itself.

If everything has worked, you should see '20.0' appear in the subscriber client terminal.

Test again by publishing another message, this time with a different number. It should once again appear in the subscriber test client terminal.

Keep the subscriber terminal window open, as we are going to use it in the next section.

Publishing messages

Before we can program in Python, we need to install a library to add MQTT functionality to our code. We are going to use paho-mqtt. Run the following command to install the library:

```
sudo apt install python3-paho-mqtt
```

Top Tip

Topic Names

Topics can be called pretty much anything you like, but it helps to decide on a structure for when you add more devices later.

The program **mqtt_publish.py** is the minimal code you can write to send MQTT messages. Type it in and run it. You should see the number '13.2' appear in the subscriber terminal window you left running earlier.

The first line of code imports the client section of the paho-mqtt library.

The second creates a client object. 'Sender' is the client identification, and must be unique for your broker as it is used to identify that client amongst all the others that may connect.

The third line connects the client to the broker. As we are running this code on the same Raspberry Pi as the broker, we are using 'localhost'.

The last line of code publishes a message with the topic **MyHouse/garage/temperature**. Any client that has subscribed to that topic will receive that message.

Subscribing

The **mqtt_subscribe.py** program starts out the same as **mqtt_publish.py** by creating a client (with a unique identifier) and connecting it to the broker.

However, there is now a 'callback' function named `message_received`. The `client.on_message` line tells the client object which function to call when a message is received on any topics that the client subscribes to.

The `client.subscribe` line subscribes the client to a topic. You can subscribe to as many topics as you want to, handling the message within the `client.subscribe` callback function

Finally, the subscription loop is started, telling the client object to start listening for messages. The program then goes into a forever loop (or until you stop it).

Open a new terminal window and run the program. In the original window (or IDE) run the **mqtt_publish.py** program. You should now see the subscriber report that it has received a message on the topic **MyHouse/garage/temperature** with its value.

Conclusion

In this tutorial we have only just scratched the surface of MQTT, but hopefully you now understand what it is and how simple it is to use. Areas not covered include securing MQTT, formatting messages, ensuring that messages are received, using MQTT in Node-RED, and more.

If you need to send information around your network, then MQTT should be included within your armoury of go-to tools.

mqtt_publish.py

DOWNLOAD THE FULL CODE: magpi.cc/mqttgit

> Language: **Python 3**

```
001. # An Introduction to MQTT, by Tim Richardson
002.
003. # Import the paho-mqtt client library.
004. import paho.mqtt.client as mqtt
005.
006. # Create an MQTT Client - the client ID must be unique
007. client = mqtt.Client("Sender")
008.
009. # Connect the client
010. client.connect("localhost")
011.
012. # Publish a message to the MyHouse/garage/temperature topic
013. client.publish("MyHouse/garage/temperature", "13.2")
```

mqtt_subscribe.py

DOWNLOAD THE FULL CODE: magpi.cc/mqttgit

> Language: **Python 3**

```
001. # An Introduction to MQTT, by Tim Richardson
002.
003. # Import the paho-mqtt client library.
004. import paho.mqtt.client as mqtt
005. from time import sleep
006.
007. # A function to handle any messages received
008. def message_received(client, userdata, message):
009.     print("Message received on topic:", message.topic)
010.     print("Message contents:", message.payload.decode("utf-8"))
011.
012. # Create an MQTT Client - the client ID must be unique
013. client = mqtt.Client("Recipient")
014.
015. # Connect the client
016. client.connect("localhost")
017.
018. # Define the 'callback' function when a message is received.
019. client.on_message = message_received
020.
021. # Subscribe to a topic
022. client.subscribe("MyHouse/garage/temperature")
023.
024. # Start listening for a message on the subscribed topics
025. client.loop_start()
026.
027. print("Waiting for a message to be sent")
028.
029. # Wait forever
030. while True:
031.     sleep(1)
```

Part 09

Raspberry Pi mecanum robot

Create a robot which can go forwards, backwards, sideways, diagonally, and turn on the spot. The mecanum wheels allow the robot to navigate the tightest of spaces

MAKER

Stewart Watkiss

Also known as Penguin Tutor. Maker and YouTuber that loves all things Raspberry Pi and Pico. Author of *Learn Electronics with Raspberry Pi*.

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twitter.com/stewartwatkiss

Take your Raspberry Pi on the move by designing and making a wheeled robot This tutorial will explain how you can design and make your own robot. Start by designing your own chassis and mount mecanum wheels with full direction control. The robot will then need four separate motors individually controlled with a H-bridge driver for each wheel. Take control by learning how to use AntiMicroX to control the robot with a gamepad.

01 Mecanum wheels

Mecanum wheels are a type of omnidirectional wheel which can be used to move a robot vehicle in multiple directions. They are particularly good at getting into tight spaces as the wheels can propel the robot forwards and backwards as normal, but can then also move diagonally or sideways without any forward or backwards movement.

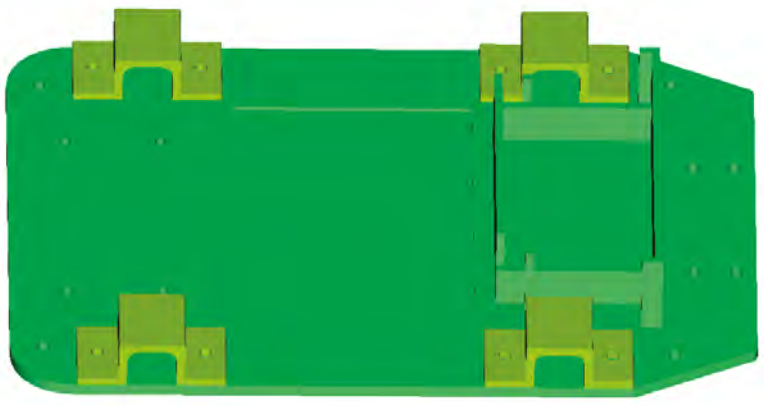


Figure 1: Robot chassis design created in FreeCAD. Includes four motor brackets which are printed separately

This is achieved by having rollers angled around the wheel. The rollers of diagonally opposite wheels need to be in the same direction. Turning the wheels in a certain combination will determine the direction. This is easiest to understand through watching the video on YouTube: **magpi.cc/mecanumrobotyt**.

02 Creating a chassis

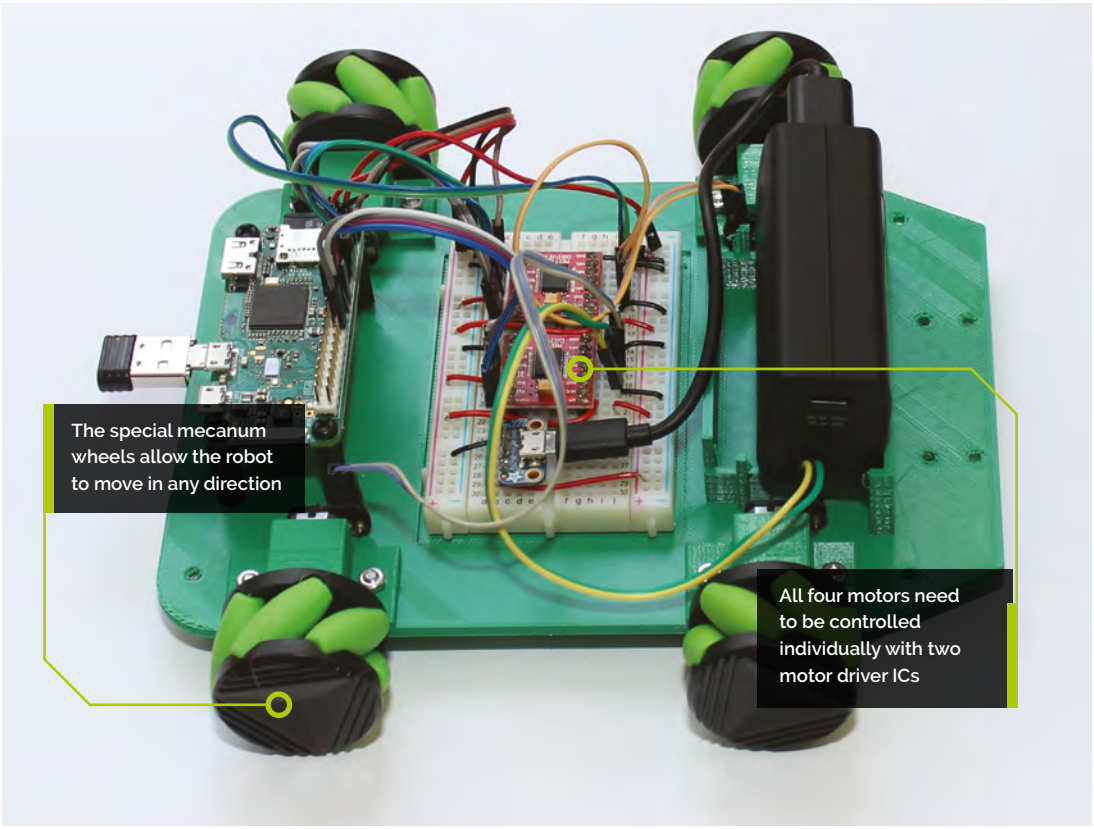
For any kind of vehicle, you will need a chassis to mount the motors and electronics. You can use any method you choose. The base should be thin enough to accommodate the size of the wheels, but otherwise most materials can be used. You could use plywood, acrylic sheet, or even thick cardboard.

If you have access to a 3D printer then you can design your own 3D-printed chassis, or use the one available at **magpi.cc/robotmecanum**. This is shown in **Figure 1**.

You will need some way of fixing the motors. Brackets are included in the 3D printer files, or you can purchase suitable brackets which are included in the component list.

03 Raspberry Pi Zero W

Whilst any model of Raspberry Pi can be used, a Raspberry Pi Zero W or a Raspberry Pi Zero 2 W are well-suited for a robot vehicle. They are small, making them easier to fit on a mobile robot, and they also have lower power requirements than some of the other models. The wireless capability is useful when programming the robot

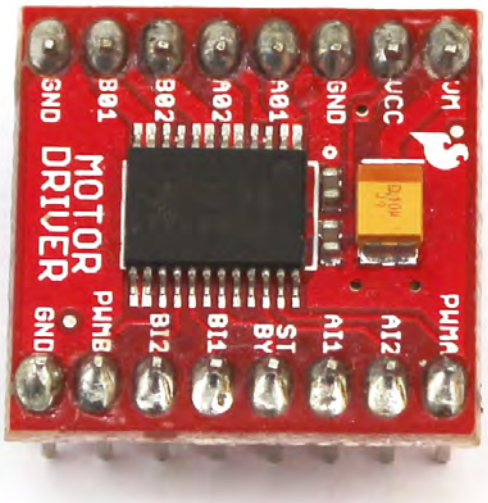


and for getting the controller working. A micro-USB to USB adapter is needed for connecting the controller. A shim adapter is also recommended.

04 Powering the robot

The motors are designed for 6V, whereas a Raspberry Pi needs a 5V power supply. In practice, you can normally use a single power supply for both your Raspberry Pi and the motors.

The different options are a 6V power supply (4 × AA batteries) or a USB power bank. The breadboard layout shows both options. Raspberry Pi is powered through GPIO 2 using a diode which protects against reverse voltage and drops the voltage slightly. If using the USB power bank and the voltage is too low, then the diode bypassed if required. In either case, power must NOT be connected to your Raspberry Pi power input socket when powered through the GPIO.



▲ **Figure 2:** The motor driver is an SMD IC soldered onto a breakout board, allowing it to be used with a breadboard

05 H-bridge motor controller

To allow the motors to go both forwards and backwards, they each need an H-bridge. A good choice is the TB6612FNG driver. This driver can handle up to 1.2A of current, and has two H-bridge circuits on a single SMD integrated circuit. To be able to use these with a breadboard, they are available on a SparkFun motor driver board. This is shown in **Figure 2**.

Along with the inputs for forwards and backwards, each H-bridge needs a PWM signal to set the speed of the motor. A single PWM output can be used from your Raspberry Pi, which will ensure that all the motors run at the same speed.

You'll Need

- 2 × TB6612FNG motor drivers **magpi.cc/TB6612FNG**
- Mecanum wheels **magpi.cc/mecanumwheels**
- 4 × geared motors **magpi.cc/gearmotor**
- Motor brackets **magpi.cc/motorbracket**
- USB power bank **magpi.cc/nanowave**
- Micro USB shim **magpi.cc/microusbshim**
- Wireless gamepad **magpi.cc/wirelessgamepad**
- Micro USB breakout board **magpi.cc/usbbreakout**

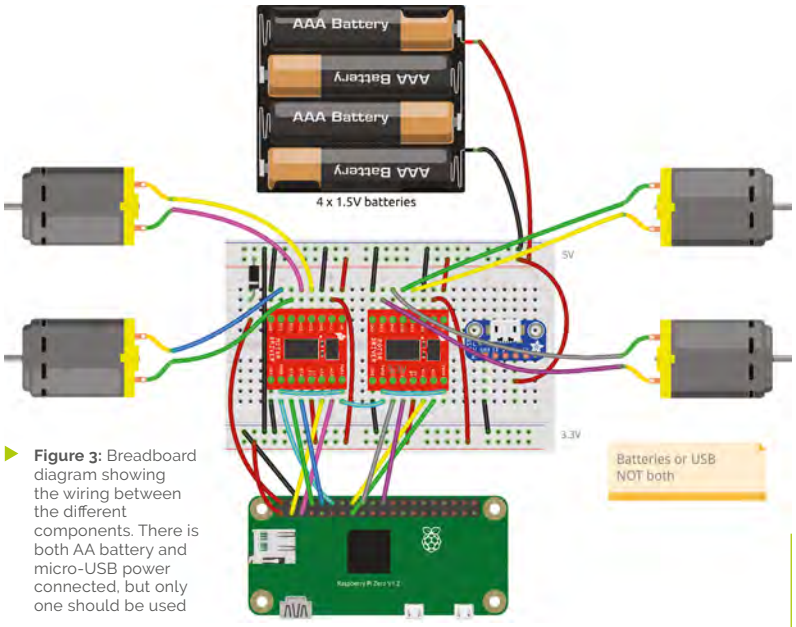


Figure 3: Breadboard diagram showing the wiring between the different components. There is both AA battery and micro-USB power connected, but only one should be used

06 Wiring up the circuit

The wiring diagram is shown in **Figure 3**. This is just a case of wiring up the motor driver inputs with appropriate pins from your Raspberry Pi. Note that the breadboard has two different power rails. The top rail is connected to the 6V or 5V supply for the motors, whereas the bottom rail is connected to the 3.3V pin on your Raspberry Pi to run the motor driver at 3.3V (so that it is at the same voltage as the GPIO pins).

A schematic diagram is shown in **Figure 4**. Note that the labels beginning with D indicate connections to the motor driver input, and M is used for the motor connections.

07 Setting up the Raspberry Pi

When setting up your Raspberry Pi, you may find it easier to enable VNC, which you can do through the Raspberry Pi Configuration tool. This will allow you to connect from another computer using a VNC client. Using VNC, you won't need to connect a keyboard or mouse, allowing the only USB port to be used for the USB dongle for the gamepad controller.

If using a game controller, then the AntiMicroX software is needed, which can be installed using:

```
sudo apt install antimicro
```

This will be configured later in the tutorial.

08 Programming motor control

The motors are controlled using GPIO Zero. There is an instance of `Motor` for each of

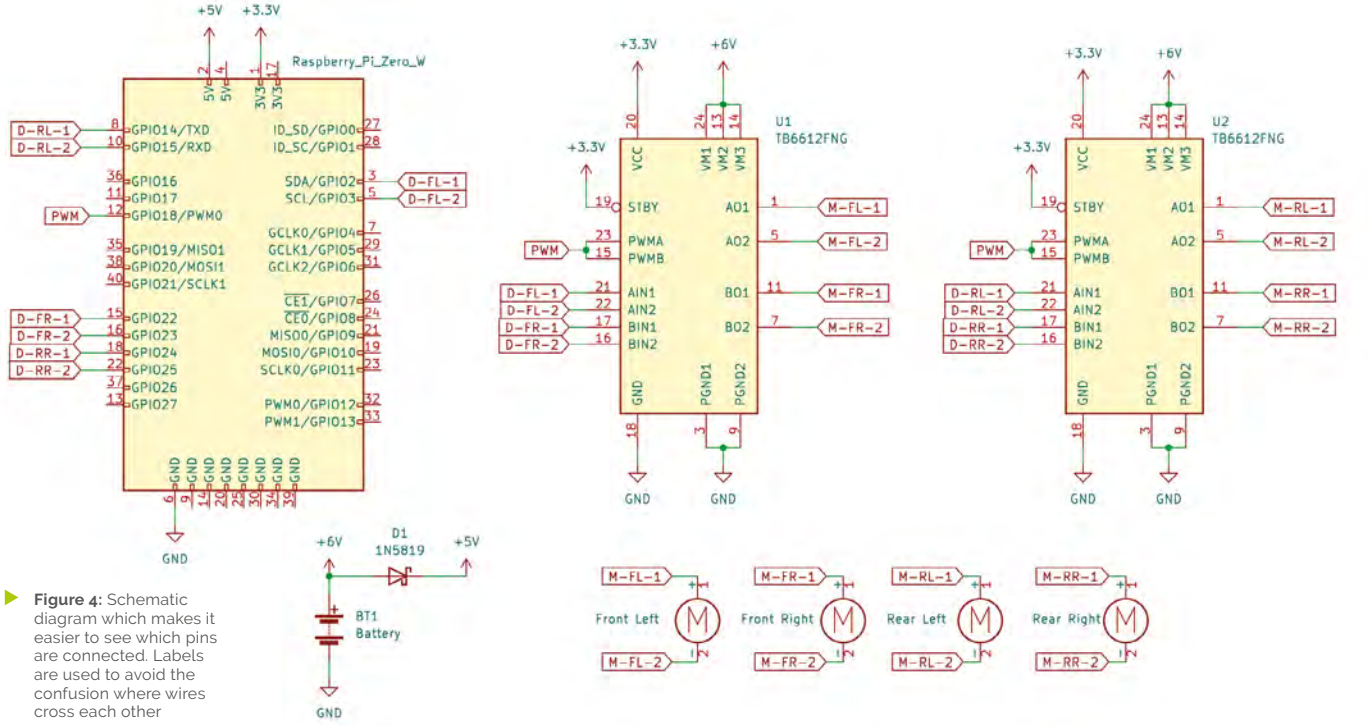


Figure 4: Schematic diagram which makes it easier to see which pins are connected. Labels are used to avoid the confusion where wires cross each other

Figure 5: A wireless USB gamepad. This is detected by Linux as an Xbox 360 controller

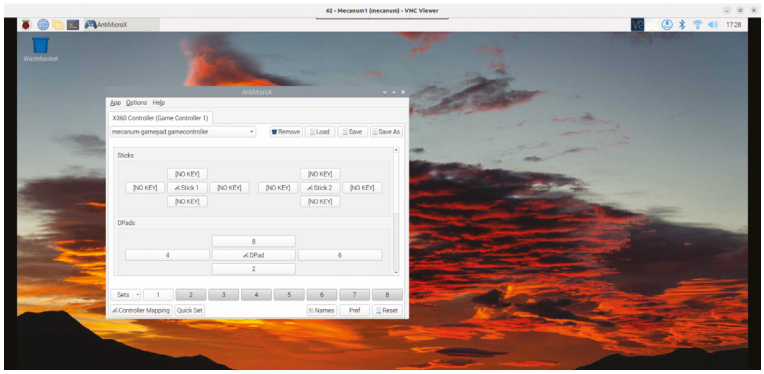
the motor drivers with a pin for forwards and reverse. There is then one more pin for the `PWMOutputDevice` which is used to control the speed of all the motors.

The dictionary `direction` holds the direction of all four motors based on the selected direction. These are `1` for the motor to go forward, `-1` for the motor to go in reverse, and `0` to stop. It does not provide speed control, which is included in the code available from the GitHub repository at **magpi.cc/mecanumrobotgit**.

09 Adding keyboard support

One thing about Python is that it doesn't directly provide a way to read input characters except when the **ENTER** key is pressed. There are various different ways around this, the one used here is a `getch()` function which provides similar functionality to the C/C++ `getch()` function. This will pause the `while` loop until a key is pressed, and then return the key into the `ch` variable.

The `direction` dictionary provides mapping between the numerical keys and the selected direction.



A wireless USB gamepad will be used, which needs to be mapped to the appropriate keys. An example gamepad is shown in **Figure 5**.

10 Using gamepad with AntiMicroX

AntiMicroX is an application which converts gamepad instructions into keyboard or similar instructions. Start AntiMicroX from the accessories menu. This will add a game controller icon to the top right of the screen. Clicking on that will allow

Figure 6: AntiMicroX converts game controller instructions to key presses. It can be configured using the GUI application, pressing the controller will highlight the appropriate button

you to map each of the buttons to the relevant keys, and this is illustrated in **Figure 6**.

You can map each button on the gamepad, or import the suggested layout which is included in the GitHub repository.

11 Troubleshooting

The gamepad must be recognised by Linux to work with AntiMicroX. Some controllers appear to work consistently, whereas others need reconnecting once or twice before they will work with AntiMicroX.

If the gamepad doesn't work after a reboot, then you may need to try disconnecting and reconnecting the USB dongle after AntiMicroX is running. Then, choosing Update Joysticks from the menu.

12 Future upgrades

The robot can be controlled using a game controller, or using a keyboard.

With some extra electronics and code, the robot can do more. There are holes included in the front of the chassis which can be used to add an ultrasonic distance sensor to detect and avoid nearby objects. Or, you could add a line sensor to allow your robot to follow a line drawn along the floor.

mecanum1.py

DOWNLOAD THE FULL CODE:
magpi.cc/mecanumpy

> Language: **Python 3**

```
001. import sys, tty, termios
002. from gpiozero import PWMOutputDevice, Motor
003.
004. motors = [
005.     Motor(2, 3, pwm=False),    #Front left
006.     Motor(22, 23, pwm=False), # Front right
007.     Motor(14, 15, pwm=False), # Rear left
008.     Motor(24, 25, pwm=False)  # Rear right
009.     ]
010. pwm_out = PWMOutputDevice (18)
011.
012. # get a character from the command line
013. def getch() :
014.     fd = sys.stdin.fileno()
015.     old_settings = termios.tcgetattr(fd)
016.     try:
017.         tty.setraw(sys.stdin.fileno())
018.         ch = sys.stdin.read(1)
019.     finally:
020.         termios.tcsetattr(
     fd, termios.TCSADRAIN, old_settings)
021.     return ch
022.
023. # list to convert key into motor on/off values to
     correspond with direction
024. direction = {
025.     # number keys
026.     '1' : (-1, 1, -1, 1),    # Turn left
027.     '2' : (-1, -1, -1, -1), # Backwards
028.     '3' : (1, -1, 1, -1),    # Turn right
028.     '4' : (-1, 1, 1, -1),    # Left
029.     '5' : (0, 0, 0, 0),      # Stop
030.     '6' : (1, -1, -1, 1),    # Right
031.     '7' : (0, 1, 1, 0),      # Diagonal left
032.     '8' : (1, 1, 1, 1),      # Forwards
033.     '9' : (1, 0, 0, 1)       # Diagonal right
034. }
035.
036. current_direction = "stop"
037. # speed is as a percentage (ie. 100 = top speed)
038. speed = 50
039. pwm_out.value = speed/100
040.
041. print ("Robot control - use number keys to
     control direction")
042. while True:
043.     # Get next key pressed
044.     ch = getch()
045.     if (ch == 'q') :                    # Quit
046.         break
047.     elif (ch in direction.keys()) :     # Change
     direction
048.         for i in range (0, 4):
049.             if direction[ch][i] == -1:
050.                 motors[i].backward()
051.             elif direction[ch][i] == 1:
052.                 motors[i].forward()
053.             else:
054.                 motors[i].stop()
055.         print ("Direction "+ch)
```

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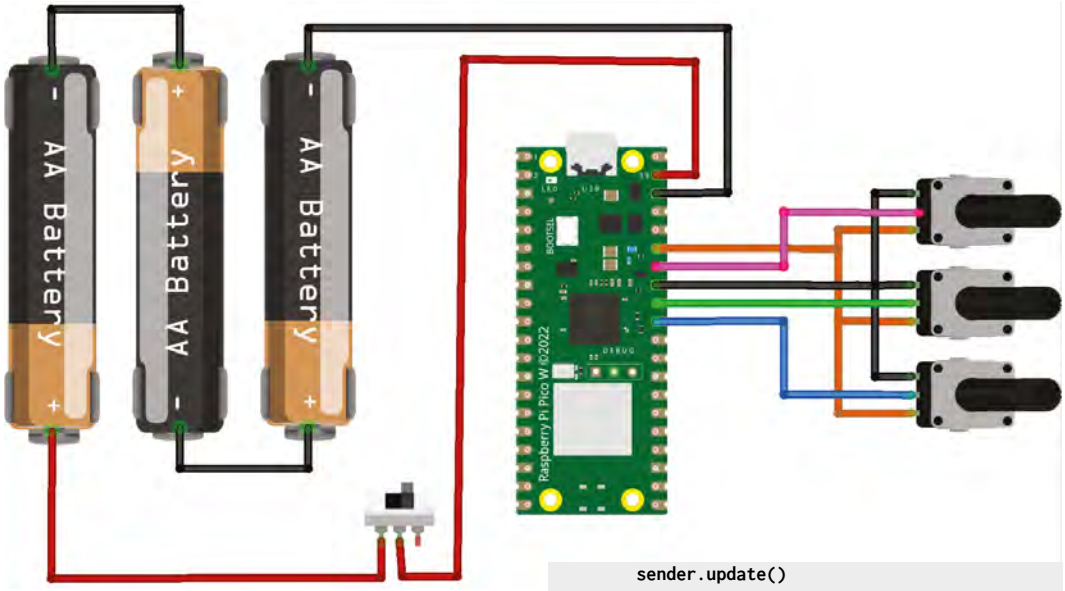
@robmiles

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**.

Recently, the author created a remote-controlled light based on an old camera flash he found for sale on a market stall. The light contains a Raspberry Pi Pico W programmed in CircuitPython that acts as a web server on a local network. The colour of the light is controlled via the web page hosted by the light. The Pico W also supports Bluetooth, and so in this project, a new version of the light is created which is controlled by a second Pico W-powered device sending Bluetooth commands. Continuing the upcycling theme of the previous article, this one uses an upcycled milkshake box as a case for the controller (**Figure 1**). You can find all the software for the light and the controller on the GitHub site for this project at this link: **hsmag.cc/Bluetooth_Flashlight**.

NO NEED TO PAIR

The Wi-Fi-controlled flashlight is configured with network credentials, and the user must visit a specific web address to connect to the flashlight controller page. The Bluetooth light and remote control use a Bluetooth addressing scheme in which there is no need to explicitly pair two devices that wish to communicate. There is no need to configure either the light or the control. However, if you wanted to use multiple lights with a single controller in the same room, things get a little trickier. You will need to use a different Bluetooth addressing scheme if you want to enable multiple



Far Left Figure 1. The light output has been reduced for the purpose of photography.

Figure 2 The remote control works well with only three alkaline batteries, as the power requirements of the device are not high

connections. However, if you just want to send data from one device to another over short distances, the method described here works very well, and it is easy to change the type and amount of data sent.

CREATING A REMOTE CONTROL

Figure 2 shows the circuit diagram for the device. The three potentiometers are connected to the analogue-to-digital converter (ADC) inputs on the Pico. The input from the ADC is scaled to produce intensity values in the range 0–255. These values are sent via Bluetooth to the light.

SENDING VALUES WITH CLASS

The Pico W in the remote control runs a MicroPython program called **ble_sender.py**, which repeatedly reads the ADC devices connected to the red, green, and blue potentiometers and sends a block of data containing the colour intensity values. If the user adjusts one of the colour settings the updated value is sent out over Bluetooth to the light. The `ble_sender` program uses a class called `BLE_sender`. This is supplied with an instance of the `ColourControls` class which interacts with the potentiometers:

```
def run():
    print("Light sender starting")
    controls = ColourControls()
    sender = BLE_sender(controls)
    while True:
        sender.update()
        time.sleep_ms(20)
```

The statements above create a `BLE_sender` instance and feed it a `ColourControls` instance that reads the control inputs. It then repeatedly calls the `update` method in the sender, which reads colour values from the control. The `ColourControls` class reads the control inputs. The code for the class is shown below.

```
class ColourControls:
   def __init__(self):
        self.red_ADC = machine.ADC(0)
        self.green_ADC = machine.ADC(1)
        self.blue_ADC = machine.ADC(2)
        self.old_red=-1
        self.old_green=-1
        self.old_blue=-1
        self.update()

    def update(self):
        self.red = round(self.red_ADC.read_
u16()/256)
        self.green = round(self.green_ADC.read_
u16()/256)
        self.blue = round(self.blue_ADC.read_
u16()/256)
        if self.red==self.old_red and self.
green==self.old_green\
            and self.blue==self.old_blue:
            return False
        self.old_red=self.red
        self.old_green=self.green
        self.old_blue=self.blue
        return True
```

YOU'LL NEED

- **A suitable box** (you can put the control into anything you fancy)
- **A Raspberry Pi Pico W** (remember to get the 'W' version as this has Wi-Fi and Bluetooth capability)
- **3 × linear 10K rotary potentiometers** Other resistance values will work as well. Make sure you get potentiometers, not rotary encoders. The potentiometers will have only three connections, whereas a rotary encoder will have four
- **A single pole single throw power switch**

QUICK TIP

Using the analogue power and ground connections on the Pico will make the analogue readings more stable.

```
    def pack(self):
        return struct.pack("<BBB", self.red,self.
green,self.blue)
```

The `__init__` method is called when an instance of `ColourControls` is created. It sets up the ADC interfaces on the Pico and sets initial values used in the class. The `update` method is called to request an update of the red, green, and blue values held inside `ColourControls` class. The class stores previous values of red, green, and blue readings and `update` returns `True` if it detects the inputs have changed. The `pack` method returns the byte values to be sent to the light. It packs the red, green, and blue intensity values into three bytes. The `BLE_sender` class calls `update` and then calls `pack` if update returns `True`.

> "You don't need to know how the BLE_sender class works **to send different kinds of information using it**"

TWO CLASSES ARE BETTER THAN ONE

You may be wondering why two classes are used, when it would be perfectly possible for a single class to do everything. This is to provide flexibility. If you want to send values from a different device (for example you might want to send values from a distance sensor) you can create your own version of the `ColourControls` class (perhaps called `DistanceControls`) to read and pack the data from the distance sensor and use this class with the `BLE_sender` class instead. You don't need to know how the `BLE_sender` class works to send different kinds of information using it. As long as the class you create contains `update` and `pack` methods (and the `update` method returns `True` if the inputs have changed) it will just work. The `BLE_sender` class itself is based on the temperature sensor example in the Pico examples you can find here: **hsmag.cc/MicroPython_Examples**.

RECEIVING LOUD AND CLEAR

Figure 3 shows the Pico from the flashlight being reprogrammed. The Pico was loaded with MicroPython, as the original Wi-Fi-controlled light uses CircuitPython. Below, you can see the MicroPython code that runs when the light starts running. The Pico W in the controller acts as a server, serving out red, green, and blue intensity values which can be used to set the intensity of a light. The program **ble_reciever.py** runs in the light to receive these values. It uses a class called `BLE_receiver` to receive data from the controller and use the data to set the colour of the light.

```
def run():
    print("Light Receiver Starting")
    pixieLight = PixieLight(0.2)
    receiver = BLE_receiver(pixieLight)
    while(True):
        receiver.update()
        time.sleep_ms(50)
```

The `run` function above implements the receiver behaviour. It creates a `BLE_receiver` instance called `receiver`. The receiver is given the device to control, in this case, an instance of the `PixieLight` class. Once the receiver has been created the `run` function repeatedly calls the `update` function of `receiver`. The `update` function creates a connection to a transmitter and then fetches blocks of data from Bluetooth which are then passed onto the `pixieLight`.

```
from machine import Pin,UART
from Pixie import Pixie
import time
import struct
```

Below
The control is set to around halfway. You can tell this because the little plastic finger over the wiper is connected to the centre of the circular track connecting the outer two contacts

POTENTIOMETERS AND ROTARY ENCODERS

There are two types of twiddly knobs you can use with microcontrollers: potentiometers and rotary encoders. The former, which we've used here, create a changing voltage as they're turned. This voltage can be read by an analogue input. They're easy to use and hold a physical memory of their position (i.e. if you power off the project, they will read the same value when you power it back on). However, they can only be turned a fixed amount. Rotary encoders emit a series of pulses as they're turned, often with a soft click as they do. You can keep on turning them forever in either direction and they'll keep on pulsing. They're great for user interfaces (scroll wheels are one type of rotary encoder).

```
class PixieLight:

    def __init__(self, brightness, txPinNo=4,
rxPinNo=5):
        uart =
UART(1,tx=Pin(txPinNo),rx=Pin(rxPinNo),
baudrate=115200)
        self.pixies = Pixie(uart, 1,
brightness=brightness)
        self.old_red=-1
        self.old_green=-1
        self.old_blue=-1
        self.pixies[0] = (0, 255, 0)

    def render(self):
        self.pixies.fill((self.red,self.green,self.
blue))

    def set_colours(self,red,green,blue):
        if red==self.old_red and green==self.old_
green\
            and blue==self.old_blue:
            return False
        self.red = red
        self.green = green
        self.blue = blue
        self.old_red=self.red
        self.old_green=self.green
        self.old_blue=self.blue
        self.render()
        return True

    def unpack(self, data):
        value = struct.unpack("<BBB", data)
        if self.set_
colours(value[0],value[1],value[2]):
            self.dump()

    def dump(self):
        print("Red:%3d Green:%3d Blue:%3d"%(self.
red,self.green,self.blue))
```

The **PixieLight** class is shown above. The receiver will get blocks of data from Bluetooth and pass them to **pixieLight** by calling the **unpack** method. The **unpack** method is supplied with a block of data which must be unpacked and then used to set a new light colour. It sets the colours of the light and, if the colours have changed, it prints the new values to the terminal.

TAKING OUT A CONTRACT

The **BLE_reciever** and **BLE_sender** classes are not aware of the content of the data they are transferring. They just move blocks of binary data from one place to another over Bluetooth. The form and meaning of the data is determined by a 'contract' between the **ColourControls** and the **PixieLight** classes. The **pack** method in **ColourControls** assembles a block of three bytes which contains the red, green, and blue intensity values selected by the user. The **unpack** method in **PixieLight** then takes these three values from an incoming block and uses them to control the colour intensities in the lights it is driving.

Both the classes need to agree on the encoding (8-bit values) and the order (red, green, blue) of the values. Any misunderstandings will result in wrong, →

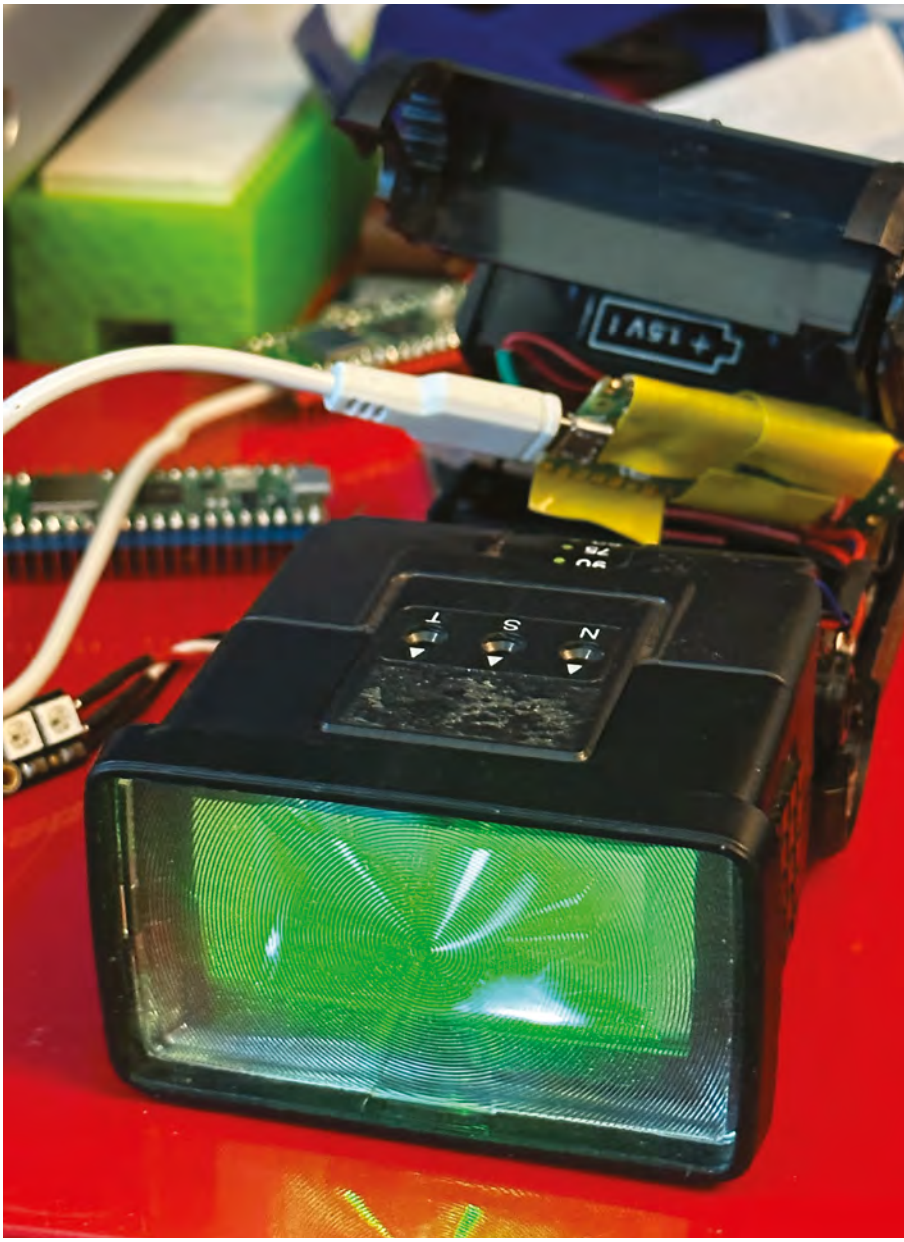


Figure 3 If the light output is not set very bright, the light software can be tested using just a USB connection for the power

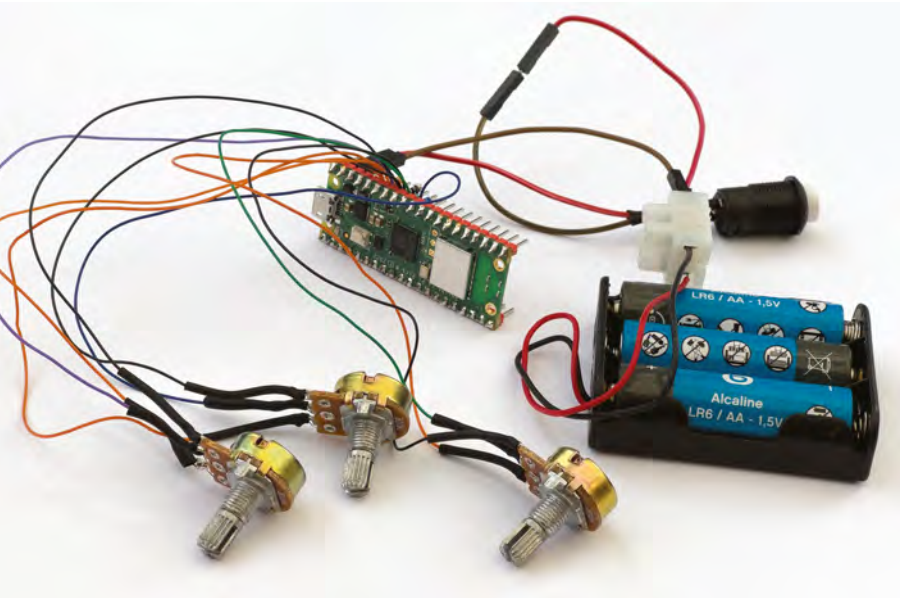


Figure 4
The potentiometer connections were wrapped around the Pico pins and then soldered to the potentiometers

or no colours being displayed. We are sending 'raw' data values like this because Bluetooth limits the size of data packets. If we were sending the data over a network connection with more capacity, we could use JSON (JavaScript Object Notation) to encode the data. JSON data includes a description of the data.

```
{
  "red_byte":0,
  "green_byte":255,
  "blue_byte":0
}
```

The JSON encoded data above could be used to send the colour bright green to a JavaScript application. The name of each value is part of the data, making it easy to understand what is being sent. However, this message contains many more bytes than the three that are used by the light. With low-capacity connections such as Bluetooth, we must make sure that both sides of the conversation agree on the data format.

If you want to use the incoming data to control a different device, you can swap **PixieLight** for a class of your own which contains an **unpack** method that acts on the data that is received from the **BLE_receiver**, but you would need to make sure that the send and receive objects agree on the form of the data being transferred.

CIRCUITPYTHON VS MICROPYTHON

The code to control the original light was written using CircuitPython. However, at the time of writing, there are no Pico W Bluetooth libraries available for CircuitPython. Bluetooth connections are presently only supported by MicroPython. CircuitPython and MicroPython are very similar; they differ mainly in the availability of different libraries for specific devices. If you are serious about becoming an experienced embedded developer, you should aim to be familiar with both implementations. The author originally chose CircuitPython because of the availability of a library for the Pixie lamp he was using. However, he was able to convert this library to MicroPython and then use MicroPython for this project.

TIME FOR AN UPDATE

Most light devices, for example NeoPixels, are easy to use. You just tell them the colour you want, and they light up with that colour until they are given a new colour value. However, the Pixie light used in the flashlight needs to be repeatedly told the colour to be displayed, otherwise it will shut down. To achieve this, we add an **update** function to the **PixieLight** class. This is called regularly by **BLE_receiver** and will refresh the colour settings on the light when required.

```
def update(self):
    millis = time.ticks_ms()
    interval = time.ticks_diff(millis, self.last_
update_ticks)
    if interval>self.update_tick_interval:
        self.render()
        self.last_update_ticks = millis
```

The **PixieLight** class contains two member values: **last_update_ticks** and **update_tick_interval**. The **last_update_ticks** value contains the time in milliseconds since the light was refreshed. The **update_tick_interval** value contains the interval between refreshes, in our case 200 milliseconds.

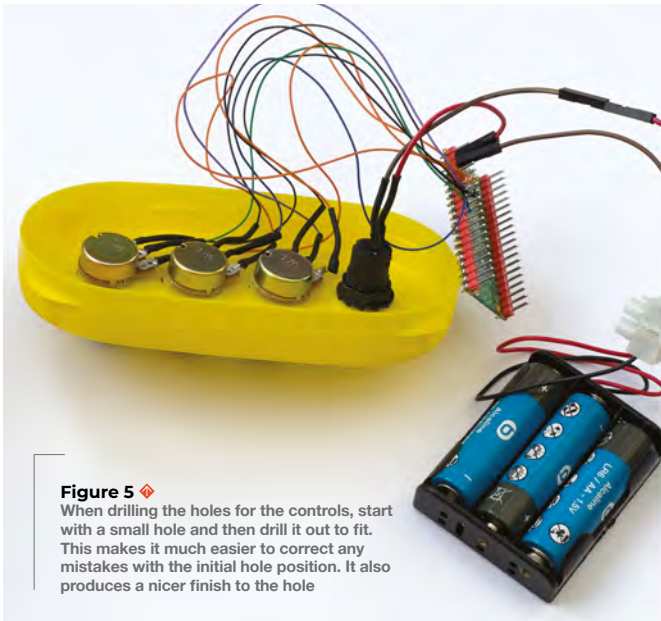


Figure 5
When drilling the holes for the controls, start with a small hole and then drill it out to fit. This makes it much easier to correct any mistakes with the initial hole position. It also produces a nicer finish to the hole

Each time `update` is called, it gets the current time and then works out how many milliseconds have elapsed since `update` was last called. If the interval is greater than `update_tick_interval`, the `render` function is called to display the lights and keep the Pixie shining.

FINAL ASSEMBLY

Figure 4 shows the wiring for the light controller. It was first built on the desk and tested before being transferred to the case. The power is controlled by a push-button which is connected in series with the battery box. Once the circuit had been tested, it was then ready to be put inside the case, which was a box of milkshake which was in no way specially purchased for this project. The author really likes strawberry milkshake.

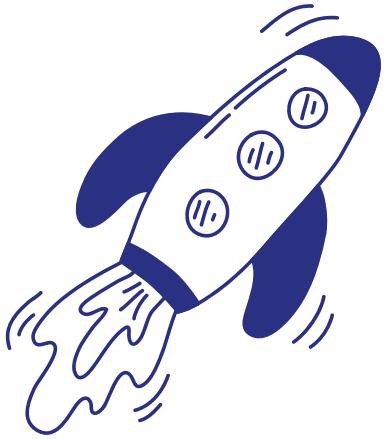
Figure 5 shows the controls fitted to the top of the milkshake box. The switch was pushed through the top of the box and then connected to the Pico and the battery. The Pico and battery holder were then secured to the inside of the box using adhesive Velcro. The resulting box looks quite pleasing (at least to the author), and the device inside works well. It would be possible (and indeed quite easy) to use the same technique to create other Bluetooth-connected devices. ◻

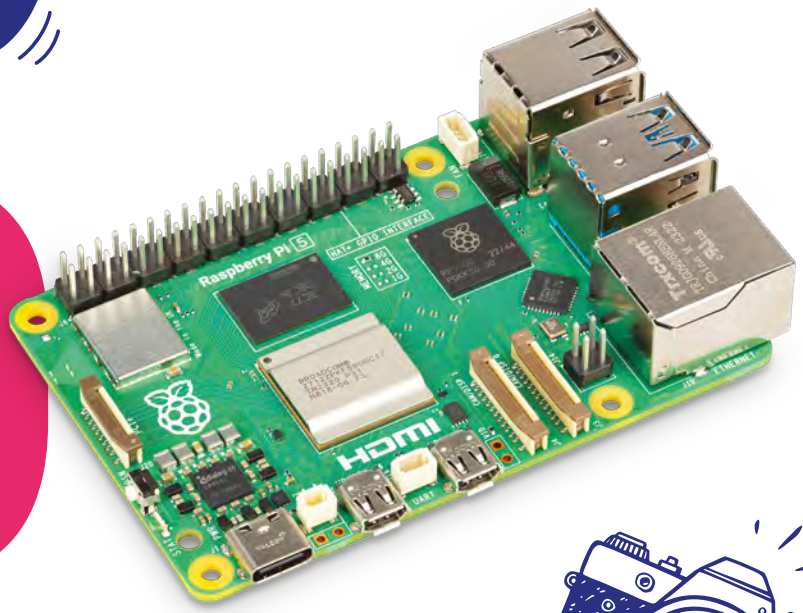
Below
Only a good idea if your device doesn't use radio communications

BOXING CLEVER

The author likes the idea of upcycling, where a project reimagines an existing product. The controller for the light is fitted inside a box that previously contained milkshake powder. Here are some tips for upcycling.

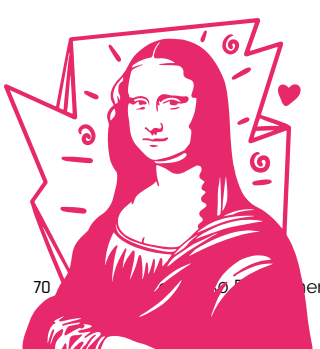
- **Don't use metal boxes for devices that contain radios.** The author's first choice of box was a tin that had previously contained mints. After a bit of thought, this was abandoned as a bad idea, but the mints were delicious.
- **Use longish connecting wires.** The author used to take great pride in how all his wires between components were exactly the right length. This, while aesthetically pleasing, did tend to make fitting the components into the box much harder and more likely to cause damage. Longer wires give a lot more leeway in case construction and can be safely tucked inside the case.
- **Don't always twist all the connecting wires together to make a wiring harness.** This sounds counter-intuitive, but it does make sense (at least to the author). If you have ten wires going to a component, you could twist them all together to make a single cable. However, because all the wires will be different lengths, this means that the weight of all the wires may end up being borne by the shortest cable connection, which will then break. If all the wires are separated, each connection will only have to support the weight of one wire. If you really do want to group cables together, make sure they are supported inside the case.
- **Construct and test your circuit outside the case.** It is very hard to check connections once you have put them in a box. Create the entire circuit and test it first. Then put it in the box.
- **Use heat-shrink tubing to cover connections and make sure that connections have physical integrity.** If you are soldering a wire to a terminal, make sure to hook the wire through a hole to give the connection physical strength, and then use solder to hold the wire in place and provide the electrical connection. Then cover the whole thing with heat-shrink tubing. This makes everything look a lot tidier and means that loose wires won't cause problems. This is particularly important if you are using a metal case, as it prevents signals shorting.
- **Use connectors with components that fit into the case from the outside.** Some components, for example, some switches and lights, are fitted from the outside of the case and then secured internally. In the light control, the push-button power switch is fitted into the case from the outside, and so it is connected using push-fit connectors rather than being connected directly.
- **Don't stick components into your case using a permanent adhesive.** The author is a big fan of self-adhesive Velcro, which can be used to hold processors and batteries in place. The components are held firmly, but they can be removed if required.

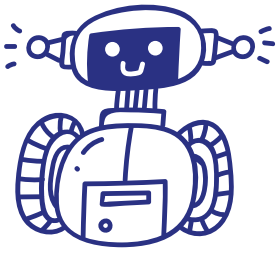




50 Phenomenal Raspberry Pi Projects

Get clued in about Raspberry Pi projects worth pursuing with your guide Rosie Hattersley





The uses for Raspberry Pi are endless – and, now Raspberry Pi 5 is here, you're all doubtless looking forward to your next build.

Here is a selection of amazing projects using all Raspberry Pi computers. We've categorised this selection, drawn mainly from the past year's issues, by theme from space and scientific sensing and investigation to photography, music and art, AI, robots, and retro.

Whether you've just taken delivery of a shiny new Raspberry Pi 5 or are using a Pico or Raspberry Pi 400, there's plenty of project inspiration to be found in the following pages, almost all of it created by makers, tinkerers and readers of *The MagPi* magazine!

Check out these examples, and don't forget to show us your own creative versions on Threads, Facebook, Instagram, or Mastodon, tagging #MagPiMonday.

Retro gaming & computing

1 Pico Pocket Gamer

magpi.cc/pocketgamer

A straightforward strategy is at the heart of this great Pico-based game, for which maker Grgo Mariani created a custom circuit board (but stresses that this bit is optional) and added a 320×240-pixel display and five simple switches. We love this project's achievable simplicity.

2 NB100 Cyberdeck

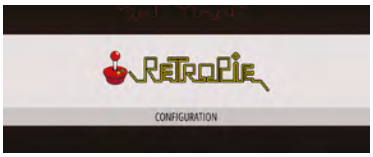
magpi.cc/nb100

Upcycling old tech using Raspberry Pi is marvellous fun, as this repurposing of an Amstrad A4 notepad with a split keyboard and 8.8-inch widescreen display shows. Retaining nothing but the 1980s case, it's now a fully functioning Cyberdeck computer with 2020s processing chops.

3 RetroPie gaming

retropie.org.uk

RetroPie provides a simple, software-based way of getting to enjoy old favourites on any version of Raspberry Pi you choose, with or without a classic console case. Half the fun is repurposing an old console or customising a biscuit tin to house your brand-new gaming device.



4 Retro Gaming with Raspberry Pi

magpi.cc/retrogaming

Our very own guide to old-school gaming, complete with project ideas and amazing builds to emulate.

5 Lunchbox Arcade

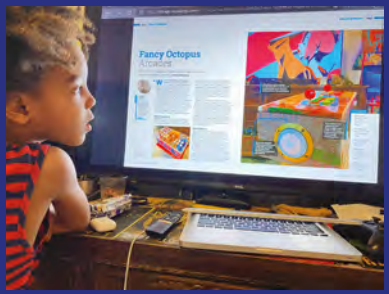
magpi.cc/lunchboxarcade

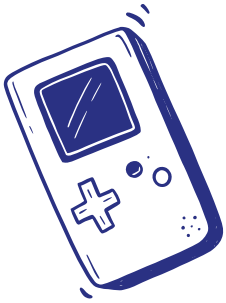
Tin lunchboxes are nostalgic in their own right. They're also ideal for adding speakers and decals for your own mini arcade.

6 Fancy Octopus Arcades

magpi.cc/octopusarcades

New Yorker Shonee Strother's amazing custom-built RetroPie arcades are co-designed by his six-year-old son and packed with incredible detail.

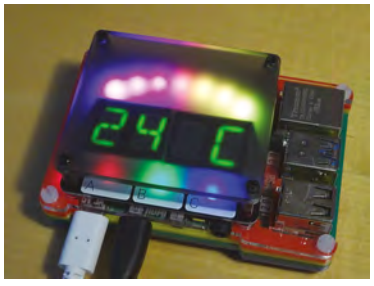




7 Raspberry Radio

magpi.cc/121

A detailed tutorial in *The MagPi* magazine issue 121 explains how to put together a Raspberry Pi Pico Radio with stations and podcasts tailored to your own interests and musical tastes. The Display-O-Tron LED screen will even show news headlines – or you can have them read aloud.



8 Clamshell BlackBerry Cyberdeck

magpi.cc/diycyberdeck

Combining an iconic early smartphone keyboard with the gorgeous HyperPixel 4.0 display via the incredibly useful GPIO pins of a Raspberry Pi 4, the BlackBerry Cyberdeck provides powerful computing power in a pocket-sized form. The icing on the cake is maker Michael's beautifully designed and laser-cut plywood case.

9 Team Pinball

magpi.cc/teampinball

Pinball wizardry has also been fascinating, for the intricate table designs as much as the flipper-based play. Wales is home to the UK's only pinball factory, where it's a labour of Raspberry Pi CM3-based love for its designer-maker team. Their retro game, The Mafia, "brings the player back to Chicago and the 1930s Prohibition Era with gangsters, casinos, and of course, a bank to rob!"

10 Mini PC

magpi.cc/minipc

This miniature PC started out as a Bluetooth speaker. Seeing its resemblance to a small desktop computer, owner Carter made the vision a reality with the aid of Raspberry Pi 3B, a BlackBerry keyboard, and some 3D printing. It runs Raspberry Pi OS and could be replicated using Raspberry Pi Zero.

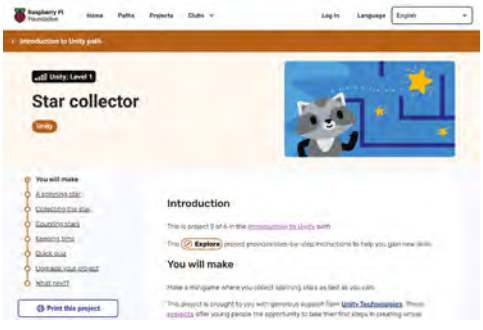
Retro gaming & computing

> "Upcycling old tech using Raspberry Pi is marvellous fun"

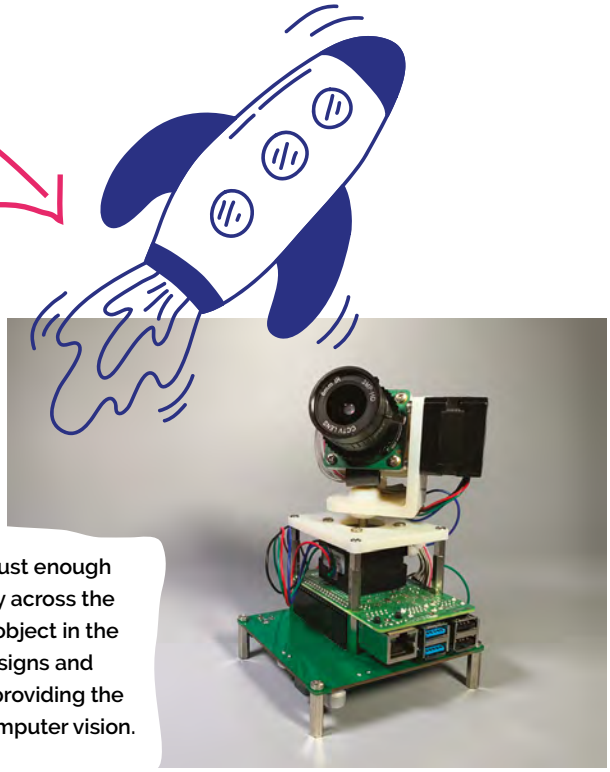
11 Unity 3D

magpi.cc/unityintro

With guidance on how to create characters and your own 3D adventure game, Unity 3D offers lots of Raspberry Pi-based coding fun and an alternative to the better-known Python, C, and Scratch. Kids will respond to the bright visuals and the chance to create their own worlds, collecting experience badges along the way.



Space Projects



12 Heavy Pan Tilt System

magpi.cc/heavypan

Astrophotographers often find it hard to create a setup robust enough to take a hefty digital SLR camera and have it pan smoothly across the night sky without it juddering, or losing either focus or the object in the viewfinder. Maker Vito put together his own mechanical designs and software to automate object tracking, with Raspberry Pi 4 providing the critical stepper motor controls and OpenCV libraries for computer vision. See the incredible results at magpi.cc/vigasanyt.

13 EPIC Satellite

magpi.cc/epicsatellite

NASA shares daily photos from its Deep Space Climate Observatory including its EPIC (Earth Polychromatic Imaging Camera) which is trained on the sunlit side of the Earth. This gorgeous project by Matt Gray shows off these visual treats wonderfully on a HyperPixel Round Touch Display, having pulled them into view using NASA's Blue Marble API and Raspberry Pi Zero W.

14 Mini Mars Rover

magpi.cc/minimarsrover

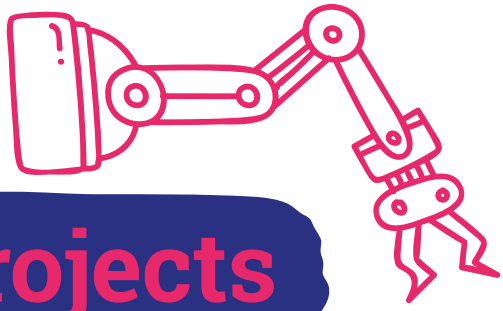
Lightweight but durable materials and a simple design that others can easily replicate were the principles behind this wonderful Pico W-based Mars rover, inspired by a workshop at Belgium's CubeSat Summer School. Maker Nikodem designed everything in CAD himself, then 3D-printed it and set up the MicroPython code to control his mini marvel.

15 Astro Pi Challenge

astropi.org

While on the International Space Station, astronauts undertake experiments on Raspberry Pi computers devised by dozens of groups as part of the annual Astro Pi challenge. Read about teenagers' attempts to measure variations in the strength of magnetic north, climate change in inaccessible locations, and much more.

Young people aged 19 and under can enter Astro Pi and Mars Mission between now and the end of the year. Entry packs will be sent out to schools, code clubs and groups of friends, regardless of where in the world you live.



Robotic Projects

16 Chip Bipedal Robot Companion

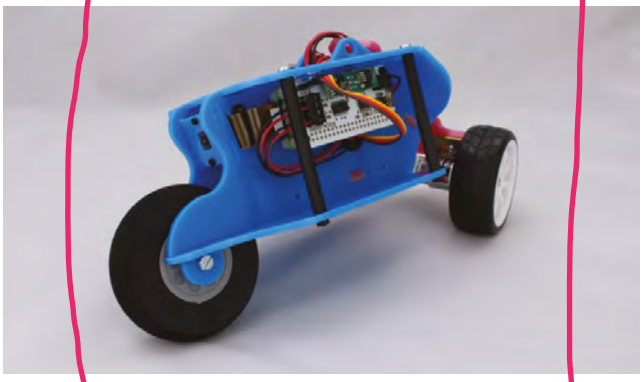
magpi.cc/chipbiped

Having a chip on your shoulder is not usually indicative of Zen-like happiness, but accomplished robot builder Kevin McAleer (kevsrobots.com) is more than content with his "cute interactive humanoid pal." The shoulder-percher has a Raspberry Pi RP2040 board inside in the form of a Pimoroni Servo 2040, chosen for its 18 servo sockets, and senses the world through an ultrasonic range finder.

17 RockyBorg

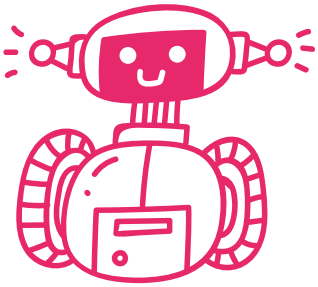
magpi.cc/rockyborg

PiBorg's RockyBorg is an enduring favourite at Raspberry Pi Towers. The three-wheeler corners like a dream and is capable of magnificent speeds. Two 180 rpm motors on the rear provide forward momentum, while a servo tilts the robot's body of the robot to change direction. This £99 kit just needs a Raspberry Pi and HQ Camera to complete.



18 K-9

magpi.cc/k9



True Whovians will approve of the fact that maker/tinkerer Fitz used whatever he had to hand when creating The Doctor's famous companion and adapting the schematic shared by other fans: magpi.cc/k9pdf. K-9 features various mechanisms to defend himself, but also uses AI to sense friends nearby – at which point, the camera in his head takes a quick snap that K-9 prints out through his mouth and presents to his new buddy.

AI Projects

19 ClippyGPT

magpi.cc/clippygpt

Microsoft's annoying Windows assistant gets a seemingly sentient makeover with this Raspberry Pi 3B+ character that uses Adafruit's Cricket HAT to connect up various servos, motors and solenoids to create a chirpy Clippy who chats back.

20 Love Machine & Olga

magpi.cc/lovemachine

Among the most endearing Raspberry Pi projects we've covered recently are two by Will Lahrs and his creative team at Kakapo Labs. First, they designed the smooth-talking Love Machine which uses AI and ChatGPT to connect with passers-by and engage them in flattering WhatsApp banter. They then went on to create Olga The Fortune Teller who shares much of the original project's Pico W-enabled interaction and prints out fortunes on a Zebra thermal printer.

Photography Projects

21 Photon DIY Incident Meter

magpi.cc/photonlight

Good photographs need good lighting as well as an interesting subject and framing. This Pico-based light meter, coded by our friends at Veeb.ch, using MicroPython helps you get the balance right.

22 Digital Toy Camera

magpi.cc/digitaltoycam

Despite declaring digital sensors "a pain," maker Volzo designed a camera that uses the 5 MP Raspberry Pi Camera Module V1 lens and Raspberry Pi Zero to capture Lomographic photos that are far more interesting, and quirky, than those you get with a boringly efficient smartphone.

23 Instant Photo Printer

magpi.cc/cameraprojects

You can easily print out your best snaps using a thermal printer housed in a cardboard box. Use any Raspberry Pi and add large push-buttons to initiate the print process.

24 POP 360-Degree Camera

magpi.cc/popcamera

A virtual reality camera in a Flip video camera-sized form, this CM4-based VR videocam is impressively straightforward to use. Although the visuals are blockier than we'd like, it's another example of Raspberry Pi pushing technological barriers.

Science Projects

25 Raspberry Pi Pico Advanced Kit

magpi.cc/picoadvkit

Pico owners will get hours of enjoyment from the excellent £29 box of electronics, all aimed at extending the way you use your low-cost Raspberry Pi using sensors, lights, and buzzers. There are 32 projects detailed and the kit even includes elements to get you started making robots!

26 Wire loop game

magpi.cc/wireloop

Making use of the Scratch visual coding interface, this fun buzzer game takes you through creating circuits with lights, jumpers, and sounds. It will even display a scoreboard to encourage healthy competition.

27 CamJam EduKit

magpi.cc/edukit3

This enduringly popular £6 kit contains everything you need to get stuck into electronics and devising your own science projects with Raspberry Pi. It literally contains bells and whistles (well, buzzers and lights) along with jumper leads, breadboards, and clips.

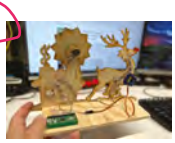
28 Open-source Gamma Spectrometer

magpi.cc/gammaspec

This Pico-based radiation detector is smaller and cheaper than a standard Geiger counter. Sensitive enough to detect even low levels of gamma radiation, it uses spectrometry to determine the composition of a radioactive material and its approximate age.

29 Rudolph The Red Nose Reindeer

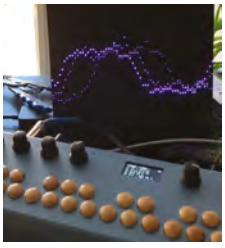
magpi.cc/rudolph



Rob was charmed by this workshop aimed at getting newbies into programming, while assembling a plywood Rudolph complete with flashing red nose, a leg that moves, and enough festive lights and a star to keep even our resident Christmas obsessive happy.

30 Ohsillyscope

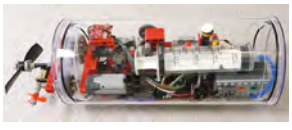
magpi.cc/ohsillyscope



Musician Thomas created a Raspberry Pi oscilloscope with an LED matrix to show the waveforms created by his electric guitar. Marvellous and suitably OTT!

31 LEGO Submarine 4.0

magpi.cc/legosub4



Propellers provide buoyancy and motion in this stunning submersible. An air compressor adjusts the water displacement and a piston ballast governs the sub's gravitational heft.

Sensing & Monitoring

32 Raspberry Shake

raspberryshake.org

Raspberry Shake provides an ideal kit for monitoring earth tremors both natural and man-made. You can see real-time seismic activity from volcanoes, thunderstorms, and tsunamis, but also log vibrations from lorries rumbling down your street or the crowd excitedly enjoying a jam-packed gig.

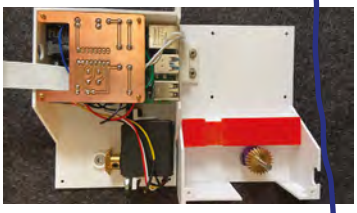
33 Flight Tracker With Weather

magpi.cc/flightweather

Inspired by a simpler aircraft tracker on Reddit, maker Adam Paulson came up with one that also provides localised weather forecasts. The three-day forecast is shown on a rather lovely 64×32 RGB matrix display, thanks to an Adafruit Bonnet, while data comes from the FlightTracker API and everything is managed by Raspberry Pi 3B+.

34 AuraLock Automatic Door Opener

magpi.cc/auralockdoor



Face recognition provides hands-free home access (good news if you're laden with groceries) with the help of Raspberry Pi 4 and camera, lock mechanism, and an Android phone. The mechanised wooden latch manoeuvres the deadbolt – no annoying PIN or fiddly keys are needed.

35 Home automation

magpi.cc/129

We covered all manner of home automation options back in issue 129, highlighting how easily Raspberry Pi integrates with the likes of Apple's HomeKit to control lights, robot vacuums, heating, and more. Download the issue to get started with voice assistants and smart sensors.

36 Bugg.xyz

magpi.cc/ecosystemmonitoring

We've covered lots of Raspberry Pi-based wildlife camera setups in *The MagPi*. Bugg.xyz is used in forests from Norway to Borneo to listen in and establish ecosystem health according to the soundscape. You can conduct your own experiments using Raspberry Pi, an HQ Camera, and some simple garden tools by following Bugg founder Sarab's instructions (linked above).

> "You can conduct your own experiments"

37 Pico Plant Waterer

magpi.cc/plantwaterer

Give your houseplants some loving care without having to bother your neighbours or kids to keep an eye on them. Simple moisture sensors either sprinkle your plants – or not – depending on whether the soil has dried out. Neat!

38 Night Clock

magpi.cc/sensehatnightclock

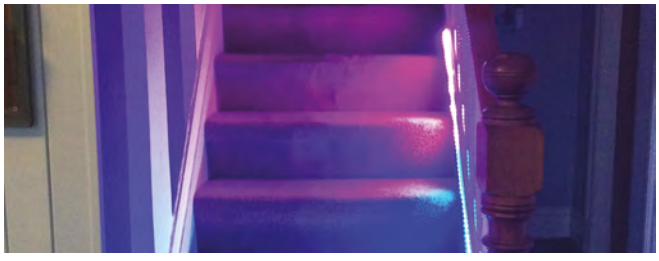
The Sense HAT is capable of all kinds of computing capers, but lends itself especially well to projects where you want to be able to get the gist of something without really trying. Lorna Jane's Night Clock Sense HAT coloured grid shows you whether it's night or day, so you can immediately decide whether to get up.

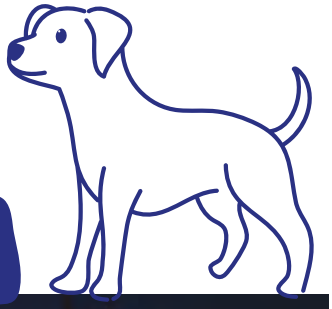
Sensing & Monitoring

39 NeoPixel Stairlights

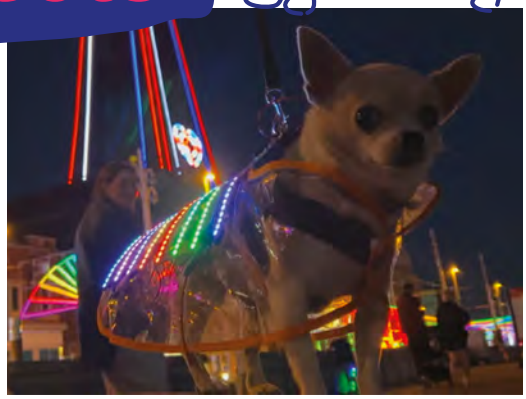
magpi.cc/neopixelstairs

The rainbow staircase in Lorraine Underwood's project sets off the lights particularly well, but it's actually temperature sensing that triggers them. A perennial *The MagPi* favourite project, it works with any Raspberry Pi alongside Adafruit's NeoPixels to create a giant visual thermometer.





Fashionable Projects



40 Disco Diva Dog Jacket

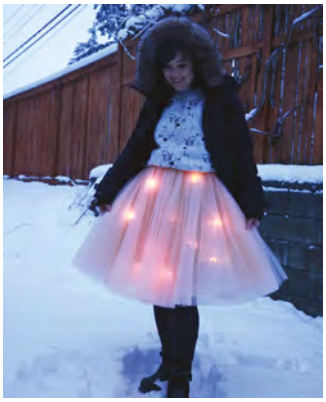
magpi.cc/cyberdogsaddle

Robot maker Kevin McAleer kitted out his beloved dogs with light-up jackets using NeoPixels, then headed to Blackpool for a celebratory promenade. This innovative dog coat is not just about style; it's about ensuring the safety of his pets during night-time walks. Kevin's creation uses a Raspberry Pi to control the LED patterns, making the coat functional and fashionable.

41 Wearable Tech

magpi.cc/wearabletech

Queen of wearable tech Sophie Wong put together this book for us featuring fantastic makes such as helmets, hoodies, and apparel – all featuring electronic elements. NeoPixels, individual LEDs, and a discreet power pack, along with a microcontroller such as Raspberry Pi Pico to add any clever time triggers are all you need.



42 Mona Lisa Fluid Painting

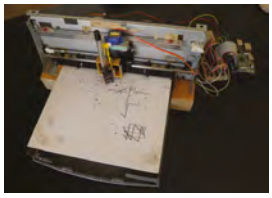
magpi.cc/monalisafluid

Showcasing the potential of fluorescent fluid in medical applications, this mesmerising liquid painting on a tiny chip was captured in all its miniature glory by a Raspberry Pi HQ Camera.

43 CNC Plotter

magpi.cc/cncplotter

Fascinated by how plotters work, maker Stratos Botsaris set about using an old scanner and printer and some G-code text files extracted via Python to create detailed A4 drawings. The Raspberry Pi-controlled device reads the text-based instructions and tells the stepper motors how to execute them.



44 Raspberry Pi Beret

magpi.cc/raspberrypiberet

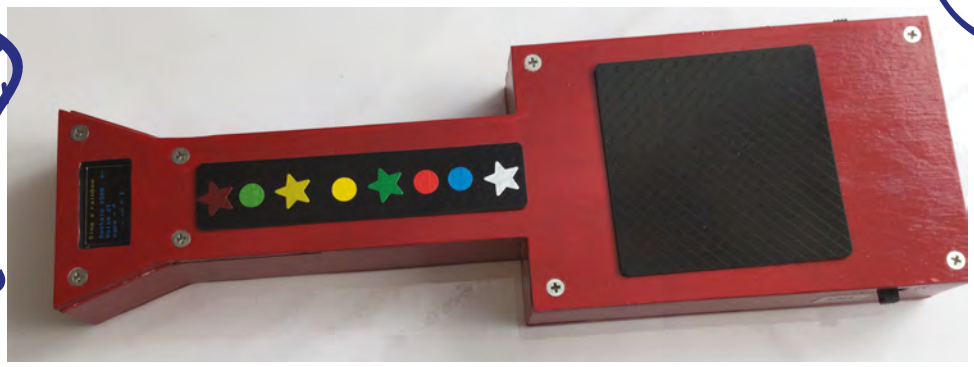
A Raspberry Beret was an early example of Pi-based wearable tech. The princely project has had a new Pi (power generation) update and gained a new audience of admirers on TikTok. A Pico W, addressable LED lights, and the effortless chic that wearing a beret conveys create an instant classic.

Music & Media Projects

45 Lo-Fi Orchestra

magpi.cc/makesound

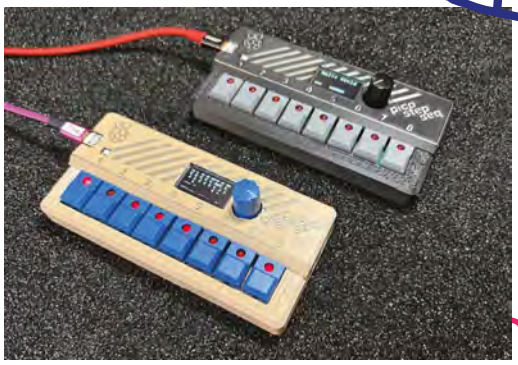
The 'Make sound with Pico' article is well worth a look if you need some ideas of what you might make. Included alongside the DIY Trill guitar (magpi.cc/trillguitar) is the Lo-Fi Orchestra, in which multiple instruments controlled by Arduino and Raspberry Pi boards feature.



46 PaperPi V3

magpi.cc/paperv3

The restful Waveshare e-ink display of this understated media player makes it a classy addition to your home décor. "Ideally, the screen would be easy to read from across the room, look great, but also fade into the room," says maker Aaron, who uses it to show off phases of the moon, as well as photos, and occasionally plugs in a HiFiBerry DAC.



47 PicoStepSeq

magpi.cc/picostepseq

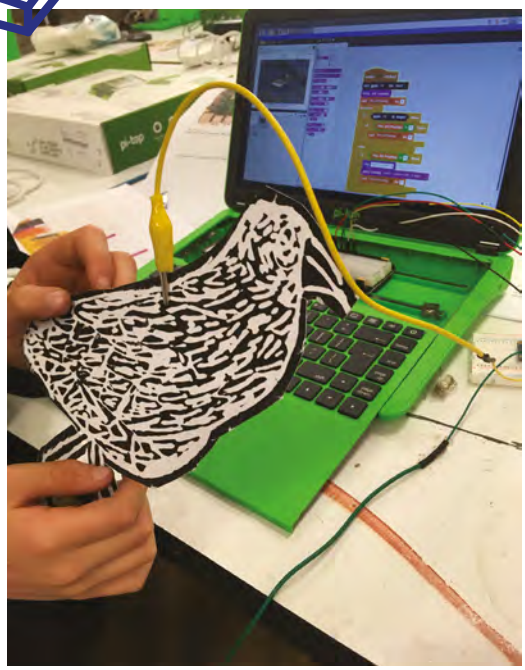
Taking advantage of the RP2040's GPIO pins, pulse-width modulation, and movable UARTs, Tod Kurt used step switches (lever switches with LEDs) to create a sequencer reminiscent of an 1980s classic synth. A super, geeky Pi project.

> “Extending the possibilities of Braille literacy for blind and partially-sighted users is no mean feat”

48 The Lost Sounds Project

magpi.cc/thelostsounds

We really like the low-tech approach to this project in which bird silhouettes emit their corresponding bird sound when the electrical circuit is complete. The Raspberry Pi-based project only costs a few pounds to replicate, and is perfect for getting citizen scientists to notice their surroundings and show off their findings.



49 Magic Mirror

magpi.cc/mirrorguide

Voted the number one greatest use of Raspberry Pi way back in issue 50 of *The MagPi*, a magic mirror is still one of the most popular, not least because you can choose or create different frame options and it can easily be customised with info feeds, as well as blending in wonderfully with your décor. Follow PJ Evans's tutorial to create your own magic mirror your own way. This LCD Chalkboard version is a really great example (magpi.cc/lcdchalkboard).

50 Bristol Braille Canute 360

magpi.cc/bristolbraille

Extending the possibilities of Braille literacy for blind and partially sighted users is no mean feat: community interest organisation Bristol Braille took eight years and a dozen iterations to bring the world's first multi-line Braille reader into being. This Raspberry Pi Zero-based device and its Raspberry Pi 400-based sibling, the Canute Console, hugely extend reading options and digital library access.

ClipZin

▶ EDAC ▶ **magpi.cc/clipzin** ▶ £4 (pack of two)

An easier way to connect Raspberry Pi Pico to PCBs.

By **Phil King**

SPECS

FEATURES:
Gold flash-plated contacts, surface-mount connectors, board retention clips

DIMENSIONS:
57 × 26 × 6 mm

Aimed mainly at breakout/carrier board manufacturers, along with advanced electronics hobbyists, ClipZin is a new way to connect a Raspberry Pi Pico to a PCB.

Ever wondered why Pico has those castellated (bumpy) edges alongside the two strips of 20 GPIO pin holes? You can use these castellations – actually gold-plated half-holes – instead of the usual pins to connect Pico to other electronics. This kind of card-edge technology has long been used in computer design.

While you could always just solder Pico's castellations directly onto metal contact pads on the surface of another PCB, ClipZin has the advantage of being able to clip the board in and out at any point – ideal for when you're prototyping a design or want to later replace a standard Pico board with a Pico W.

Clip in, clip out

In practice, we found it extremely easy to clip a Pico onto a sample PCB fitted with a pair of surface mounted, 20-way ClipZin connectors. Just push Pico down and it clicks securely into place, held by individual springy pins that maintain a good connection with each castellation. Small plastic retention clips on either end also help to keep it in place.

> "Just push Pico down and it clicks securely into place"

Removing Pico from the ClipZin connectors is as simple as gently pulling one of the retention clips and lifting the board out.

While a little more expensive than the alternative of using FlexyPins (**magpi.cc/flexypins**), ClipZin connectors benefit from being all-in-one (coming in 6-, 8-, 17-, and 20-way versions), making them far less fiddly to solder onto a PCB.

▶ Pico clicks neatly and securely into place between two 20-way ClipZin connectors

▼ The connectors' springy pins maintain a reliable connection with Pico's castellations

Verdict

Should prove handy for Pico-based PCB prototyping and could also be used in final products.

8/10

CM4 XGO-Lite Robot Dog Kit

▶ Elecfreaks ▶ **magpi.cc/cm4xgo** ▶ £469 / $599

A Compute Module 4-powered robot dog with five limbs and a huge amount of potential. **Rob Zwetsloot** takes it for a walk

SPECS

SIZE:
250 mm × 145 mm × 170 mm while standing, 620g

LIMBS:
Four walking limbs and one gripper allowing for 15 degrees of movement, and three on the arm

PROGRAMMING LANGUAGES:
Blockly, Python, ROS

BATTERY:
2500 mAh lithium ion battery with 120 minute life

We've seen a small explosion of dog-like robot kits over the past few years, although we cannot put a finger on what might have started it. Perhaps the cuteness of a four-legged pet is hard to resist when you can program it yourself, which brings us to the very powerful XGO line of robot kits.

Unlike a lot of a robot kits, this one has metal construction throughout, making it chunky and weighty in the satisfying way quality technology can be. It also comes all pre-assembled so you won't be bending any metal plates or doing any complicated wiring to get it working, like with other legged robots.

Smart dog

At its core is a powerful Compute Module 4, controlling the robot and allowing for reprogramming with custom code over a web browser – although you can also plug it into a monitor (or go a VNC route) if you want and program it the old-fashioned way. There are several bits of example code that illustrate the impressive features of the robot, such as facial recognition with the inbuilt camera, remote control, and more. There's a full breakdown of the Python commands on the quite detailed documentation over at **magpi.cc/xgodocs**, and it even has a block code editor for people not quite up to speed on Python.

It's definitely a very well put together product, although it's not the most stable looking robot we've ever seen. The price is also a little eyewatering, but we think the tech inside justifies it, especially if you're looking for a more advanced bit of kit.

> "There are several bits of example code that illustrate the impressive features of the robot, such as facial recognition"

▼ The box comes with some coloured balls that you can program XGO to pick up

Verdict

A very impressive robot kit that while fine for beginners may be better suited to those already into robotics due to the price

9/10

Learn circuits with Raspberry Pi

Start building electronic circuits with the help of these resources. By **Phil King**

CamJam EduKit

AUTHOR

CamJam

Price:
From £6

magpi.cc/camjamkits

Raspberry Pi's 40-pin GPIO header is its 'superpower', enabling you to connect not only HATs and other breakout boards, but also your own custom electronic circuits.

If you're looking for a low-cost way to learn how to begin building circuits, you can't go wrong with the CamJam EduKit series. The first of these, EduKit #1, has everything (bar a Raspberry Pi) you need to get started: a 400-point breadboard, three LEDs (red, yellow, green), push-button, buzzer, resistors, and a selection of jumper wires to connect components to each other on the breadboard and to Raspberry Pi's pins.

Best of all, online worksheets guide you through a series of electronics projects, coding them with Python on Raspberry Pi. Once you've mastered the basics of circuits, you might well want to explore adding sensors (including temperature, light, and IR) with EduKit #2, and/or build a simple two-wheeled robot with EduKit #3.

Get kitted out

Start building circuits with these electronics kits

RASPBERRY PI ULTIMATE KIT

CanaKit's electronics kit lives up to its name and also includes a Raspberry Pi 4, 3+ or 3 and quick-start guide. A full-size breadboard is complemented by an interface to extend Raspberry Pi's GPIO pins.

▶ magpi.cc/canakitultimate

MONK MAKES PROJECT BOX 1

This kit includes LEDs, a thermistor, phototransistor, switches, and handy GPIO pin identifier overlay – everything you need to get started with the projects detailed in a 46-page downloadable PDF guide.

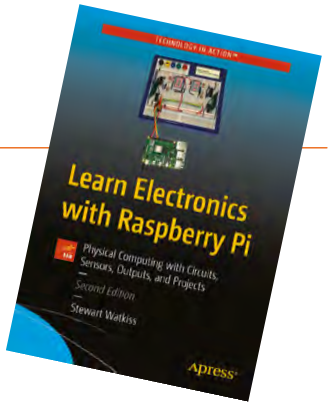
▶ magpi.cc/projectbox1

WAVESHARE SENSORS KIT

Enable your Raspberry Pi to sense the world around it with this selection of 13 sensors – as used in our Sensory World tutorial series (issues 111 to 114) – including gas, moisture, and tilt.

▶ magpi.cc/wavesensors

Learn Electronics with Raspberry Pi



AUTHOR

Stewart Watkiss

Price:
£40

magpi.cc/learnelectronicsbook

You may recognise author Stewart Watkiss from the series of electronics tutorials he's written for *The MagPi*, starting in issue 127 and covering everything from the basics to creating a Pong game and controlling a model railway.

His book, *Learn Electronics with Raspberry Pi*, guides you step-by-step through the creation of a variety of electronics and hardware projects using a Raspberry Pi. These include mastering input and output from the GPIO pins, programming in Python, and reading light and PIR sensors.

Of particular interest is the chapter on making your circuits more permanent by soldering components to stripboard or protoboard. The final chapter looks at designing your own custom circuits – using the Fritzing tool (**fritzing.org**) to create schematics which you could even turn into a PCB (printed circuit board).

Wokwi

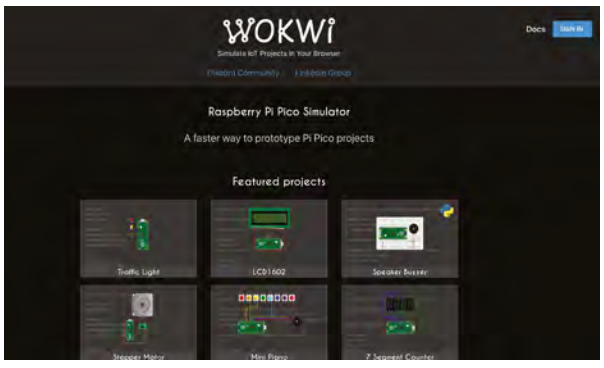
AUTHOR

CodeMagic

Price:
Free

wokwi.com

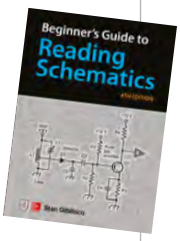
Sometimes you may want to test out a circuit design before you go ahead and build it, which is where a circuit simulator comes in handy. There are several available online, but Wokwi is free and simple to use. It covers Raspberry Pi Pico among other microcontrollers and there's a variety of examples and shared user projects to try out, along with starter templates for Pico.



In the Simulation window on the right, you can add all sorts of electronic components – including sensors and motors/servos – and wire them up (with or without a breadboard) to Pico's pins. The left-hand window is used to code your project, in MicroPython or C/C++; just run it to see if it works correctly. If so, you can download the project code to use on Pico for real.

Recommended reading

Books to help you learn more about circuits



BEGINNER'S GUIDE TO READING SCHEMATICS

A proper schematic diagram offers a much clearer, high-precision view of circuit designs, once you understand the symbols used. Stan Gibilisco's book explains how to read schematics and design your own for projects.

▶ magpi.cc/readschematics

RASPBERRY PI COOKBOOK 4TH EDITION

Simon Monk's 650-page tome is an all-round Raspberry Pi user and programming guide that includes several chapters dedicated to connecting electronics such as LEDs, push-buttons, and sensors.

▶ magpi.cc/rpicookbook4

GET STARTED WITH MICROPYTHON ON RASPBERRY PI PICO

This official Raspberry Pi Pico guide book features step-by-step guides on building a range of circuits and programming them in MicroPython on the powerful microcontroller board.

▶ magpi.cc/picobook

Nai-Wen Hsu

Taiwanese Raspberry Pi reseller and Raspberry Pi community organiser, you can't miss Nai-Wen in the Taiwanese maker space

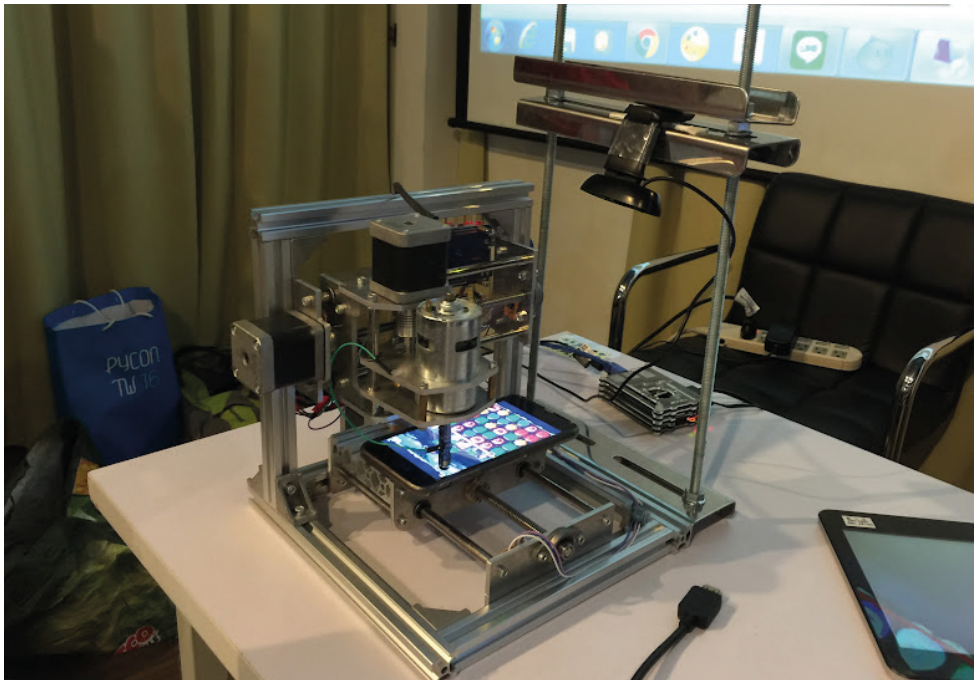
> Name Nai-Wen Hsu | > Occupation Raspberry Pi reseller
> Community role Advocate | > URL piepie.com.tw

While the Raspberry Pi community spreads across the globe, each country has its own unique community with its own events and ideas. Taiwan is no different, with the founder of the Taiwan Raspberry Pi Community also an Approved Reseller of Raspberry Pi.

"My job is to promote and sell Raspberry Pi, provide Raspberry Pi–based solutions, and design Raspberry Pi educational courses," Nai-Wen tells us.

What is your history with making?

I studied manufacturing technology and computer engineering in college and graduate school respectively, so I am familiar with program development and processing of various materials such as metal, wood, and acrylic.



▼ Excellent projects are shown off at the meetups – we wonder if this one can beat captcha

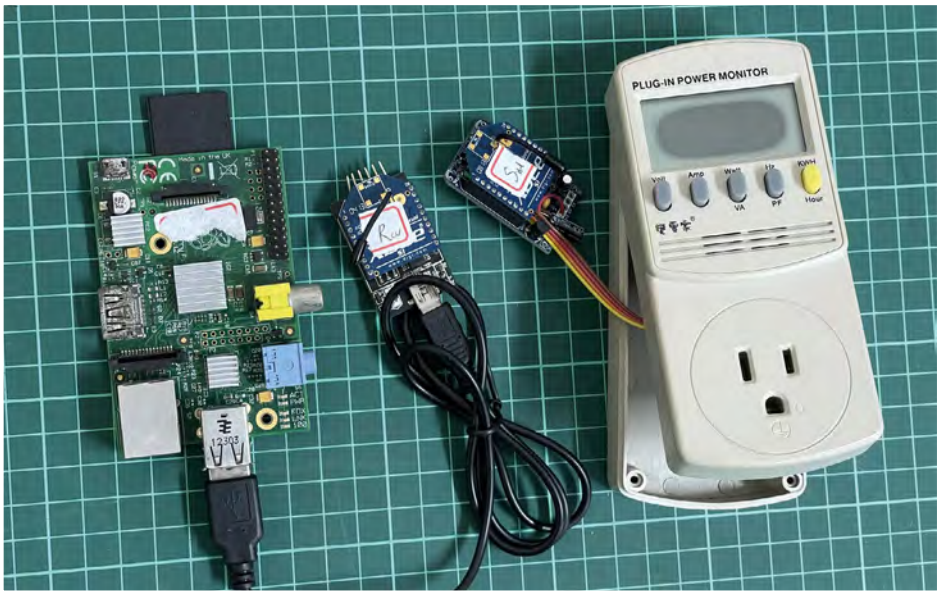
Since coming into contact with Arduino in 2009, I have been using MCU and SBC combined with mechanical structures to solve problems in small projects.

When and where did you learn about Raspberry Pi?

In July 2012, I was looking for a small computer for a power-saving project and bought a Raspberry Pi 1 Model B. The first one was 256MB. The goal of the project, at that time, was to monitor the flow of people and adjust the air-conditioning settings according to the people present to achieve energy saving.

What is it like to be a maker in Taiwan?

Because the land in Taiwan is relatively small, most makers also solve small problems. If makers in Taiwan want to be influential, they can first establish a small community for promotion. If the government finds it suitable and adopts it, it will have more influence. For example, the PiM25 air pollution detection box I cooperated with Academia SINICA has more than 4000 monitoring points, and can be drawn into an air pollution map to assist government decision-making.



This energy-saving project was one of Nai-Wen's first Raspberry Pi projects

ThermalPi is used around Taiwan to check temperatures of people so COVID can be detected

> I started a meetup and established a community in 2013 to promote Raspberry Pi

In addition to promoting PiM25 AirBox in Taiwan, I also go to other countries to share related experiences [such as Hong Kong].

How did the meetups start?
I started a meetup and established a community in 2013 to promote Raspberry Pi [and it exists to this day].

At that time, people were very interested in what the Raspberry Pi could do, so I hosted a meetup every one-to-two months, each with a different topic, such as GPIO, cameras, robots, IoT, mass production manufacturing, etc. I invited friends who use Raspberry Pi for projects to share their experiences. My own code name in the community is 'sosorry', and I share different technologies at almost every meetup.

What is your favourite thing you've made with Raspberry Pi?
ThermalPi is my favourite project. ThermalPi is a solution I designed to detect human body temperature for COVID-19. It features the use of an RGB camera and a Thermal Camera, and can accurately detect various objects after dual-camera calibration. It is widely used in schools and government agencies, and some companies have adopted it and mass-produced it into products.

I also shared the technical details of the ThermalPi project at PyCon Taiwan 2020, including the principles of thermal imaging cameras, how to use Raspberry Pi to read, dual camera calibration and temperature measurement applications, etc.

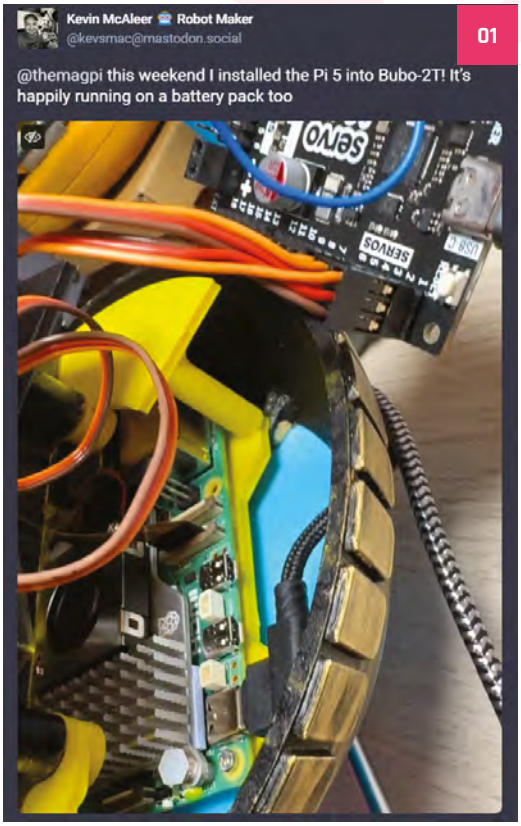
A big turn out for the Taiwanese Raspberry Pi community

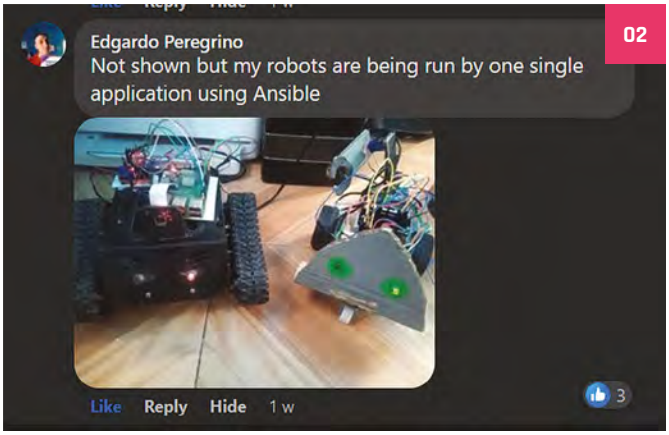
MagPi Monday

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. Remember to follow along at the hashtag #MagPiMonday!

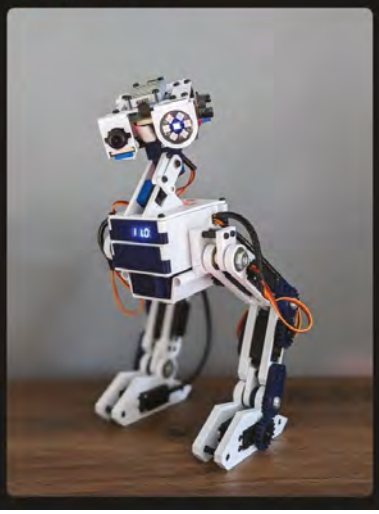




01. Raspberry Pi 5 robotics has begun and it's not even out yet
02. A robot-heavy month, we love to see all these automatons
03. A very cool robot, it reminds us of the one in Jedi Survivor
04. Raspberry Pi Pico is still a great controller for robots
05. If you're getting interrupted during video calls, a little notifier can be a lifesaver
06. A camera that specifically reads QR codes is a great idea – perhaps an NFC alternative?
07. We're calling this a rave in the box. Who has a Ministry of Sound CD?
08. Do, Re, Egon, let's light 'em up

03

dan.makes.things
I've been building this guy!
raspberrypi.com/news...



04

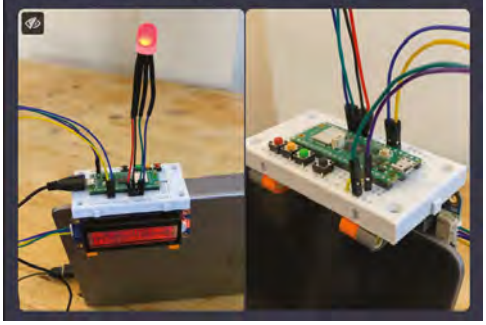
johnlblue 1 w
First Robotics Competition team Pike RoboDevils 1018 picked up several Experiential Robotics Platform kits (XRP) that have a Pico W - see experientialrobotics.org

We are using them to help students get started programming robots on a simple platform before diving into the National Instruments roboRIO ni.com/en-us...

05

Pater Practicus
@paterpracticus@mastodon.world

@themagpi #VISI (Video-call Interruptibility Status Indicator) prototype now has a #lego mount for attaching to laptop screen. The #raspberrypi Pico is powered by USB cable from the MacBook. #MagPiMonday on #mastodon

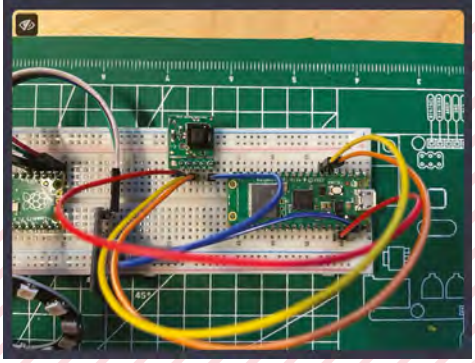


06

Roland
@r_schulz_maker@mastodon.social

@themagpi Hello #MagPiMonday, I know I'm late. But I was still waiting for Monday on the dark side (former Twitter). I'm currently playing around with my Tiny Useful Sensor and @Raspberry_Pi pico. A small camera sensor that can read QR codes.

Translate



07

Top fan
Jason Brett
This is a prototype of an audio project my students will build this fall. It uses an XY-P40W Bluetooth audio receiver with a 40W Class D amplifier, and filters the Class D signal to get a classic analog audio signal. It uses an op amp and RC filters to... See more

Like Reply Hide 2 w

08

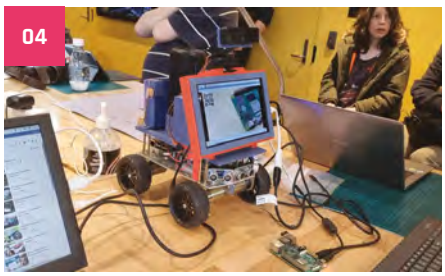
Jonathan Pittock
Yes, electronics for a Ghostbusters proton pack for Halloween

Events in pictures: Experiencing Raspberry Pi 5 at the Melbourne Raspberry Pi Makers Meetup

Community and official events in the wild

We showed some images from the Melbourne Meetup last month but, this time, the meetup was a bit more special, allowing people to experience Raspberry Pi 5 before it was even out! You can find out other events with a Raspberry Pi 5 on our events calendar over on page 94.

01. There were still room for other projects, like this Raspberry Pi Zero robot
02. Free swag of excellent magazines always goes down well
03. It's a Raspberry Pi 5 in the wild!
04. This robot is not powered by Raspberry Pi 5 in the traditional sense



Best of the rest!

Other cool things we saw using Raspberry Pi this month

Lockdown handheld project

Peter Anderton, who made the Gutter Probe project you can find on page 26, also sent us this handheld Raspberry Pi project he'd made. It was apparently a challenge he set for himself during Lockdown in 2020, and it looks pretty good.

Mini nineties PC

Is nineties nostalgia here? Has it been and gone? We're not sure, but this fun project styled after a classic late-1990s package PC is very small and employs Raspberry Pi. Although it does run Windows XP, which is a bit advanced for your Gateway.

▶ **magpi.cc/mini90spc**

Your Letters

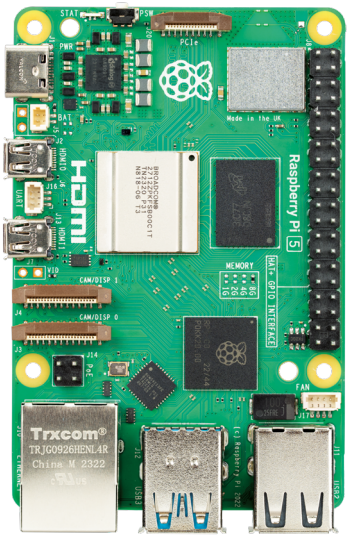
Raspberry Pi 5 projects

I'm very excited by the news of Raspberry Pi 5 coming out, and really looking forward to getting mine. My mind is abuzz with ideas but I was wondering if you'd be able to propose any projects that make use of the new features?

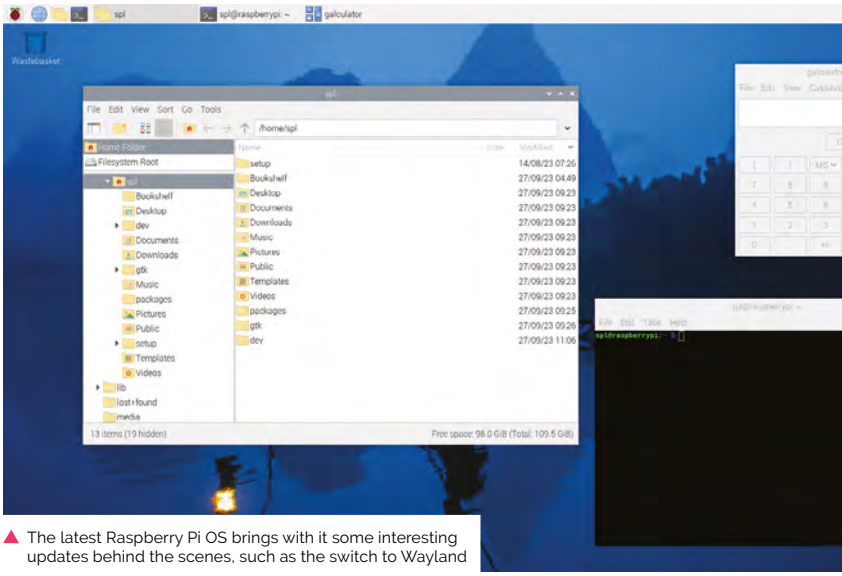
Chuck via email

We're as excited as you are, and we also have a load of project ideas in mind – check out this month's features for some excellent ideas on where to get started! Features Ed Rob is really looking forward to checking out VR movie filming with Raspberry Pi, a project Ben Everard, Editor of HackSpace Magazine, is currently working on too.

If anyone has any project ideas, or complete projects they want to share with us, don't hesitate to drop us a line.



▶ By the time you read this, Raspberry Pi 5 will already be out



▲ The latest Raspberry Pi OS brings with it some interesting updates behind the scenes, such as the switch to Wayland

Booking Bookworm

I read about the upgrade to Debian 12 ("bookworm") for Raspberry Pi OS in your latest issue. I went over to the Raspberry Pi website to download it but could not see it. Is it not out yet?

Cole via Mastodon

The date for Raspberry Pi OS Bookworm slipped a little to the week after *The MagPi* 134 came out but, as you read this, it is out now! It's also the version that you should be using for Raspberry Pi 5 when you get one, and 64-bit is included on Imager as well.

Priority boarding now

How does Priority Boarding work? What kind of subscription do you need, and will I get the code now or with my first issue?

Nicole via Threads

You can get a Priority Boarding code – a code to pre-order Raspberry Pi 5 and be one of the first to get one – by subscribing to the print edition of the magazine. Within a few days, you'll get a code which can be used on Approved Reseller sites. Get more info at **magpi.cc/priorityboarding.**

Raspberry Pi 5

PRIORITY BOARDING

We've reserved Raspberry Pi 5 boards *for The MagPi subscribers*

GET YOUR RASPBERRY PI 5 ***FIRST!***

magpi.cc/priorityboarding

▲ We're very excited to offer these codes to print subscribers!

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. Raspberry Pi Club @ Makespace Cambridge - Experience Raspberry Pi 5!

- Tuesday 31 October
- **Makespace Cambridge, Cambridge, UK**
- **magpi.cc/rpc135**

Tuesday nights in the Makespace Classroom are Raspberry Pi, Microcontroller, and CAD Clubs meet-ups. Come and join fellow coding and computer aided design enthusiasts for an informal evening of tinkering with tech. Help is on hand to assist you with any problems.

02. Pi Fawkes at HackWimbledon Experience Raspberry Pi 5!

- Sunday 5 November
- **Wimbletech, London, UK**
- **magpi.cc/fawkes135**

It's a very special HackWimbledon. We meet and make every fortnight, but Pi Fawkes Night (well, afternoon really) will be a festival of Raspberry Pi 5s on November 5th. If you want to get a look at a Raspberry Pi 5 in the flesh, or if you want to hear how it's going, come along. If you're getting a Raspberry Pi 5, come and tell how you're finding yours.

03. Melbourne Raspberry Pi Meetup

- Sunday 5 November
- **Docklands Makerspace and Library, Melbourne, Australia**
- **magpi.cc/mrpm135**

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

04. Cape Town Raspberry Pi Jam Experience Raspberry Pi 5!

- Saturday 2 December
- **CTV Training Centre, Cape Town, South Africa**
- **magpi.cc/ctrpj135**

Cape Town's first Jam since lockdown! Learn about the new Raspberry Pi 5 and more.

FULL CALENDAR

Get a full list of upcoming community events here:

magpi.cc/events

Where can you find Raspberry Pi next?

- Next location Maker Faire Shenzhen
- Where Vanke Design Commune, Shenzhen, China
- When Saturday 11 November to Sunday 12 November

Raspberry Pi is proud to partner with Raspberry Pi Approved Reseller Seeed Studio, to be at Maker Faire Shenzhen for the first time ever. Come and meet members of the Raspberry Pi team, learn about their latest products, and share what you've made with Raspberry Pi technology.

magpi.cc/smf23

WIN ONE OF TEN RASPBERRY PI 5 CASES

With a new Raspberry Pi comes a new and improved case - the official Raspberry Pi 5 case has improved airflow and a fan to help keep the insides nice and cool. We have ten to give away.

Head here to enter: magpi.cc/win | Learn more: magpi.cc/rpi5case

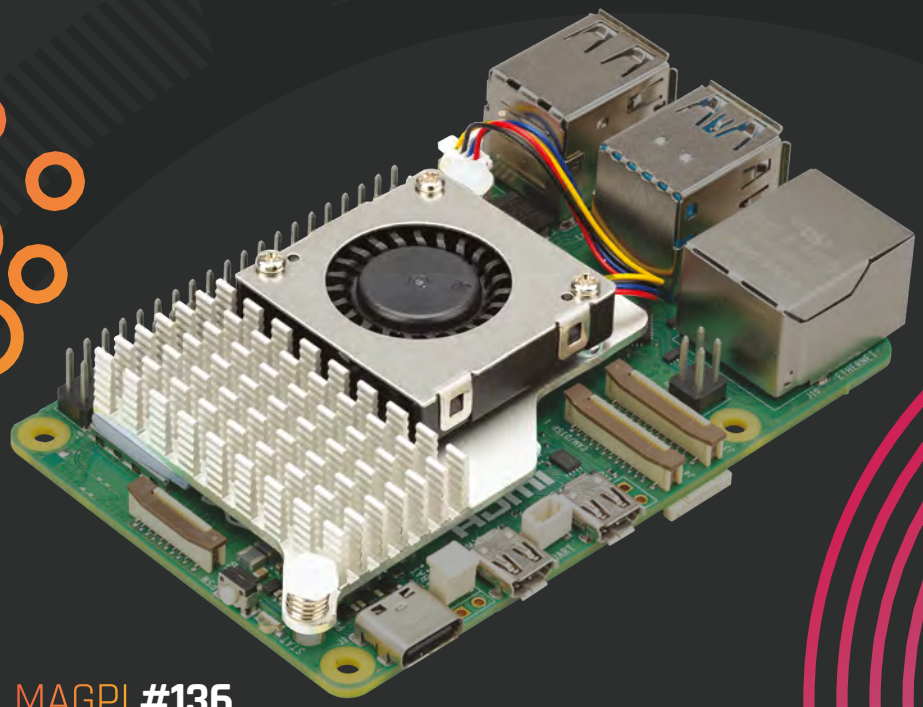
Terms & Conditions

Competition opens on **25 October 2023** and closes on **23 November 2023**. 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.

Raspberry Pi 5

BENCHMARKS & THERMAL TESTING

Take Raspberry Pi to its full potential with our benchmarks, testing and thermal control



THE MAGPI **#136**
ON SALE **23 NOVEMBER**

Plus!

Holiday buyer's guide

Raspberry Pi OS Bookworm

Remote control with TigerVNC

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Raspberry Pi PRESS

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Number 5 is **alive!**

Now what will we all make with it?

By Lucy Hattersley

Watching Raspberry Pi 5 come to life was an incredible process. From hearing about the initial designs, to seeing the problem-solving, and hearing clever solutions proposed by the incredible design team.

On our part, there was the stress of making sure everything was ready for launch. And the fear of being the one to accidentally leak it and ruin the surprise for everyone. It's been a real eye-opener.

It's not really real until this point though. When it launches and gets into the hands of our readers, and they start to build stuff with it: that's when Raspberry Pi 5 becomes a real product.

So, what are we all to do with this super-fast, packed-with-new-features, and ringing and singing full of bells-and-whistles new computer?

Where to start?

Like many new Raspberry Pi 5 owners, my first port of call was Raspberry Pi OS Bookworm (**magpi.cc/downloads**). This is now available for download and offers a vast increase in speed. I've also been testing out the advances in retro gaming (expect a big feature on this soon). Early reports suggest a big leap forward for console support along the lines of the PlayStation and GameCube era. Cloud Gaming from Games Pass is also an incredible experience (and a whole lot cheaper than buying an Xbox Series X).

We're also busy looking at the dual camera support and stereographic photography for 3D images. And,

> Machine learning is another area where we're very keen to see what advantages the new, much faster CPU offers

we've mooted the idea of using two small screens for creating a virtual reality option (although this is very much in the ideas stage).

Machine learning is another area where we're very keen to see what advantages the new, much faster CPU offers. We're waiting on an update to TensorFlow Lite to get things working, and are going to be all over image recognition projects.

We're also waiting on the M.2 drive, at which point we will be turning Raspberry Pi 5 into a server. So, there's lots to talk about in the coming months!

Over to you!

That's just the start! What we're really looking forward to is what you all make with Raspberry Pi 5. Our readers always surprise us with the incredible things they make with Raspberry Pi products. Whether it's live-action RGB lighting in a pole dancing club, automatic weeding machines for Japanese gardens, retro equipment repairs, or monitoring animals in the wild: the uses for Raspberry Pi are wildly varied.

I was reminded of this while reading through our Handbook 2024 (available now: **magpi.cc/handbook**). This collects all the best community projects, tutorials, and kits from the last year. It's a tour-de-force of the best *The MagPi* readership has to offer - which is an incredible amount of variety and cleverness.

I really can't wait to see what you all make with Raspberry Pi 5. Here's to 2024, and another year of Raspberry Pi-goodness.

AUTHOR

Lucy Hattersley

Lucy is editor of *The MagPi* and is currently putting this issue to press with an 8BitDo controller in her inbox, which is ready and waiting for a Raspberry Pi 5 retro gaming weekend.

magpi.raspberrypi.com

HiPi.io

HIGHPI PRO

The new case from the HiPi.io team

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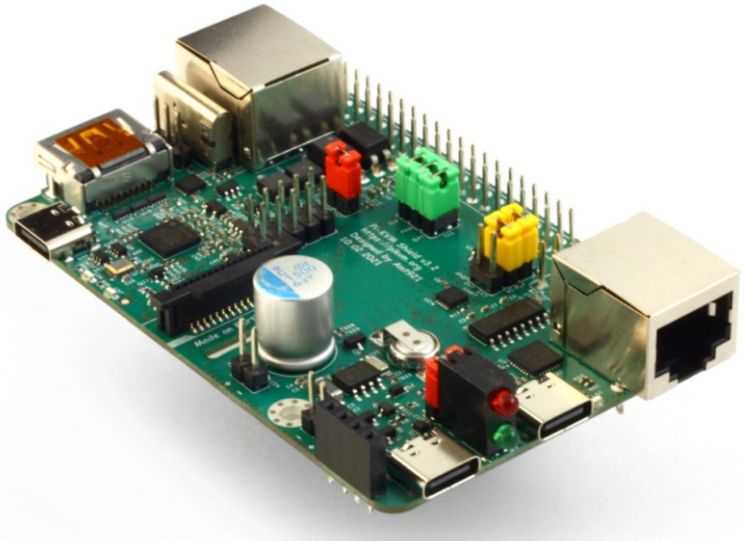

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