START YOUR

RASPBERRY PI ADVENTURE

New projects for 2024

Projecting with CiniPi

£5.99
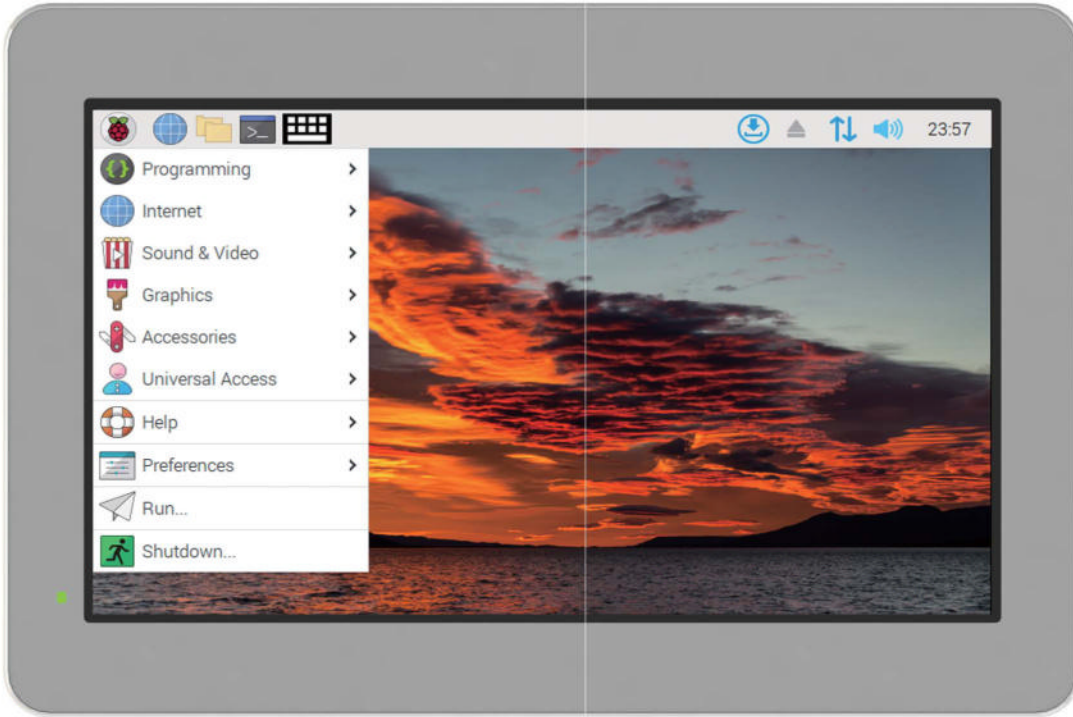
MAKE AN AMAZING RASPBERRY PI PDA WITH BEEPY!

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
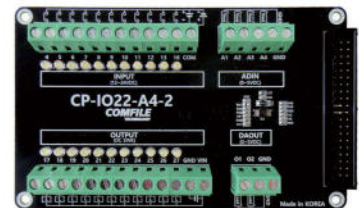
WELCOME
to The MagPi 137

I **still remember unboxing my Raspberry Pi for the first time.** My first encounter with this single-board computer was daunting to say the least. I got the keyboard, mouse, and operating system set up, but didn't get much further.

It wasn't until six months later that I got around to building 'Tyres', my first beloved Raspberry Pi robot. He's still trundling around here somewhere.

What made the difference was a good guide. And that's what we want Start Your Raspberry Pi Adventure (page 40) to be! This feature will walk you by the hand through setting up Raspberry Pi and starting out on a maker's journey. We hope you'll forgive PJ's puns, but isn't Sam's artwork lovely!

Rob has also crafted a great Beginner-Friendly Projects guide (page 72). If anybody knows Raspberry Pi projects it's our Rob, and these builds will help you make something with your new computer. I know we're not all newbies. But we all had to start somewhere and this month is our chance to welcome Raspberry Pi newcomers to the adventurer's guild. So don't be afraid to show off what you've made with us on Threads (**threads.net/@themagpimag**). Welcome to the community!

Best wishes,

Lucy Hattersley Editor

EDITOR

Lucy Hattersley

Lucy is editor of *The MagPi* magazine and is really getting into synth projects at the moment. Expect her new-wave retro synth album to drop one day.

magpi.cc

GET A
RASPBERRY PI PICO W
WITH A SUBSCRIPTION!
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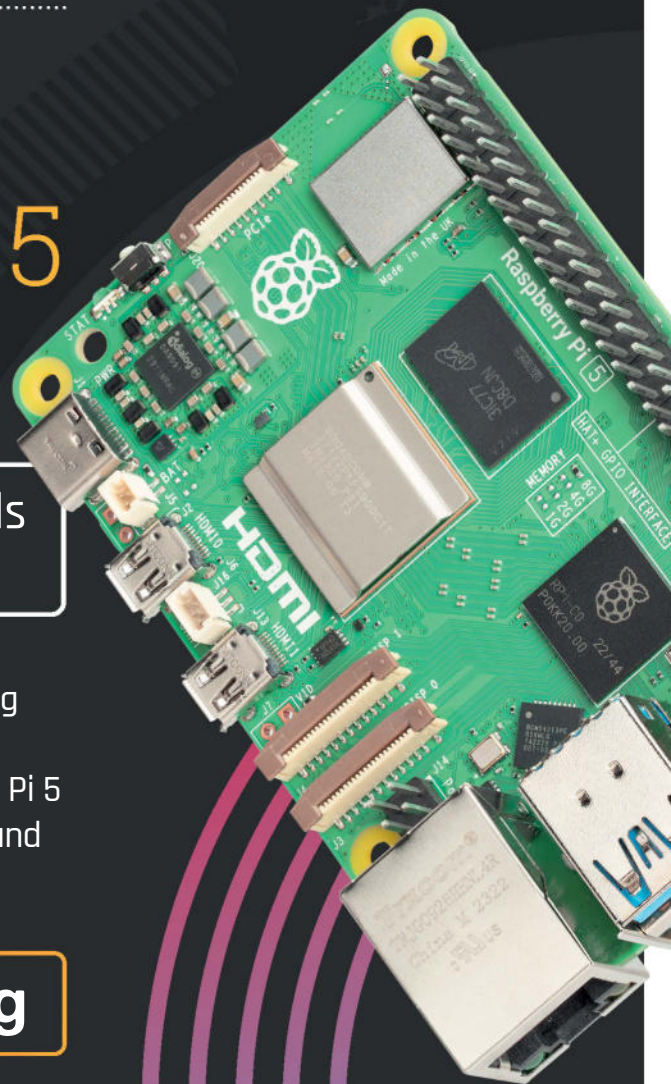
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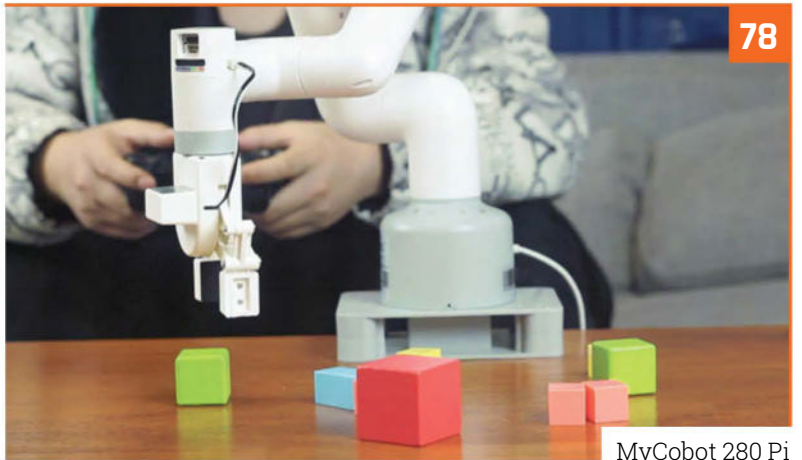
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WIN 1 OF 5 **U-MAKER BOX** RASPBERRY PI CASE **95**

This Amiga
is not an Amiga

The name says it all. This project looks like an Amiga. It functions like an Amiga. But there's a very different computing hidden inside, as **David Crookes** discovers

MAKER

Rob Fisher

Rob is a professional computer programmer, VR flight/space/racing SIM enthusiast, amateur videographer and general lover of gadgets, including old ones.

magpi.cc/ robfisher

Buying a used Amiga 1200 – a computer launched by Commodore in 1992 just two years before it filed for bankruptcy – is sure to leave a dent in your wallet. The 32-bit machine in its most basic form tends to sell for upwards of £300. Add a hard drive, memory expansion or an accelerator card and you may want to arrange a meeting with your bank manager.

You may then need to splash out more replacing the capacitors which are prone to leaking, potentially causing damage to the circuit board. Beyond that, you may find some keys don't work

or the disk drive is broken too. But if you still want to own an Amiga 1200 (maybe to play a host of amazing games or merely to tinker), there's a cheaper option. You could build your own, based around Raspberry Pi.

Rob Fisher has done just that, making use of the PiMiga OS for Raspberry Pi, to create a modern-day Commodore machine. PiMiga requires an Amiga 1200 Kickstart ROM which can be purchased from **amigaforever.com** and it directly boots into an optimised emulator called Amiberry. This allows enthusiasts to enjoy a rather faithful Amiga experience, but Rob has gone further by

▶ The Amiga 500 keyboard fits neatly on top of the components with plenty of space available in the case

The 'Tank' Amiga mouse is also new. These USB mice were created for THEA500 Mini console and can plug into Raspberry Pi

> This machine works just like an Amiga

> It runs the popular PiMega distribution

> The build costs around £250

> Legal ROMS can be bought from Amiga Forever

> The parts list accompanies Rob's YouTube video

The Amiga 500 keyboard is connected to Raspberry Pi using a £25 Amiga USB keyboard adapter from Retro32.com

While the keyboard is an original – hence the yellowing – the case, available in different colours, is a new replica. An A1200 sticker from eBay was added

making his project almost indistinguishable from the original.

Key components

One look at Rob's machine and you wouldn't know that it's not actually powered by 1990s technology. The case is a replica, manufactured using injection moulding and made from UV-resistant plastic. Normally, people buy them to replace age-old, yellowing cases on their original Amigas, but Rob spied an opportunity.

"I've used a new replica case from **A1200.net** because it's allowed me to get closer to the
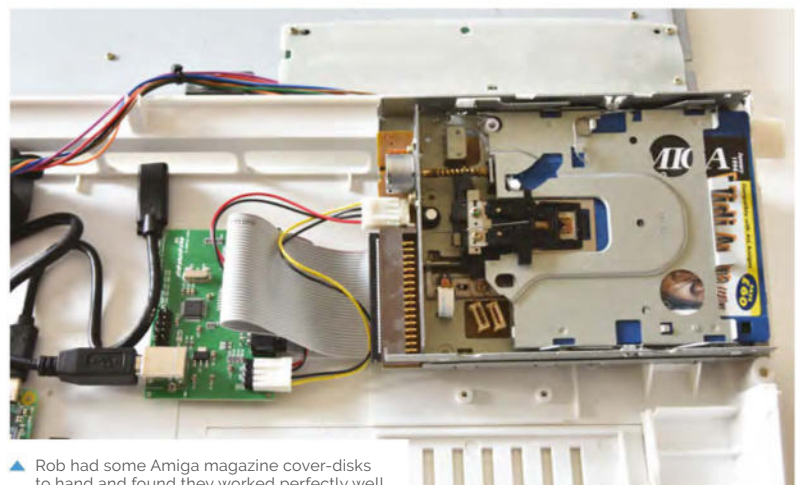
▲ Rob had some Amiga magazine cover-disks to hand and found they worked perfectly well.
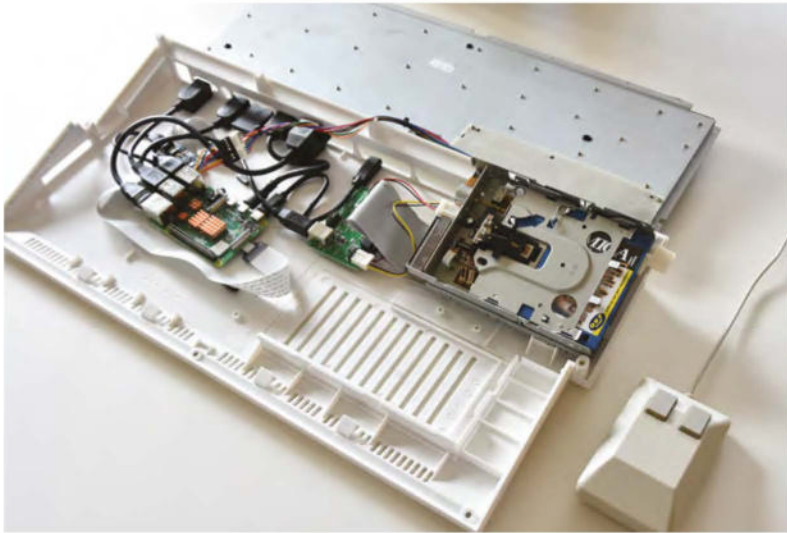
▲ No soldering was needed for this build. The components are simply connected up

experience of having a brand new Amiga," he says. Even so, it didn't come with a keyboard leaving Rob to search for one online.

"Finding components was the main challenge," he says. "Quite often, I would watch a YouTube video about an amazing new bit of kit, only to find that the production run was very small and they were all sold long ago. An example of this is the Keyrah board which has an interface for an A1200 keyboard, but I could not find one anywhere."

It's why Rob has ended up using a keyboard made for the Amiga 500 computer instead.

> 🔲 Rob decided that a replica Amiga based around Raspberry Pi should also have a 3.5-inch floppy disk drive 🔲

"The A500 has a different connector and more circuitry on its own board, so is easier to talk to. **Retro32.com** had a ready supply of pre-built and configured Amiga 500 keyboard adapters, and I found an eBay seller who had several A500 keyboards for sale."

Case open

There was an alternative. "I probably should have used an A500 case with my A500 keyboard, but the new A500 cases were not available in beige, and beige was important for nostalgia," he says. Importantly, Rob found the A500 keyboard was easy to connect to Raspberry Pi 4. "The Arduino-based USB adapters for the A500 keyboard are

plug-and-play," Rob says. Despite that, a little bit of tinkering was needed.

To allow the A500 keyboard to fit into the case, a couple of LEDs needed to be bent out of the way. Some small modifications were also made to the inside of the case. But then Rob became more ambitious and he decided that a replica Amiga based around Raspberry Pi should also have a 3.5-inch floppy disk drive. This would enable him to insert an Amiga-formatted disk and enjoy whatever was on it.

"Floppies were one of my main nostalgia-based requirements," he says. "I remember the clicking sound and being amazed that the floppy was automatically detected when inserted, unlike when I was using my 6128 and 286 PC."

Floppy success

To achieve this, Rob bought a Greaseweazle floppy adapter which connects between a Raspberry Pi computer and a PC floppy drive. "I thought that I would need a real Amiga for floppy disks, but I saw a video by the YouTuber Proteque-CBM installing Workbench from floppies using the Greaseweazle adapter (**magpi.cc/protequegw**) and realised how much was possible with emulation.

"The Greaseweazle V4 has a USB interface on one side and a floppy interface on the other. Unlike a traditional floppy controller, it gives complete control over the drive at the physical layer. So, with the right software, exotic disk formats can be read and written."

As he discovered, it works really well. Rob mounted the drive so that it could be accessed via the right-hand side slot in the case and he created a 3D button so that the floppy disks could be easily released. "The software comes from Rob Smith (**magpi.cc/floppybridge**), who integrated the Greaseweazle seamlessly into Amiberry. The combination acts like a real Amiga disk drive, clicks included!"

Sticking around

Mounting the different parts inside the case was the biggest challenge. Extensions were connected to Raspberry Pi 4 so that they could be accessible from the port holes in the case and they needed to be at the right heights and fixed sufficiently well.

"Apart from finding parts which had to come from lots of different suppliers, the hardest part for me was the physical assembly," Rob says. "So far, 3D printing is not yet on my roster of hobbies and there don't seem to be any ready-

made brackets for mounting things, so I ended up arranging everything as well as I could and sticking it all down with 3M sticky pads. It's honestly not very pretty or robust, but with the case on and not looking too closely at the back panel, the illusion is good enough!"

Even so, the build has done its job superbly, giving Rob a warm nostalgic glow. "I had friends who had Amigas and there was an Amiga at school for music, video titling, and playing Jimmy White's Snooker at break-time," he explains. "I think the Amiga has hit a certain sweet spot of being easy to emulate from an end-user perspective because of the excellent tools that are available and the large community of people involved. It's also retro while still being modern enough to be a pleasant computer to use."

As for the next steps, well, Rob still hasn't given up hope of recreating an Amiga 500. "If A1200.net came out with a beige A500 case then I might switch to that, as these were the Amigas I first remember, and the keyboard would fit better.

"I'd also like to get a real CRT display working somehow. I don't know if I would need to switch to FPGA emulation to do this properly, though. And if anyone designs a set of brackets that fit my USB, Ethernet, HDMI, and microSD connectors, I'd be very interested to add those." 🅼

▼ Here you can see the Greaseweazle connected to the floppy drive and Raspberry Pi
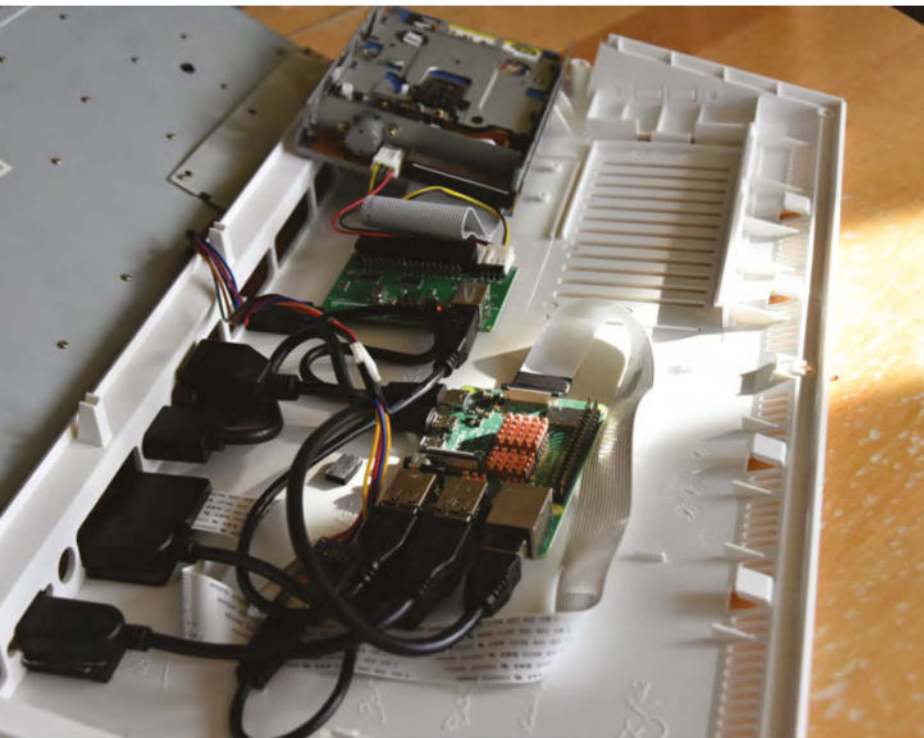
Working with a non-Amiga
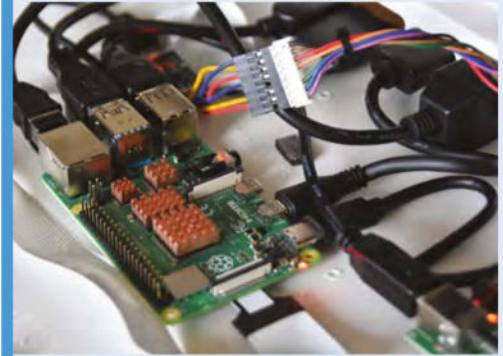
01 Rob considered using either a laptop mainboard from Framework or a MiSTer board which incorporates an FPGA. "But I wasn't ready to upgrade my laptop and there was no way to connect a floppy to MiSTer," he says. "Raspberry Pi it was."

02 With an assortment of cables, Rob was able to add various ports to the back of the 'Amiga' by ensuring the ends were accessible via the holes. They include HDMI, USB-C, and USB-A, meaning peripherals can be connected to the machine.

03 Once this Raspberry Pi-based Amiga is booted, it will run Workbench and allow games and other apps to run via emulation. "Everything seems to run at the right speed and even the sound is perfect," Rob says. "The graphics would look better on a CRT, though."

Volcano-monitoring
Ultraviolet PiCam

Volcanic activity is dramatic but often devastating for nearby communities.
Rosie Hattersley finds out about a Raspberry Pi-based alert system

MAKER

Tom Wilkes

Dr Tom Wilkes is a lecturer in volcanology at the University of Sheffield, where he has used Raspberry Pi for several monitoring projects.

volcanotech.org

I celand is currently on standby for imminent eruptions, while Sicily's Mount Etna gave off stunning emissions in late summer. However, most volcanic activity takes place in lesser-known, less touristy and often poorer nations, where preparations for a big blowout are far harder to facilitate. Furthermore, their remote locations can make installing equipment to track seismic activity an expensive challenge.

"UV cameras provide invaluable data for both monitoring and research," explains University of Sheffield volcanologist Dr Thomas Wilkes, "but funding in volcanology, particularly for monitoring organisations, is often limited, prohibiting their widespread adoption." For his PhD thesis, Tom set about designing low-cost ground-based remote sensing instruments using Raspberry Pi 3B+, having initially been attracted by the £20 Camera Module after a tip-off from a colleague (also called Tom). He read up on all things Raspberry Pi using our forums and online resources and was able to publish both his research paper and set up his first sulphur dioxide monitoring camera in 2016. Two images are taken – one in which UV light is absorbed and one where it isn't. Overlaying the images reveals where sulphur dioxide – a corrosive, acidic gas – is being emitted and in what quantity (**magpi.cc/so2**).

The two Toms continue to work together and are both members of Sheffield-based VolcanoTech (**volcanotech.org**). They aim to get more instruments onto volcanoes and acquire unprecedented long-term datasets that contribute to volcano research and monitoring. Designing and constructing low-cost scientific instrumentation is crucial for developing countries, where funding for equipment can be quite limited but where many of the world's active volcanoes are located.

Tell-tale signs

A volcano's degassing behaviour changes before an eruption, often increasing or decreasing. Since

▶ Tom Wilkes and colleague Tom Pering beside their UV camera rigs monitoring Kīlauea volcano, Hawaii

A Witty Pi HAT and Starlink satellite broadband provide wireless connectivity so photos can be sent for analysis

This fully enclosed, Raspberry Pi 3B-based volcano monitoring system can be deployed in remote locations

Quick **FACTS**

> VolcanoTech's smartphone version of the concept can be seen here: **magpi.cc/ monitorvolcanoesYT**

> NASA liked VolcanoTech's project so much, they…

> …worked with them on geological formation mapping on the Moon!

> The lunar exploration camera also looked for…

> …possible traces of water that astronauts could drink

Two HQ Cameras, one capturing ultraviolet images, show sulphur dioxide emission levels, and whether an eruption might be imminent
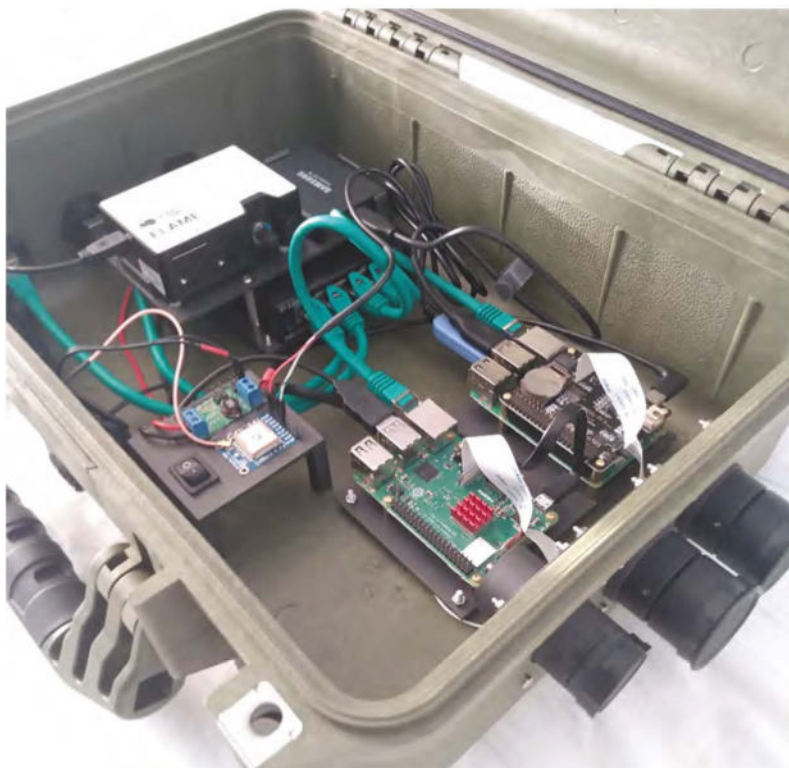
▲ The weatherproof Peli case provides a robust housing and enough space inside to mount everything

Warning!
Strong chemicals

De-Bayering the sensor requires dangerous chemicals such as nitric acid and carcinogenic dichromates. It should not be done at home. It requires a fume cupboard and proper chemical disposal procedures. An alternative is to simply scratch the Bayer filter away with something like a piece of plastic – this can have a reasonably good result but may not clean the sensor up quite as nicely as the chemical procedure.

magpi.cc/chemicals

(**magpi.cc/leslabYT**) which simplified the process of removing the Bayer filter from the camera lens to enhance its sensitivity to ultraviolet light. This worked well for a Raspberry Pi Camera 1.3, but Tom reports that he was unable to remove the Bayer filter in the same way for the newer Raspberry Pi Camera Module. The process in any case requires a fume cupboard and dangerous chemicals (see 'Warning' box). Tom originally made use of the UV camera in a spectrometer he

> ❝ Tom aimed to develop a UV camera an order of magnitude cheaper ❞

used for sulphur dioxide monitoring. Although this worked well, he subsequently decided to focus on the camera-based system.

How predictable

Having created an affordable alternative to the £10,000 scientific cameras, Tom has been working on modifying the camera design so they can be deployed permanently on volcanoes, without the need for human interaction. To date, only Stromboli in the Aeolian Islands, and Etna just to the south, have fixed monitoring. "We are now beginning to build high time-resolution sulphur dioxide emission rate datasets from several volcanoes, the likes of which are quite rare in volcanology," he says.

sulphur dioxide is the gas most prevalent at active volcano sites, Tom focused on monitoring this using a UV camera. There were already scientific-grade UV cameras in the field in some locations, but they cost tens of thousands of pounds, whereas Tom aimed to develop a UV camera "an order of magnitude cheaper" and much smaller, making it suitable for permanent installation and remote reporting. Monitoring volcanoes often involves tracking how sulphur dioxide diverges from a baseline and then investigating those changes. Tom's system uses the Beer–Lambert law of absorption, comparing the optical depth of plume pixels in an image to the background sky radiance (**magpi.cc/beerlambertlaw**).

Tom and his colleagues didn't know much about Raspberry Pi at the outset, "which made the detailed knowledge and wealth of experimentation by others invaluable when it came to asking specific questions or pulling ideas from pre-existing threads." A particularly fruitful discovery was a YouTube video by Les Wright
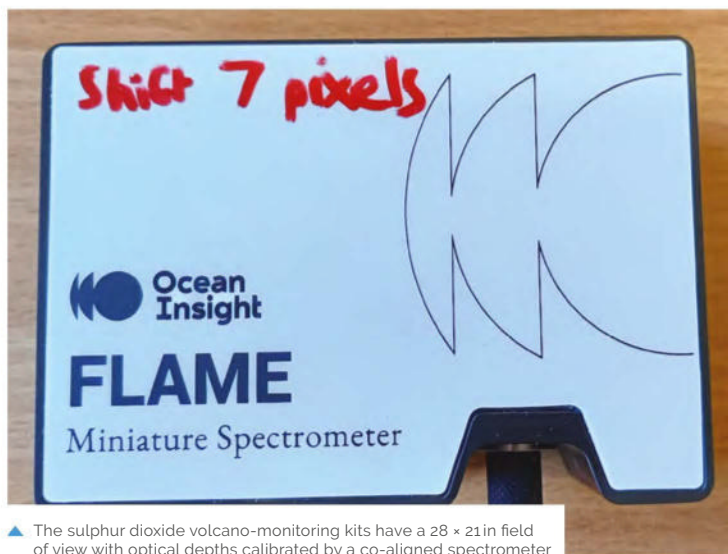

▲ The sulphur dioxide volcano-monitoring kits have a 28 × 21 in field of view with optical depths calibrated by a co-aligned spectrometer

▲ Optical depth image captured at Lascar volcano near Buenos Aires with a control rectangle of clear sky
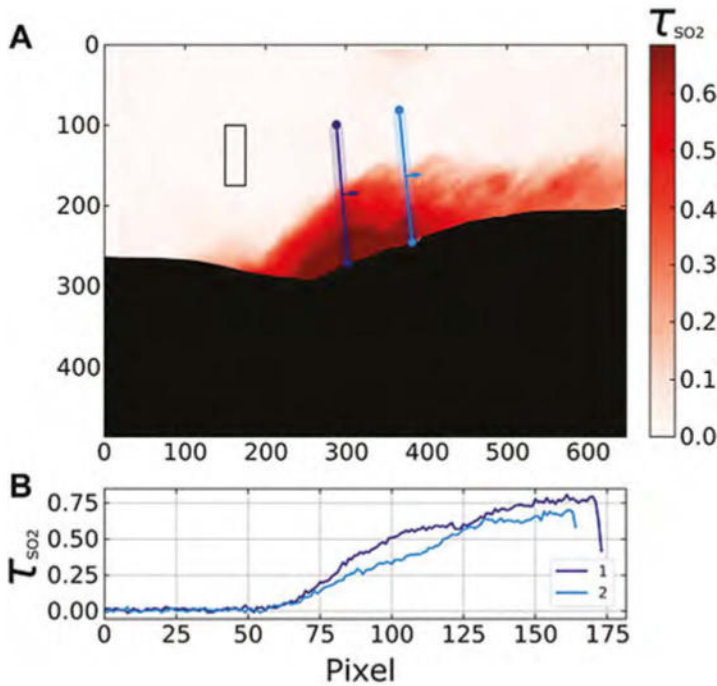
Getting the cameras installed on hazardous volcanoes is no mean feat! Using a Starlink satellite connection has helped them overcome the major issue of handling and processing the terabytes of data each camera acquires each year, as well as partially solving issues relating to debugging camera installations remotely. With cameras in the Amazon rainforest as well as the Atacama desert, temperature extremes and huge amounts of rainfall add to the challenges. However, once in place, they'll give volcanologists significantly improved monitoring capabilities that contribute to longer-term volcanological research – an increasingly critical aspect of their work "since a volcano can exhibit significant changes in activity over a wide range of time scales." **M**

▼ Digital elevation models (DEMs) of Lascar and Kīlauea; the blue dots are camera positions
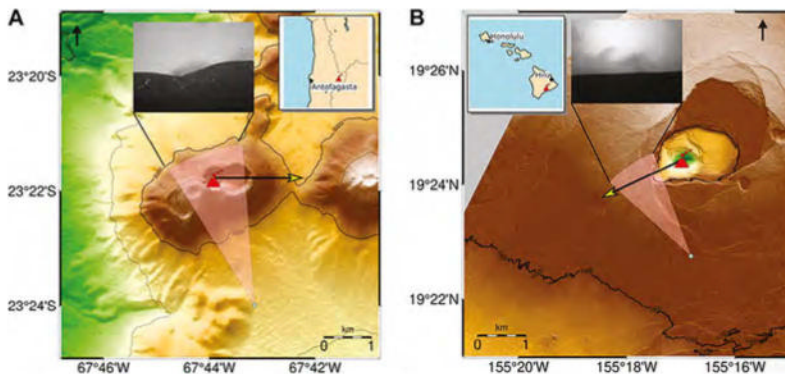
Glowing report
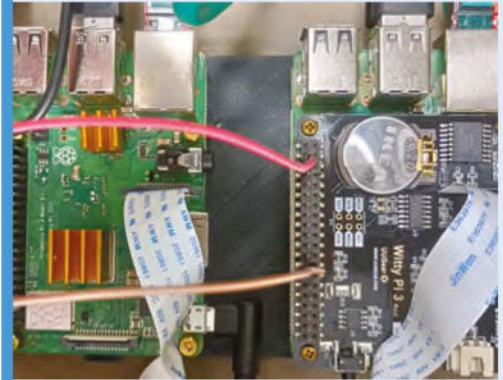
01 A modified Raspberry Pi camera is fitted with an ultraviolet transmissive optical system, designed in Zemax ray-tracing software. Bandpass filters compensate for changing wavelength transmission and light incidence angles.
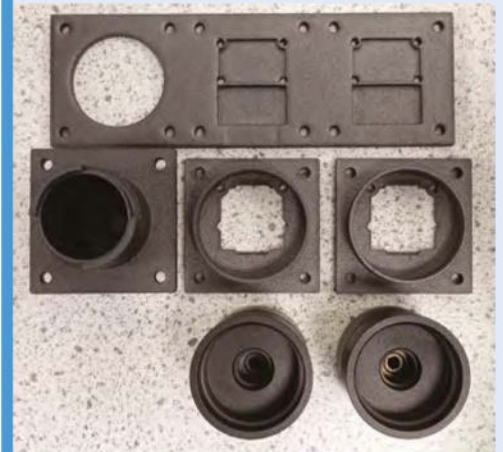
02 The triplet mount was made from machined black anodised aluminium, resulting in improved precision and longevity over previous 3D-printed, non-triplet versions.

03 A UV spectrometer, WittyPi HAT, and network drive manage data and send it back to the volcano monitoring team for analysis.

BlueROV2 R4

This Raspberry Pi-powered submarine ROV safely explores the depths. By **Ashley Whittaker**

MAKER

Rusty

Rusty started out with a solar-powered surfboard trying to autonomously head from LA to Hawaii and Blue Robotics grew to develop hundreds of low-cost marine components.

bluerobotics.com

BlueROV2 is an underwater ROV that surveys the darkest depths – well, the really very gloomy depths anyway – with the help of a Raspberry Pi 4 wearing its bespoke Navigator Flight Controller as a HAT.

What is an underwater ROV?

If you're not sure what an underwater ROV is, the short answer is: a Remotely Operated Vehicle you chuck in the sea. But if you're our favourite kind of geek and wish to feast on a much longer answer, Blue Robotics has shared a short history and explanation of how they work, including the excellent tidbit that the first ever ROV was called the Poodle (**magpi.cc/whatisrov**).

BlueROV2 is billed as "the world's most affordable high-performance underwater ROV." While $3,950 seems like a lot, this ROV buying guide quotes prices up to $40,000 (**magpi.cc/rovbuying**). We like to think our affordable Raspberry Pi brain had a lot to do with bringing that cost down

What's it made of?

The device measures 18 × 13.3 × 10 inches and can capture live 1080p HD video, thanks to a wide-angle low-light camera mounted to a tilt mechanism on the front. An on-board gyroscope, accelerometer, and magnetometer, along with pressure, depth, temperature, voltage, and leak

> **❝ Splash out on the aluminium option and you're safe to dive up to 300 metres ❞**

detection sensors, make sure everything is functioning and navigating as it should.

If you choose a ROV with an acrylic enclosure, you can get to a depth of 100 metres, but splash out on the aluminium option and you're safe to

▲ ROVs are often used by police and fire departments for search and rescue missions, looking for missing people, ships, cars, and any other sunken objects
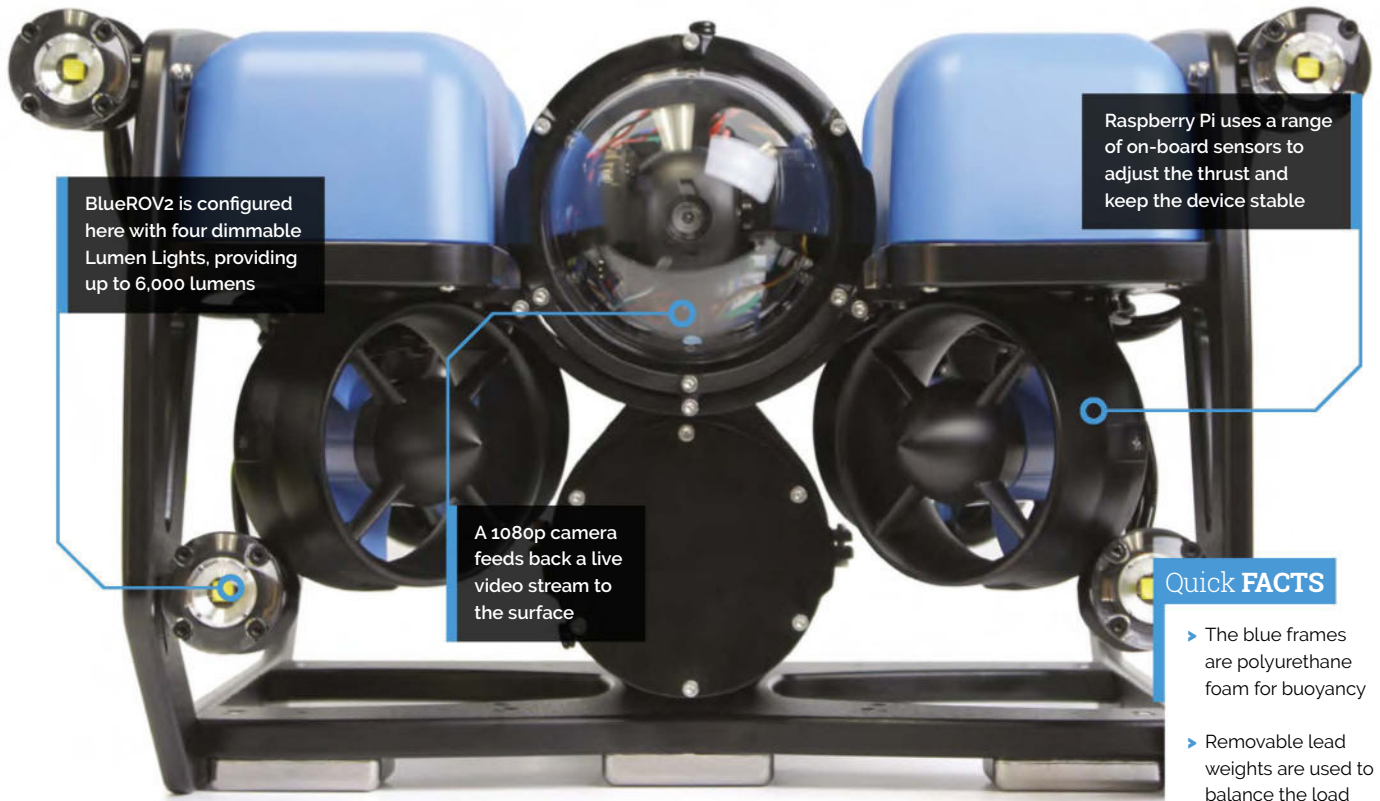
BlueROV2 is configured here with four dimmable Lumen Lights, providing up to 6,000 lumens

Raspberry Pi uses a range of on-board sensors to adjust the thrust and keep the device stable

A 1080p camera feeds back a live video stream to the surface

Quick **FACTS**

> The blue frames are polyurethane foam for buoyancy

> Removable lead weights are used to balance the load

> There are six to eight thrusters to control movement

> Raspberry Pi and the Navigator HAT control stability

> It runs BlueOS, a custom operating system

▲ Small-scale ROVs are widely used in aquaculture, infrastructure inspection, and commercial diving

and computing requirements inside the ROV (**magpi.cc/navigatorhat**).

All of those sensors are provided by the Navigator, and Raspberry Pi 4 communicates what's happening back to base on dry land via BlueOS.

While we do think BlueROV2 is cool and all, we're still too traumatised by the shark chase at the beginning of *The Little Mermaid* to watch any of the video it captures. 🅼

dive up to 300 metres. As far as we can tell, that's deep enough to explore right down to the sea bed over much of the North Sea and almost all of the Irish Sea. Feel free to Google other bodies of water yourself.

What does its Raspberry Pi do?

The BlueROV2 is controlled by the Navigator Flight Controller, which is a HAT designed for Raspberry Pi 4. Raspberry Pi runs Blue Robotics' bespoke BlueOS software and handles all of the processing

▲ A standard Xbox controller can be used to control BlueROV2

World's First Raspberry Pi 5 tablet

Putting Raspberry Pi 5 inside a RasPad 3. By **Ashley Whittaker**

MAKER

Leepspvideo

Lee is a technology enthusiast covering Raspberry Pi single-board computer projects.

magpi.cc/ leepspvideo

Lee, of the Leepspvideo YouTube channel, was having a whale of a time testing out Raspberry Pi 5 using the Dolphin emulator (dolphin-emu.org), as well as running his dual-screen setup (magpi.cc/dualscreensetup). So far, so impressed – but then his mind wandered and landed on the question: "Will a Raspberry Pi 5 fit inside SunFounder's RasPad 3?"

RasPad 3 is a tablet designed around Raspberry Pi 4, which has an Ethernet port on the opposite side of the board to Raspberry Pi 5. There were also questions around whether RasPad 3 could power the more powerful Raspberry Pi 5.

You can watch the 'First Raspberry Pi 5 tablet' build on YouTube (**magpi.cc/5tabletYT**).

Tight fit

The project began with disconnecting the fan wires from the GPIO on Raspberry Pi 5 and unscrewing the standoffs. The Ethernet and USB 3.0 cables inside the RasPad are quite short, so they were a little more stretched than is ideal in order to reach the ports on Raspberry Pi 5. The slightly different layout of Raspberry Pi 5 also meant they had to cross over each other.

▼ Surgery taking place

Once it was all connected, everything worked as normal in the Chromium browser. And the touchscreen was "nice and responsive" under the control of the super-speedy Raspberry Pi 5. RasPad 3 (**magpi.cc/raspad3**) is a touchscreen device, but there are plenty of ports for you to plug in wireless keyboard and mouse dongles, which Lee did to test out accessing his YouTube channel (**magpi.cc/leepspvideo**). We were pleased to see that everything loaded nice and quickly, and of course, our Raspberry Pi 5 handled full-screen, high-resolution video with ease.

> ❝ Once it was all connected, everything worked as normal ❞

We're officially crowning Lee as the creator of the first-ever Raspberry Pi 5-powered tablet. A special prize goes to the creators of RasPad 3, SunFounder (**sunfounder.com**), of course.

Retrofit dreams with Raspberry Pi 5

We cannot wait to see what weird and wonderful objects our newest board ends up inside. Eben is particularly keen to see someone using a 1950s TV as a display for Raspberry Pi 5, since, as he and
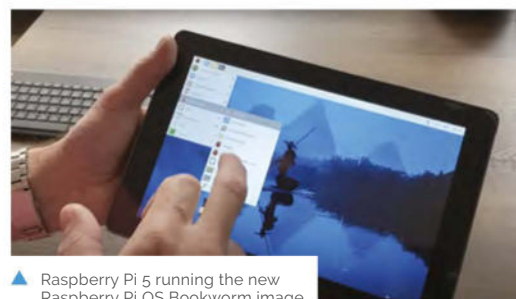
▲ Raspberry Pi 5 running the new Raspberry Pi OS Bookworm image

The build-in lithium battery provides power for Raspberry Pi 5 and the screen
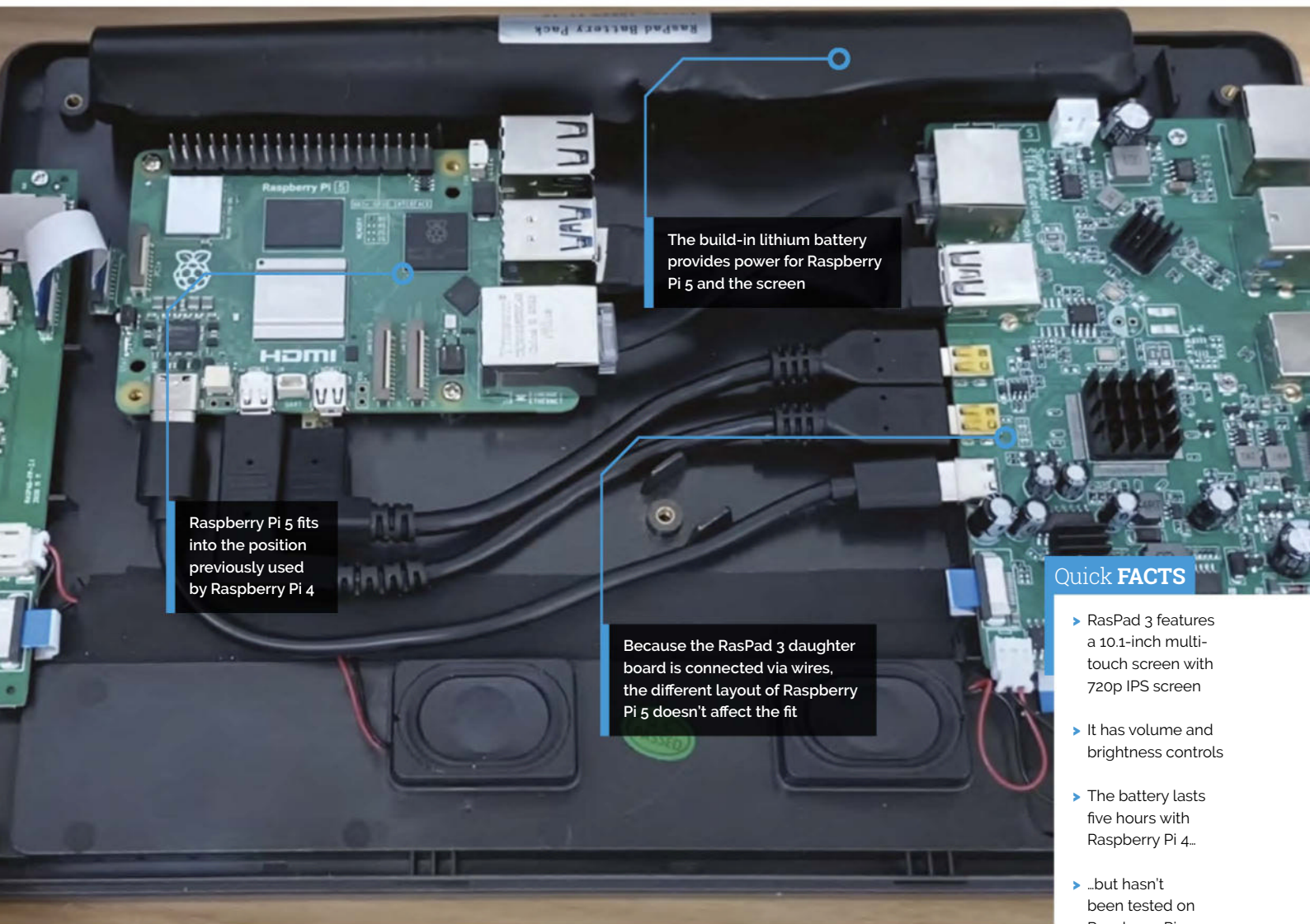
Raspberry Pi 5 fits into the position previously used by Raspberry Pi 4

Because the RasPad 3 daughter board is connected via wires, the different layout of Raspberry Pi 5 doesn't affect the fit

Quick **FACTS**

> RasPad 3 features a 10.1-inch multi-touch screen with 720p IPS screen

> It has volume and brightness controls

> The battery lasts five hours with Raspberry Pi 4…

> …but hasn't been tested on Raspberry Pi 5

> It contains a fan for cooling

James keep telling everyone (**magpi.cc/rp1tvout**), it can output an ancient TV standard [Editor's note: please be careful working with old CRT TVs as they can be extremely dangerous – **magpi.cc/crt**]. Of course, an old Pye (**magpi.cc/pyetv**) would be the dream for this, both for our nearly-shared name and for our shared Cambridge heritage. We spent a happy interlude on eBay, and someone dug up this informative and also daunting page about restoring old 405-line TV receivers (**magpi.cc/405alive**), before sighing wistfully, closing about a dozen tabs, and going back to what we were all supposed to be doing. So, if you are pals with a retro TV enthusiast who'd relish the challenge, make sure you tip them the wink. M
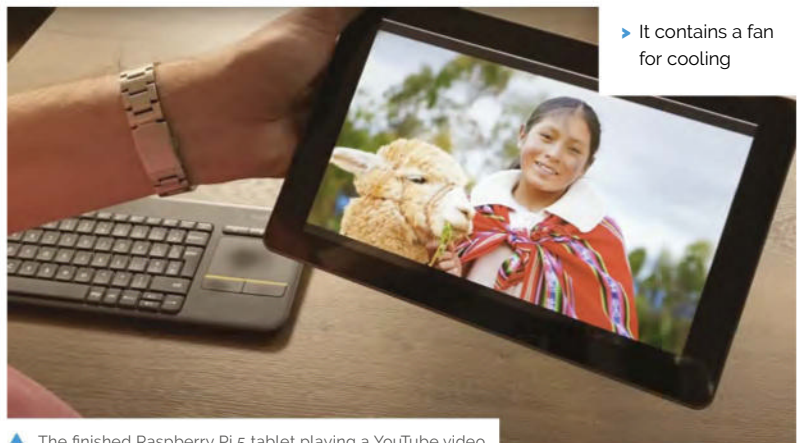
▲ The finished Raspberry Pi 5 tablet playing a YouTube video

Smart Vertical Farming

Rather than grow crops horizontally across large fields, plants can be cultivated vertically too. And, as **David Crookes** discovers, it doesn't need to cost the earth

MAKER

Tanay

Tanay is an undergrad student pursuing a bachelor's degree in Software Engineering. He's enthusiastic about hardware and software technologies.

magpi.cc/ verticalfarm

Farmers always need lots of land, right? Well, not necessarily. There is a practice called vertical farming which involves cultivating crops in stacked, tower-like layers. When using this method, the environment is carefully monitored and controlled, lending factory-style precision to the process of growing plants. It has the potential to revolutionise food production, but it's also quite expensive.

Recognising the costs involved, Raspberry Pi enthusiast Tanay has produced his own version. In creating a smart vertical farming system powered by a Raspberry Pi 4 computer, he's enabling plants to be monitored and precisely watered with minimal human intervention while taking into account numerous environmental factors to optimise their growth.

"The inspiration came from the need to address the challenges in traditional farming and leverage technology for efficient crop management," Tanay explains. "It's a forward-thinking approach to agriculture and my project was born out of a passion for sustainable agriculture. The aim was to explore innovative solutions, driven by a desire to contribute to a greener future."

Making sense

Although Tanay has not had first-hand experience of vertical farming, he says he has read lots about it. "It's a fascinating concept," he adds. His research meant he had a good idea of what was needed to create his own system. "Raspberry Pi was chosen for its versatility, affordability, and the vast community support it offers," Tanay says. "It's a robust choice for managing and controlling various components in a system like this."

These components include ambient light, soil moisture, and water level depth detection sensors. "The project was planned by first identifying the key requirements, such as real-time monitoring, efficient water supply, secure communication, and a user-friendly interface," Tanay continues. "Components were selected based on their compatibility and functionality within the system."

The sensors gather data about the plants. This data is then processed by a peripheral control unit (in this case an Arduino Nano 33 IoT) and sent to the central unit (Raspberry Pi 4) via Bluetooth Low Energy (BLE) communication. "The central unit makes decisions on actions such as activating actuators to adjust environmental parameters," Tanay says. "This continuous loop ensures optimal conditions for crop growth."

Friendly farming

A thermoelectric Peltier refrigeration cooling system kit has also been used. "A humidity-to-water conversion, with the help of the Peltier

> **"** The inspiration came from the need to address the challenges in traditional farming **"**

module device working on the principle of condensation, ensures a continuous supply of water," Tanay explains. It ensures plants are kept alive and are able to thrive but there's also a user-friendly GUI for remote manual control.

"The software was crafted with modularity and user-friendliness in mind," says Tanay, who used
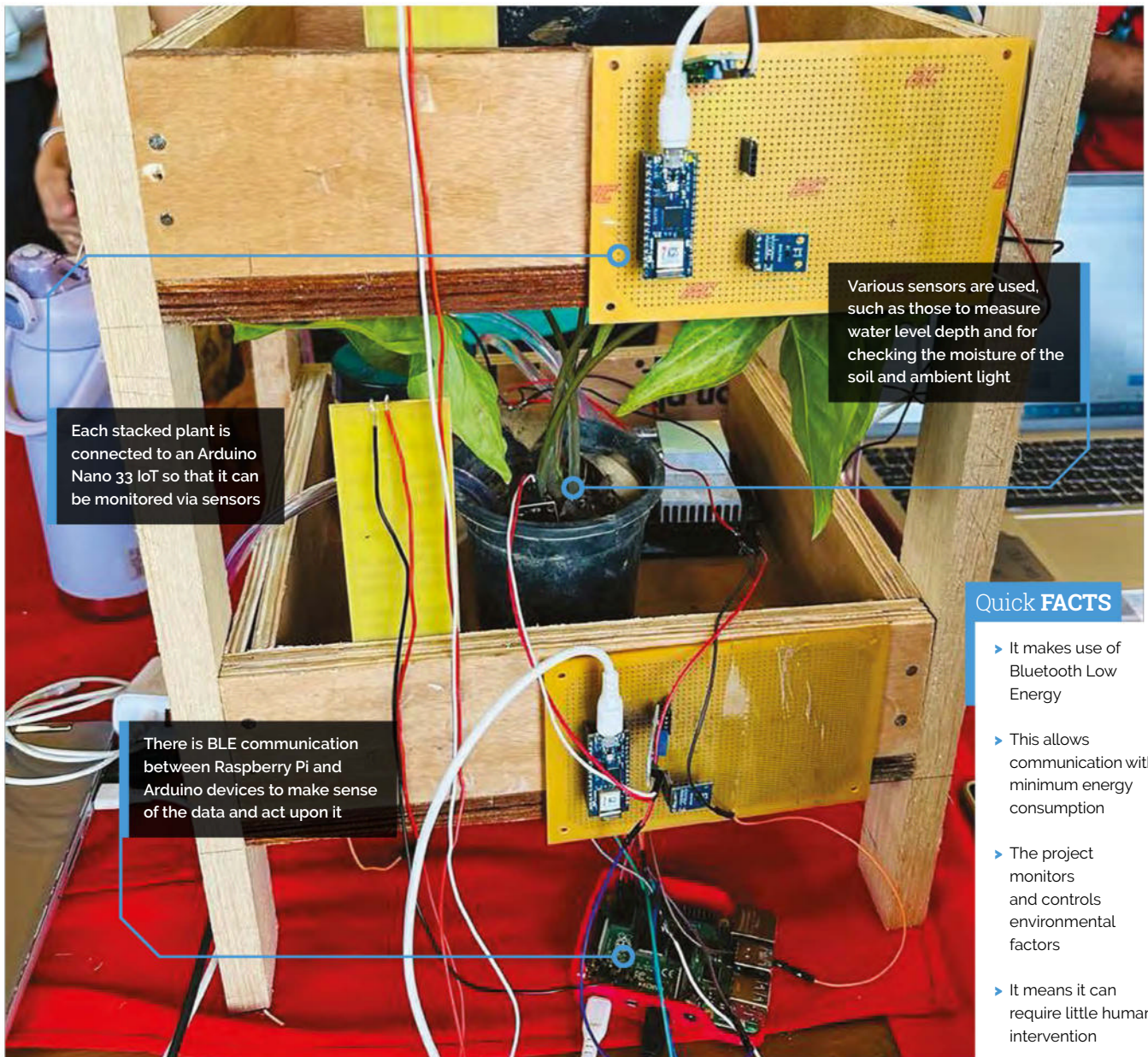
Each stacked plant is connected to an Arduino Nano 33 IoT so that it can be monitored via sensors

Various sensors are used, such as those to measure water level depth and for checking the moisture of the soil and ambient light

There is BLE communication between Raspberry Pi and Arduino devices to make sense of the data and act upon it

Quick **FACTS**

> It makes use of Bluetooth Low Energy

> This allows communication with minimum energy consumption

> The project monitors and controls environmental factors

> It means it can require little human intervention

> There is also a user-friendly GUI

the IoT platform ThingSpeak. "ThingSpeak is useful for visualising data from sensors in real-time which provides valuable insights to farmers," he continues. "A user-friendly interface makes it accessible to those without extensive technical knowledge and providing a fault tolerance to the system."

Tanay hopes the project will show that vertical farming doesn't have to be expensive. "The project's cost-effectiveness is a standout feature," he says. It's also scalable. "The project is aimed at small and large-scale farmers," Tanay adds. "The modularity and scalability design principles suggest it's adaptable to various farm sizes, making it accessible to a broad audience." M

▲ The system can work out how much water a plant needs and automatically deliver it

Giant Fine-Art
Game Boy

The iconic handheld console can now be treated as fine art, especially when you deconstruct it and rebuild it six times larger, like Connor Gottfried. **Rob Zwetsloot** plays it loud

MAKER

Connor Gottfried

A visual artist, musician, and engineer whose art explores obsolescence, nostalgia and rebirth by deconstructing, enlarging and twisting the forms of early handheld gaming systems.

connorg.ca

You can see the Game Boys and more work from Connor at the S16 Gallery in Montreal on 16 December!

There have been a discussions for decades now on whether or not video games can be considered art. The short answer in our minds is; yes, they can be. Unfortunately the longer answer isn't really relevant to this magazine, but what is relevant is three-foot-tall Game Boy (and other handheld) replicas powered by Raspberry Pi that are displayed as fine art themselves.

"I had been working building large format fine art using canvases, paint, and paper and had just started exploring using Coroplast [corrugated plastic – Ed] to add a three-dimensional element to my work," creator Connor Gottfried tells us. "I was working on a project that had a character whose head was shaped like a TV set and I thought 'I should put a screen in there'! That was the beginning seed and I've just kept pushing the idea further and further. Once I realised that I could take the Game Boy's form and twist it almost beyond recognition, the idea really started to take off. The Game Boy's design is iconic and early handheld electronic devices haven't been explored to a large extent in the fine art world."

Some fine art can be interactive, but how many let you play Tetris as part of the interactivity? Thanks to a Raspberry Pi inside running RetroPie,

▶ This bare-bones version showing off the PCB is based on an Analogue Pocket
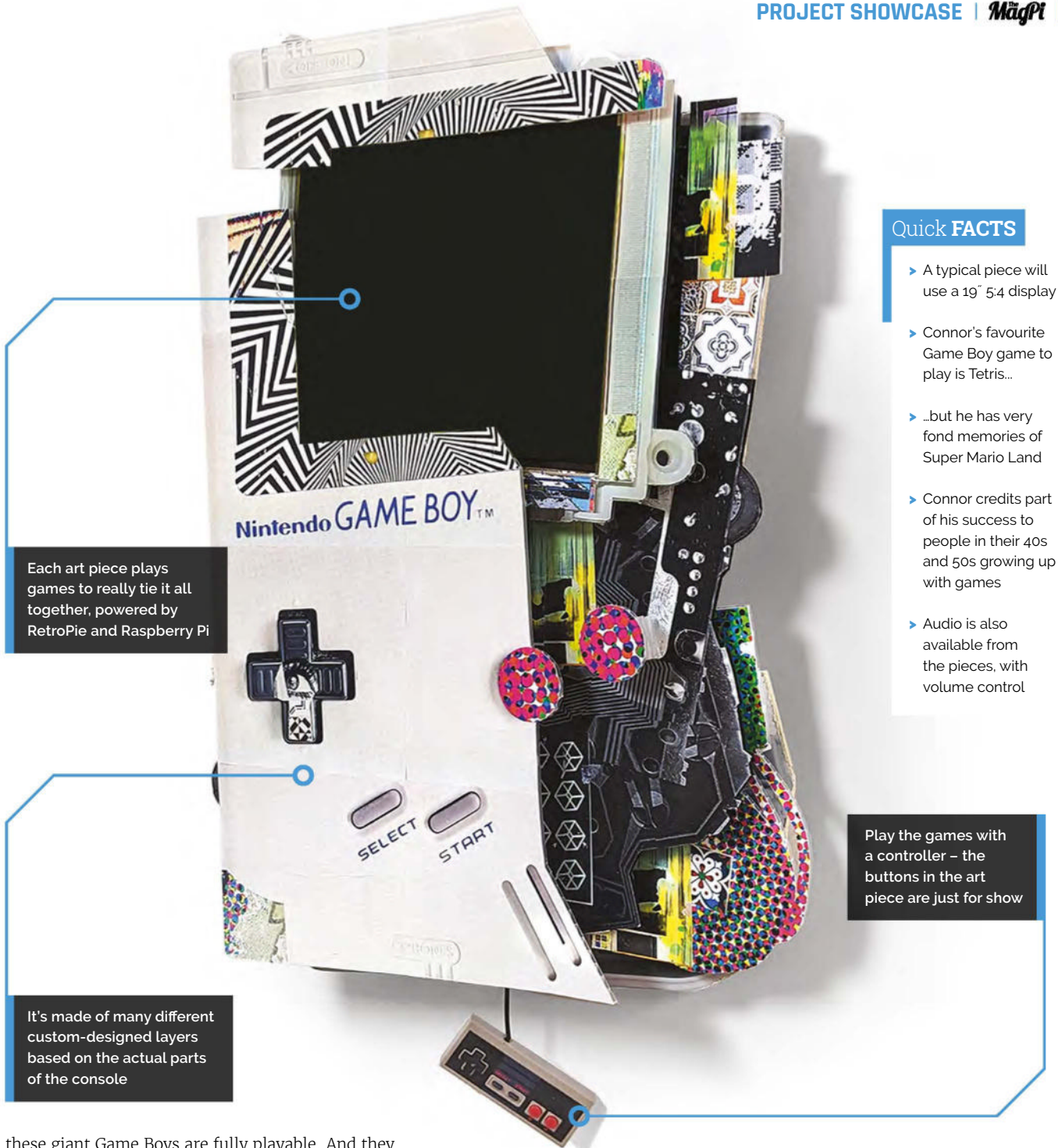
Each art piece plays games to really tie it all together, powered by RetroPie and Raspberry Pi

It's made of many different custom-designed layers based on the actual parts of the console

Play the games with a controller – the buttons in the art piece are just for show

these giant Game Boys are fully playable. And they look fantastic even when you're not.

Reimagined retro

Everything starts with an idea and as each build is unique. Connor does his research on each idea before figuring out how to construct it.

"This usually involves locating high-resolution photos of the exterior and circuit boards for the device online," he explains. "I then upscale these using AI with Gigapixel (I actually like the AI artifacts that get introduced). Next, I bring everything into Photoshop and create a full-size layered mock-up. This can take a lot of time to get

right as this is where all of the design work is done. I like to explore incorporating 'op-art' patterns from artists like Bridget Riley, or paint scrapes with bright colours to add a psychedelic element. I think the juxtaposition between the basic plastic enclosures/electronic boards of these devices and the psychedelic colours and design twists of the final product can be really interesting."

Once he's finished designing, he'll print the designs onto acrylic, Alupanel (an aluminium composite with a plastic core), Coroplast, and

DOT MATRIX WITH STEREO SOUND

BATTERY

Nintendo GAME BOY™

SELECT   START

◀ A more typical build, this version is for Tetris, the classic Game Boy game

even sometimes wood, depending on if the piece is a prototype or if it has to be shipped to specific locations. The more polished, 'production' units use acrylic and Alupanel.

"I then mount the monitor and electronics on the back layer and use spacer stacks to position

> ❝ The Game Boy's design is iconic and early handheld electronic devices haven't been explored to a large extent in the fine art world ❞

the additional layers," Connor reveals. "Everything is held together with various forms of adhesive, screws or bolts, depending on the design."

Art in demand

The final versions are either locked to a single video game if they're part of an installation, or open for any game if you buy them. Either way, people seem to like them.

"People have really gone crazy for these," Connor tells us. "I think I've tapped into a real soft spot, both for myself and for millions of others, that combines nostalgia and reinvention in a fun and unique way. I've sold these pieces internationally and get a ton of really nice feedback on my Instagram account. It's really cool to hear from people who connect with the work!"

Currently, Connor is selling his pieces through art galleries and is working on his first solo show, which opens on Saturday 16 December in the S16 Gallery in Montreal! If you can't make it, then you can always follow along with his creations on his Instagram page: **magpi.cc/cgottfried**.

"It's really cool to see how, as the generations change, what is acceptable in the fine art space that's evolving," Connor says. "Now that people in their 40s and 50s who grew up with video games are buying art, it's really opening the door for some cool new stuff in the art world."

▼ One part Care Bear, one part weird Tellytubby hybrid

More than Game Boys

01 Sega's oft forgotten Game Boy rival, the Game Gear also gets the Connor Gottfried treatment. The wires poking out of the case really make it three-dimensional.

02 A sort-of precursor to Game Boy, these LCD Game & Watch games came in various iterations, including a Donkey Kong one shaped like so.
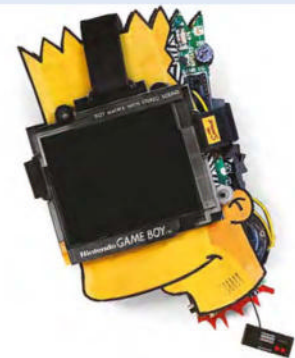
03 Connor doesn't just make Game Boys – he also does art pieces based on specific characters, such as this Bart Simpson creation.

CinePI XL

CinePI is an open-source cinema camera that lends itself to DIY design, including larger sensors, learns **Rosie Hattersley**

MAKER

Csaba Nagy

Csaba's extensive interests cover technical and artistic domains including programming, hardware development, 3D printing, photography, and filmmaking.

github.com/ CinePI

Canadian creative maker Csaba Nagy spent hours during his university course immersed in the world of camera sensors and computer vision, nicely complementing his degree in computer science.

Raspberry Pi's ability to connect with so many other devices, plus the possibilities of the camera module, piqued his interest. He subsequently developed CinePI – an open-source project that was "a direct result of the intersections between my passions for programming and filmmaking" – to add cinema camera features to Raspberry Pi. In early 2023 Csaba launched version 2, based around a Raspberry Pi 4 and 12.3 megapixel HQ Camera (**magpi.cc/CinePI**). Now he's back, with CinePI XL.

Big ambitions

Csaba says that CinePI was always intended to push the possibilities of Raspberry Pi as a video camera with features found in cinema cameras, but in an open-source device so developers could integrate it into their own designs. CinePI V2 can record 2K RAW Cinema DNG video at frame rates up to 50 fps with 12-bit colour depth that far surpasses the 8-bit or 10-bit usual video fare. Csaba showcased its abilities, using CinePI V2 to film more than half of his *Timekeeper* short film this summer: **magpi.cc/timekeeper**.

Having completed CinePI V2 in early 2023, it wasn't long before Csaba began work on developing this latest version, with a Compute Module. He has been inspired all along by the
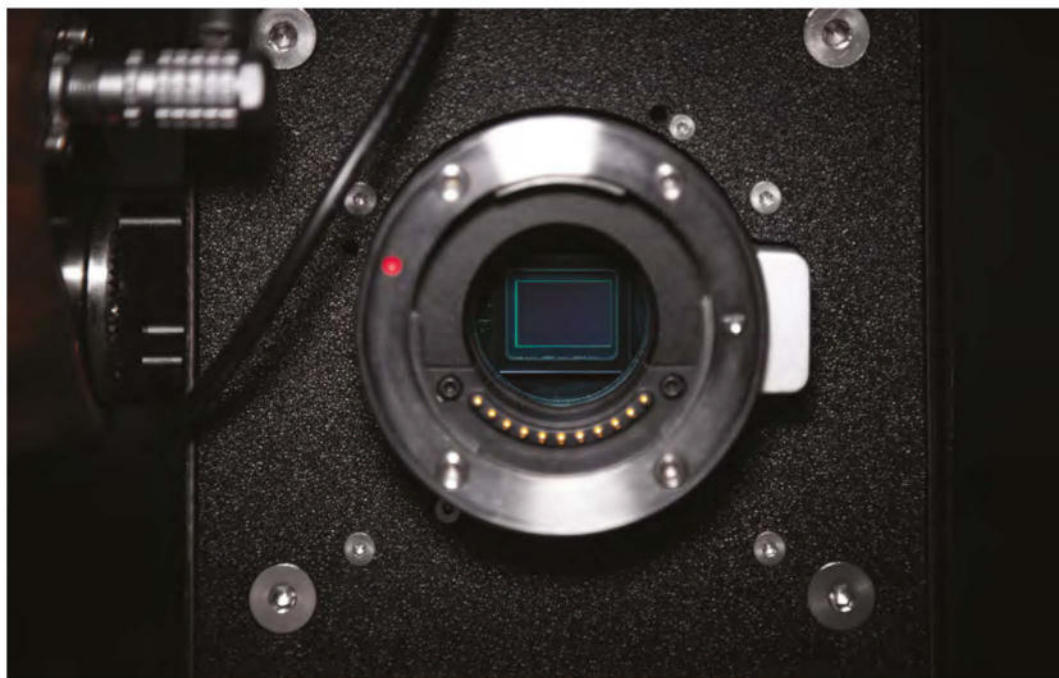
▶ Csaba is a big fan of Blackmagic Design's camera housings

A 2.8 in WaveShare DSI screen also distinguishes CinePI XL from the HyperPixel 4.0 display on CinePI V2

The Blackmagic camera box encases a Raspberry Pi Compute Module – and CM4IO board necessitated by the sensor's need for a MIPI CSI-2 link with four data lanes

Behind CinePI XL's machined metal lens turret is a OneInchEye sensor that can capture 12-bit video footage and photos at 20.3MP, even in low light conditions

▶ CinePI XL is much larger than its CinePI V2 stablemate

Quick **FACTS**

> Csaba learned about the OneInchEye sensor and its maker…

> …on a Raspberry Pi forum thread: **magpi.cc/overclockcsi2**

> Meanwhile, Will had discovered Csaba's Discord server…

> …where he posted more details about the impressive sensor

> And Csaba realised it would be ideal for CinePI XL

▲ As intended, CinePI has inspired many takes on how such a Raspberry Pi cinema camera might look

cameras made by Blackmagic Design. "They were one of the very first manufacturers to offer RAW video capabilities at affordable prices; democratising tools used for filmmaking." This means cameras cost a couple of thousand dollars rather than many thousands. If, as Csaba intends, you were to build your own CinePI camera, it would cost far less again, and can largely be built

> ❝ People have been using CinePI, modifying and customising it for their unique needs ❞

with off-the-shelf components and sensors from the likes of Adafruit. He estimates CinePI V2 costs $250–$300 while CinePI XL in the same or similar configuration would be closer to $400–$600. "A steeper cost, but still very affordable in comparison to the types of camera it would aim to compete with on the market."

Whereas CinePI V2 was a compact form factor handheld camera, the XL model is noticeably

larger. That's because it features a specially developed sensor, OneInchEye, designed by Will Whang (**willwhang.dev**). This larger sensor enables greater image quality and higher frame rates than the Raspberry Pi HQ Camera and also necessitated a switch to Compute Module because it required a MIPI CSI-2 link with four data lanes. Csaba decided to embrace the possibilities this offered in terms of additional sensors and design a camera that mimicked the feature set and capabilities of real professional cinema cameras. Advantages included a larger battery, bigger display, more mounting points for accessories, and a larger physical lens mount.

Community spirit

This summer Csaba saw membership of his Discord server grow from 300 to 1000 members, "It's been amazing to see the ways people have been using CinePI, modifying and customising it

Extraordinary scenes

01 Csaba's lens turret was repurposed from another camera. He encourages others to design their own CinePI. You will need a Raspberry Pi Compute Module, CM4IO board, connectors, a screen, and battery.
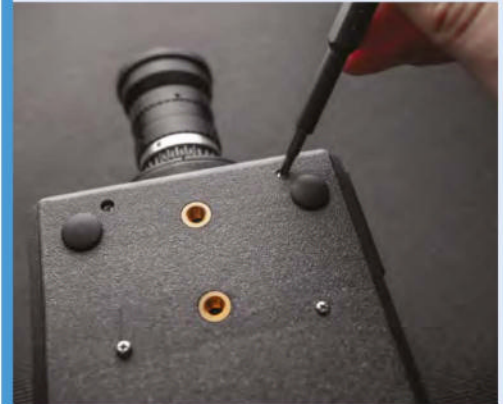
for their unique needs. Exactly what I was hoping for when I started the project." With the launch of Raspberry Pi 5, Csaba expects to see even more interest. "Perhaps in the future, with the efforts of talented individuals from the community or established companies already in this space, we can see the production of larger sensor modules that will work on the Raspberry Pi platform," he suggested to CineD: **magpi.cc/cined**. 🅼

▲ A side view of the CinePI XL camera

▼ *Timekeeper* was shot largely using CinePI 20.3MP cameras

02 CinePI XL uses a OneInchEye sensor. Code for it is built on top of Raspberry Pi OS 64-bit Lite using libcamera-apps / libcamera. Setup instructions for the original CinePI are at **github.com/CinePI**.

ER | Short Film

1:56 / 6:15

03 Csaba details the core build elements at **magpi.cc/CinePIbuild** and will add CinePI XL instructions in due course. Camera design resources are at **github.com/schoolpost**.

Fixing Galaga

The arcade classic itself doesn't need fixing, but Nick Bild found his copy in need of maintenance. **Rob Zwetsloot** finds out how he went above and beyond a simple repair

MAKER

Nick Bild

An engineer and electronics hobbyist who likes to experiment with the latest hardware and technologies, he also builds retro gadgets around 1980s tech.

magpi.cc/ fixgalaga

When you get to your early 40s like 1981's Galaga, you may find that everything doesn't quite work as well as it used to. Maker Nick Bild's mini Galaga arcade machine is significantly younger than the original cabinets, but still found itself in a position for repairs. They wouldn't be easy, so Nick came up with a very creative solution.

"I came up with an elaborate way to 'fix' it involving robots, Raspberry Pis, computer vision, and more," Nick tells us. "I first created a first-person view robot that streams data to a Raspberry Pi 4 that I put in the arcade cabinet. Using the Galaga machine's joystick, I can drive that robot around and see what it sees on the arcade cabinet's display. I have an installation of RetroPie on a Raspberry Pi 3 in another room that includes Galaga for the Atari 7800. I drive the robot into that room and point its camera at the TV playing Galaga. I then press a button to switch the arcade into 'game' mode, and I can control the action in the game using the mini arcade controls."

It's like a Rube Goldberg machine from Looney Tunes or Wallace and Gromit, and we think it also crosses the boundary into modern art too. Nick says he hates to throw away electronics, and likes to repurpose them if he can't fix them, which has resulted in this interesting fix.

What a fix

"After gutting the arcade cabinet, I installed a new 320×240 LCD display of the same size as the original," Nick reveals. "The display, along with the joystick and buttons, are wired to a Raspberry Pi 4 computer that fits inside the casing. Raspberry Pi runs fbcp-ili9341 to use the LCD as its main display. It also runs a custom Python

> 🟦 I came up with an elaborate way to 'fix' it involving robots, Raspberry Pis, computer vision, and more 🟦

script which handles input from the joystick and buttons.

"The arcade operates in two modes – 'drive' and 'game', which are toggled by the 'Start' button. In drive mode, the script sends HTTP requests to a laptop that issues ROS 2 commands over Wi-Fi that control the movements of the robot. In game mode, HTTP requests are sent to an Arduino Nano 33 IoT attached to a Raspberry Pi 3, running RetroPie and emulating Galaga, that acts as a keyboard emulator. This allows remote key-strokes to be sent to control the action in the game."

▲ This robot plays Galaga for you – with your guidance
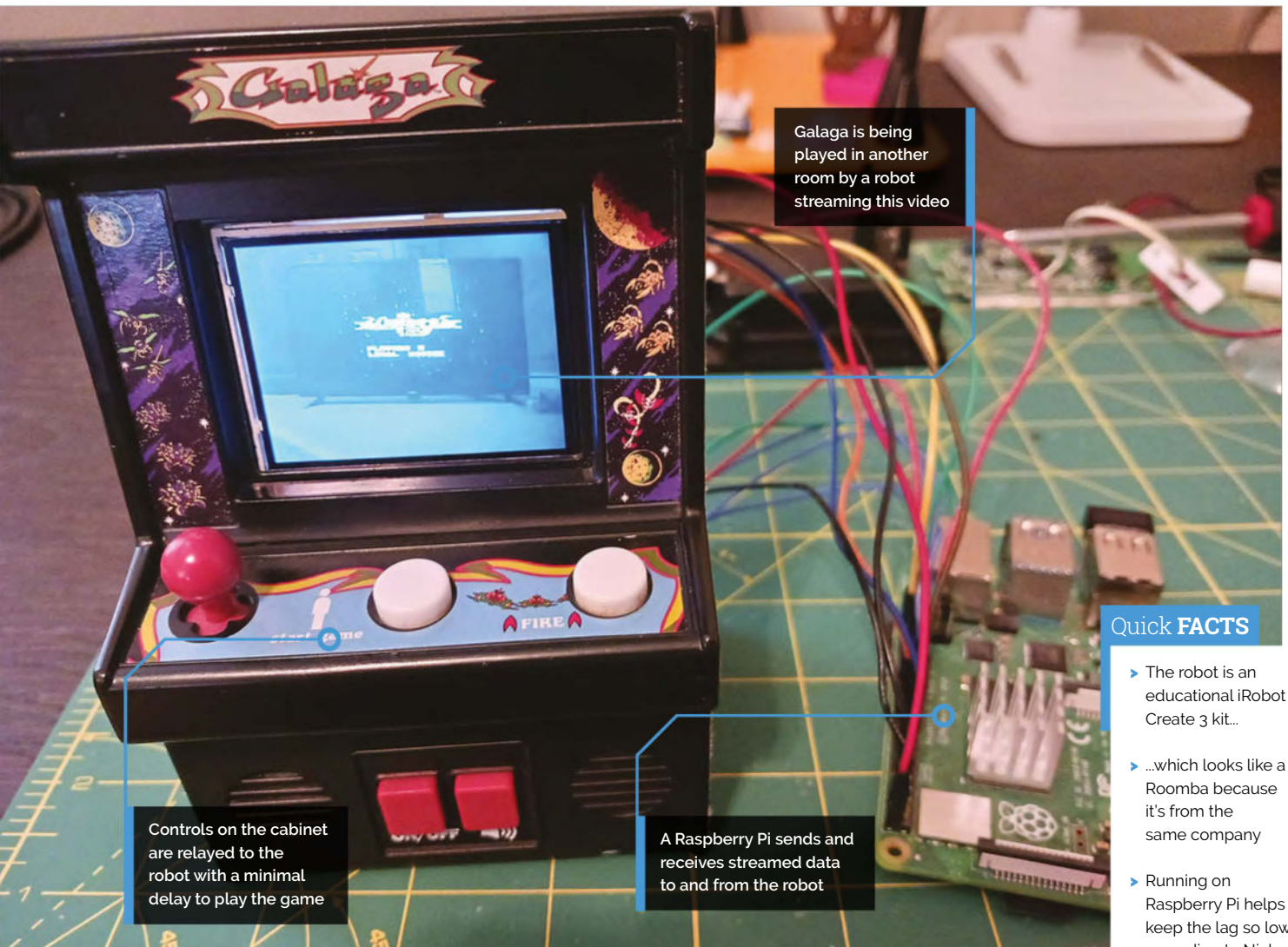
Galaga is being played in another room by a robot streaming this video

Controls on the cabinet are relayed to the robot with a minimal delay to play the game

A Raspberry Pi sends and receives streamed data to and from the robot

The robot has an Espressif ESP‑EYE camera board connected to ESP32 MJPEG streaming server which allows for sub‑second video streaming delays – very impressive and also fairly necessary for the experience to feel as organic as possible.

Remote control

With all this tech, was Nick able to fix his Galaga machine? Yes, as he explains.

"It works surprisingly well in some respects. The game is clearly visible on the display screen, and the lag is only about 200 milliseconds, which is acceptable for most retro games — nothing happens much faster than that in games of that era," Nick says. "As for the robot, the controls are smooth and it is easy to get around without bumping into obstacles."

We look forward to the explosion of arcade cabinet repair kits with streaming robot cameras at their core. M

▲ The special camera here allows for very quick relaying of video

PiArtFrame

Display fractal art with this art frame project. By **Ashley Whittaker**

MAKER

Karl Mose

Karl is a PhD student at Trinity Hall Cambridge.

magpi.cc/ piartframegit

▼ You can see the ribbon cable peeking from behind the wooden frame at the top of this image

This excellently simple fractal art display (magpi.cc/piartframe) by Cambridge student Karl Mose is perfectly pitched as a beginner project for someone looking for a geeky desk trinket.

What are fractals?

Fractals are shapes that contain complex detail however closely you look at them, or however far you zoom in. Often, they are self-similar: if you zoom in on the small-scale detail, you find it resembles the overall shape. Some of the most familiar forms that have fractal features are ones found in nature, like fern leaves and frost patterns, and we bet we're not the only ones who call Romanesco "fractal cauliflowers".

They are also beautiful. Fractal art can be created algorithmically by software, with the results usually represented as still digital images or animations. It all kicked off in the mid-1980s, so it's the kind of thing that's likely to be right up our street.

The maker kept the assembly pretty simple, cutting a small hole in the picture frame's back mount panel to slip the display HAT's ribbon cable through, with the project's Raspberry Pi left free-floating behind it. The e-ink display itself fits snugly inside the frame, with a card mount providing a little breathing space between the display and the glass.

Software setup

Getting the software going looks to be as elegantly easy as the hardware. All the code you need is on GitHub (**magpi.cc/piartframegit**), including a step-by-step guide in the README. It generates part of a Mandelbrot set with dimensions to suit the e-paper screen, then renders it for display.

Fellow maker Rob Weber has added extra code to the GitHub repository from the Omni-EPD project

> ❝ Fractal art can be created algorithmically by software, with the results usually represented as still digital images ❞

(**magpi.cc/omniepd**). The additional code allows for more electronic display types to be used.

We're not going to get into what the Mandelbrot set is, but Jimi Sol in this here video seems to do a great job of explaining: **magpi.cc/mandelbrotsetYT**.

"I bought the panel from the Waveshare Amazon store (**magpi.cc/waveshare75**)," says Karl. "For the 7.5 in Waveshare panel, I'd recommend getting an 18×24 cm frame [such as **magpi.cc/ waltherframe**]." Karl also ordered a custom frame from Best4Frames (**best4frames.co.uk**): "I ordered mine around 15×9.7 cm, which is one of the smallest cutouts they can make."
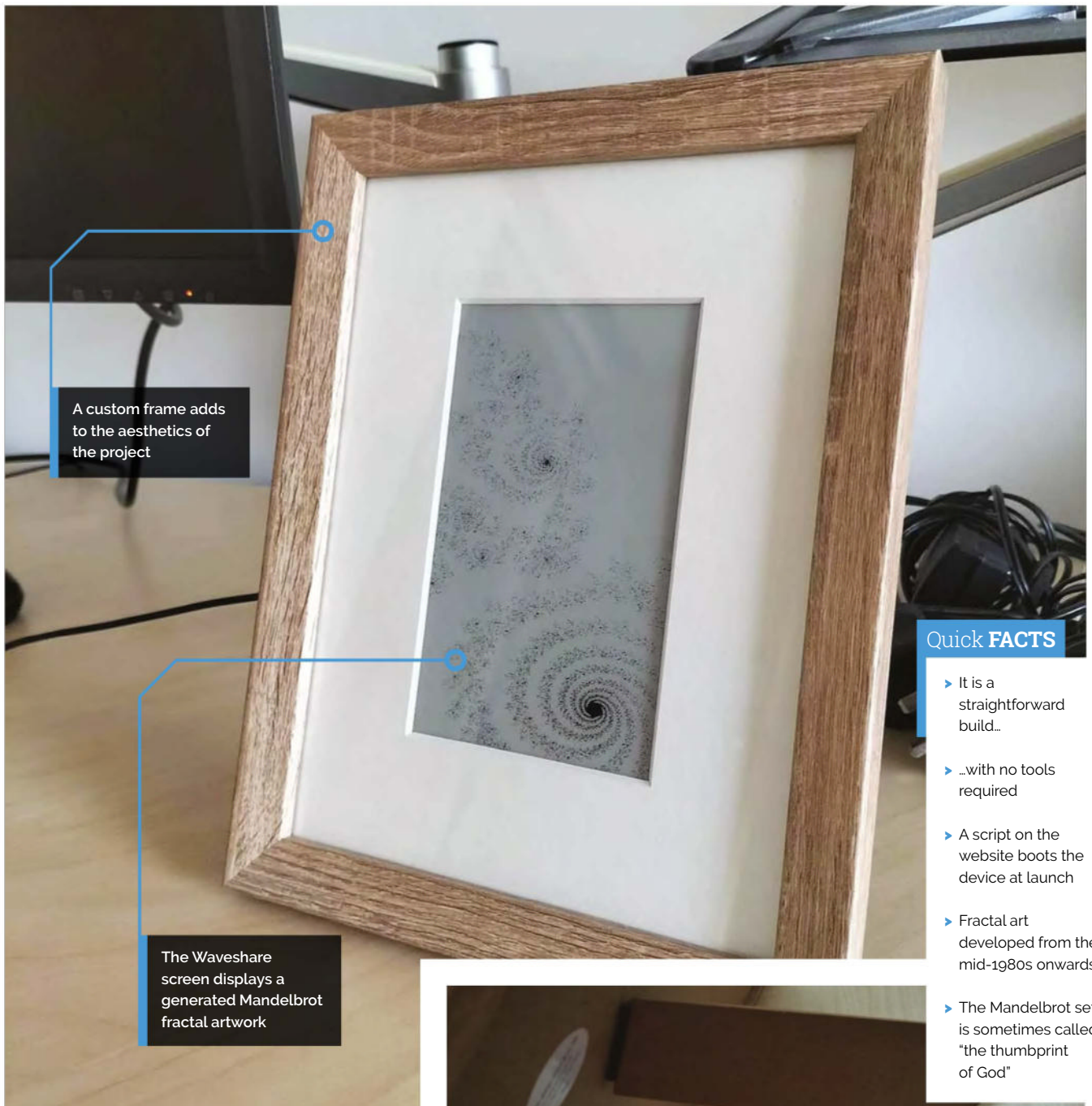
A custom frame adds to the aesthetics of the project

The Waveshare screen displays a generated Mandelbrot fractal artwork

Quick **FACTS**

> It is a straightforward build…

> …with no tools required

> A script on the website boots the device at launch

> Fractal art developed from the mid-1980s onwards

> The Mandelbrot set is sometimes called "the thumbprint of God"

"The picture mount is good for aesthetics," explains Karl alongside offering "extra protection." A small slit on the side of the back panel of the frame allows access to the ribbon cable. "I attached it to the header which comes with the Waveshare panel, and which goes directly on [Raspberry] Pi Zero.

"Those of you who are more gifted in building might be able to come up with an enclosure, but in my build Raspberry Pi is free-floating," says Karl. **M**
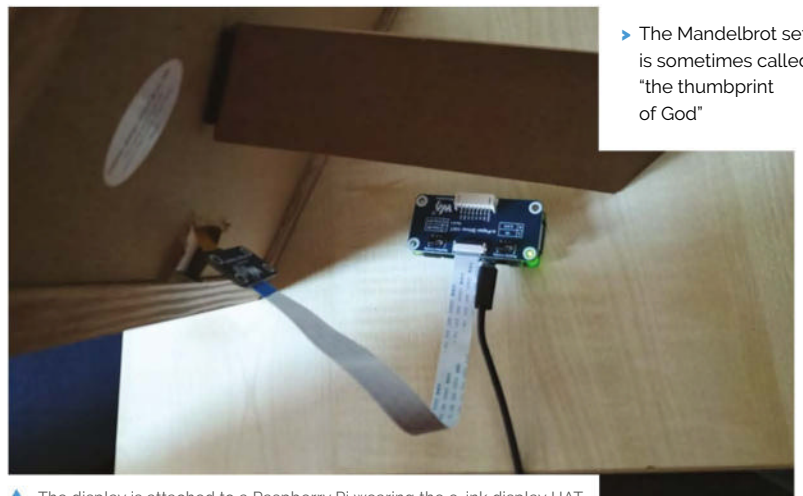
▲ The display is attached to a Raspberry Pi wearing the e-ink display HAT

Clinical IT device: EKORA

Clinical IT makes clever use of Raspberry Pi to securely manage patient data. By **Rosie Hattersley**

Clinical IT was set up by two NHS cardiologists to help physiologists and cardiology specialists and has a mission to transform both heart cardiology departments and patient care. With decades of patient care experience gleaned during their work at NHS hospitals, founders Dr Alan Robertson and Dr Dougie Elder knew there was a real issue with the physical management of patient records, and a lack of satisfactory and secure means to transfer data securely from pacemaker programmers. The pair set about filling an unmet need for efficient data management while also speeding up access to the thousands of patient records that were languishing in filing cabinets. Clinical IT was set up to address this costly and inefficient means of accessing patient records.

THE CHALLENGE

Physiologists have huge patient lists and need to assess data from pacemakers and other personal medical equipment easily, so they can decide how well each patient is and make any necessary changes to their care. At present, this data is often output in the form of successive small sheets by a thermal printer integrated into a ruggedised laptop used solely for this purpose. NHS security protocols preclude more straightforward means of accessing and storing this data, which has led to a legacy of paper records still being kept and stored in filing cabinets in dedicated strongrooms in order to adhere to patient confidentiality requirements. With 7000 cardiology patients on the books of the NHS Lothian region alone, paper record keeping and laborious note-taking by specialist staff is very time-consuming, can easily lead to inaccuracies, and the resulting storage requirements take up significant areas of hospital real estate.
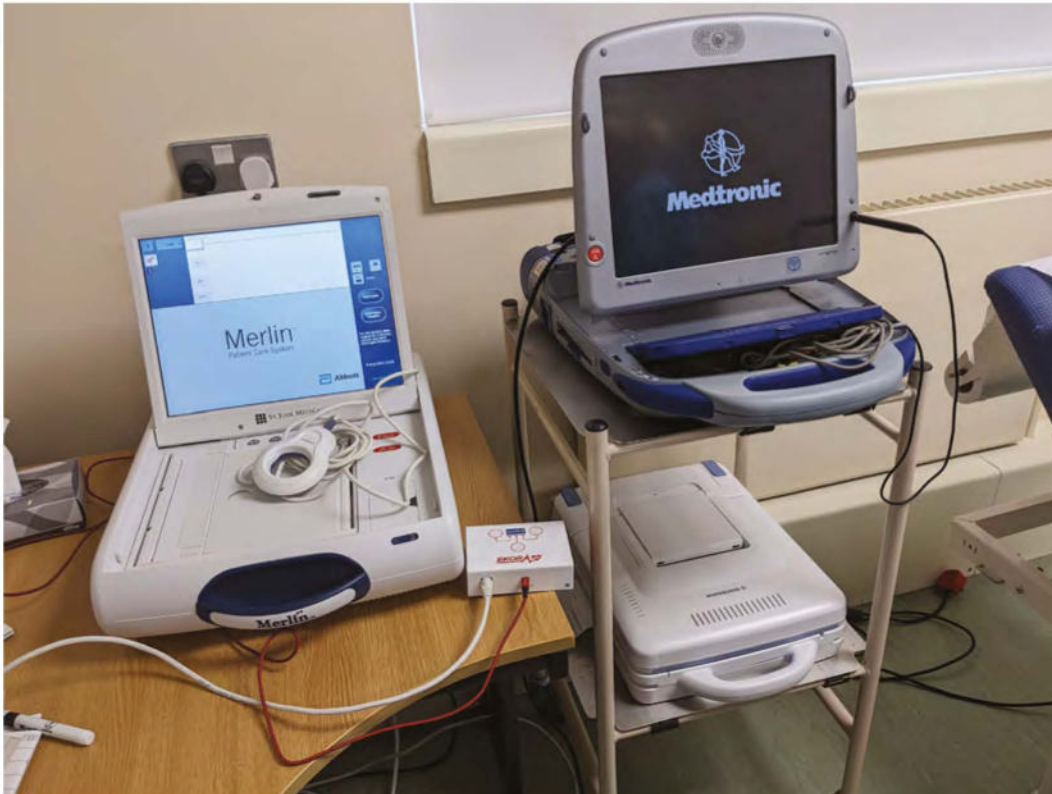
Furthermore, there are at least four manufacturers of pacemakers and defibrillators that a patient may have fitted, so there is no single solution for conveniently accessing the electronic data using a single brand's sensor reader. Details can, however, be downloaded to a USB thumb drive for access offline. Unfortunately, USB sticks are a known security risk, so hospitals IT systems block their use for fear of both viruses and of confidential data being leaked.

About a decade ago, consultant cardiologist Dr Alan Robertson of Ninewells Hospital in Dundee had been grappling with these issues and got talking to a colleague who was also a cardiologist. "We were basically fed up about not having an IT solution that helps us properly look after patients, so we decided to come up with something ourselves."

Alan explains that some people get a defibrillator fitted because their heart's response at times needs a strong electric shock to get them back to a normal rhythm. "That episode is the kind where you want to store what happened because it will actually show the heart rhythm during the episode and whether the treatment was appropriate. It's something you don't really want

to lose. So therefore, we ended up having literally filing cabinets full [of paper records]".

With plenty of non-networked devices that also held vital data he needed to read, Dr Robertson knew legacy hardware was another issue that would need to be overcome. "One of the pain points and issues we had was: when you have a patient who's got a pacemaker, they come to get follow-up at the hospital even though there is wireless connectivity there, but the information can't be accessed due to security. They want to download information to a program on a special laptop and you want a way to get information out of that. You could get this information using a USB stick, but in a hospital you can't just use normal USB sticks due to NHS security. Our difficulty was how to get this information across."

Faced with an ever-expanding patient list, Alan was delighted when he made the discovery that USB On-The-Go could be used to in a similar way to a hard disk and quickly realised that Raspberry Pi could potentially provide a workable solution.

WHY RASPBERRY PI?
Having been looking into Raspberry Pi for a while, Dr Robertson realised that it could play a role,

especially as it can emulate a flash drive [using USB OTG]. He then wrote code for the Raspberry Pi Zero W "to pretend to be a flash drive" and, when you plug it into the specially programmed laptop, it is able to access the relevant information while remaining encrypted.

"You can save all information in an encrypted form and then it gets sent over the network back

> **"** Physiologists have huge patient lists and need to assess data from pacemakers and other personal medical equipment easily **"**

to the core system, which then is able to deal with it and process it," says Alan of the EKORA solution to how you bridge getting information from a kind of standalone device into the network system they wanted.

The pacemaker programmers are, in effect, ruggedised laptops running custom software provided by the manufacturer, explains Alan. "Thanks to Raspberry Pi Zero W, we've got a lovely compact and low-power solution that includes USB OTG functionality that was just spot-on for

our requirements." Alan designed custom PCBs in KiCAD for touch control – an important factor was the sturdiness of the plastic casings and the fact they can be wiped down to reduce infections – with an OLED screen to feed back to the user "making excellent use of Raspberry Pi's GPIO capabilities (both I2C and SPI)."

The level of support available from the community, and running on such a well-designed OS such as Raspberry Pi OS Lite, made all the difference during development, he says.

THE SOLUTION

In contrast to the patient-centric data-reading devices that abound – Libre and Dexcom for glucose monitoring; Noom for calorie intake; and others for cholesterol, heart rates and other metrics – EKORA is specifically designed to be accessed and read by healthcare professionals. These specialist physiologists are able to securely access the patient information, but no one else can.

Code for the EKORA device has been developed and iterated over time using feedback from the physiologists who use it. There is no specialist knowledge required on their part to operate it, as the code pairs up as the Raspberry Pi Zero W inside
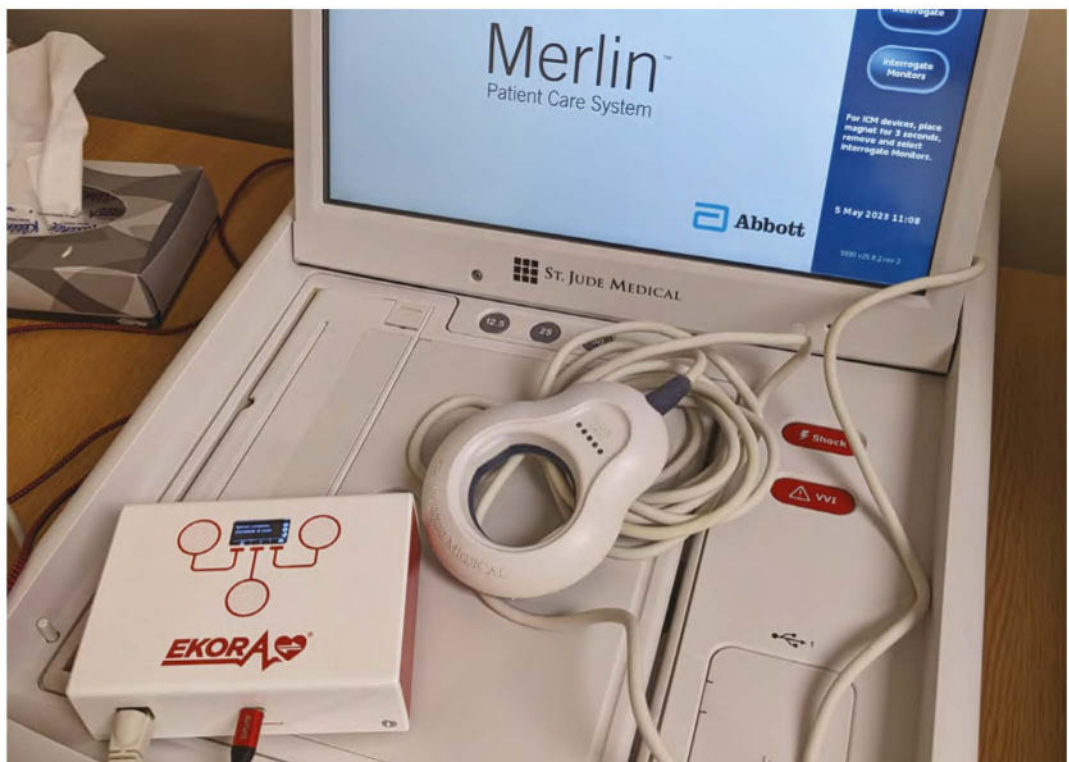
loads up and then automatically locates and sends the data they need securely over the network.

Alan took charge of the EKORA box design himself, specifying the custom circuit board and working with a UK-based company, Custom Design Technologies, to create a case from "a particularly robust plastic since normal 3D printed plastic wouldn't cut it" in a hospital environment. It was also important to minimise the risk of germs, so there is a ruggedised touchscreen device with a wipe-clean surface rather than physical buttons for the user information screen.

They have gradually evolved what was to become EKORA over the past six years, improving and refining their Raspberry Pi Zero W-based device. At present they are "investing money into other hospitals and places that use EKORA and trying to grow the business to continue to improve care for cardiology patients."

THE RESULTS

The system was trialled and rolled out in 2016 at the hospital in Dundee where Dr Robertson works, and is now also in hospitals in Ayr and Edinburgh (**ekora.io/nhs-lothian**). During the Covid pandemic, the EKORA approach to holistic patient data really proved its worth. In fact, Alan says the broader purpose is being able to securely pull information from devices made by all of the four or five big pacemaker manufacturers, and from their different websites to integrate it into one place. The aspect that Raspberry Pi helped with was "this important, in-person bit" when they come into hospital for their check-up.

There was a risk with the previous, paper-based, system that urgent follow-up appointments were overlooked and learning from across the spectrum of cases was not able to be easily shared. Now, however, the secure and confidential EKORA
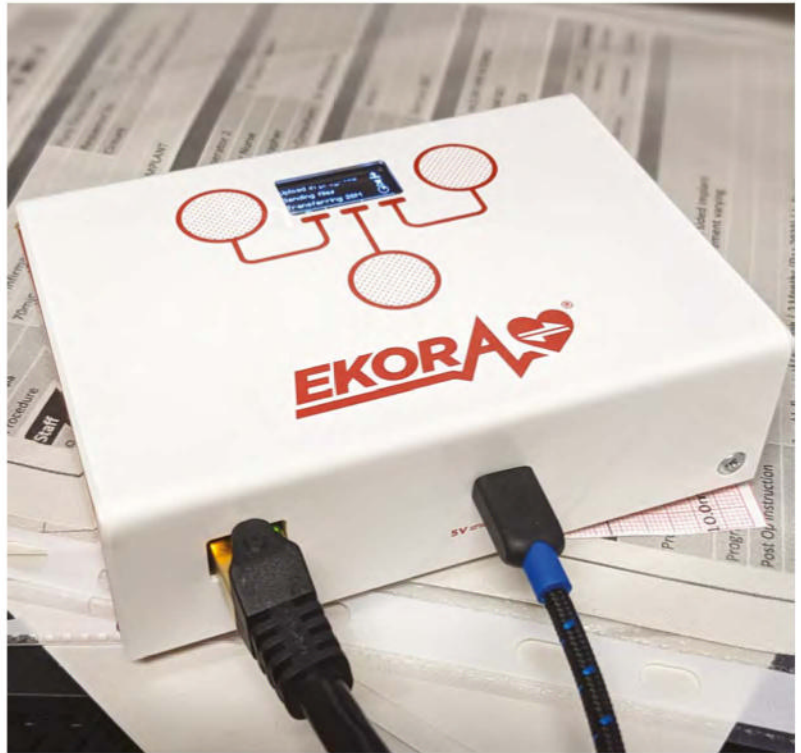
system provides a central management system that can be set to flag urgent cases for follow-up and automatically schedule review meetings for each patient. This streamlines cardiology care, speeds up data downloads, automates readings and stores records securely, while also freeing up physiologists to see more patients. Raspberry Pi USB On The Go secure data downloads from the cardiology programmers is the linchpin for this setup.
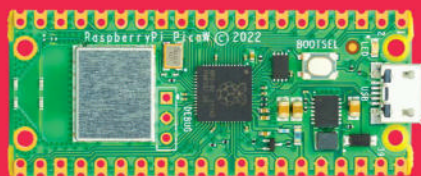
As well as hospitals in Scotland, Critical IT is in discussions with a number of NHS trusts elsewhere in the UK as well as Finland and Sweden, and also has an eye on expansion further afield. "At some point, I imagine all the programmers that we have in the hospital will start to go wireless. Already some companies have ones that are tablet-based, but interestingly a lot of hospitals don't like having things on wireless; they want to have it on a physical wired network." This provides a new commercial angle for EKORA since it's essentially a secure bridge between wireless devices and wired networks. The development of wireless programmers was something that might have made the uploader unit redundant, yet it appears, in fact, the opposite is the case. "It is slightly ironic," says Alan, "but it looks like there will be an ongoing use for it for many years to come." M

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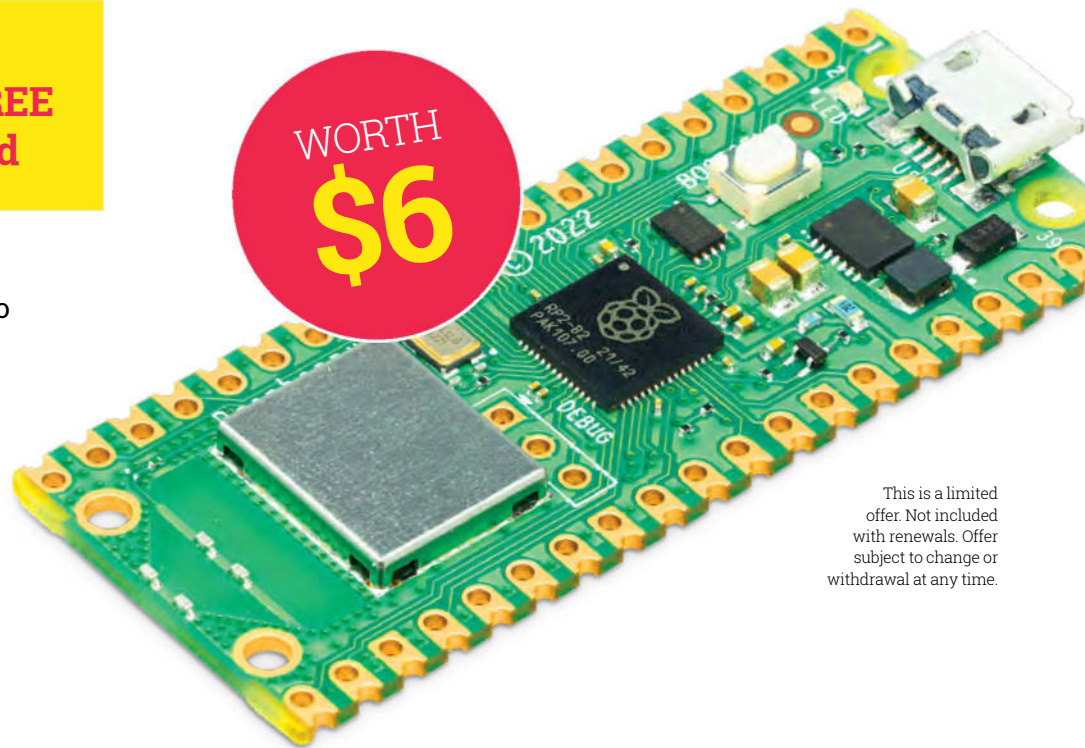
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Raspberry Pi 5
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magpi.cc/priorityboarding

START YOUR RASPBERRY PI ADVENTURE

So you seek the power of Raspberry Pi, adventurer? Look no further, let us share ancient (and not-so-ancient) wisdom. PJ Evans grabs his foam sword

We're not going to labour the Dungeons & Dragons metaphor (OK, maybe just a bit) but just like anyone setting out on an adventure, you may have little idea of how to start. If you did, it wouldn't be an adventure, and where's the fun in that? If you're completely new to Raspberry Pi, these pages will take you from the beginning and guide you through your first experiences with this little marvel. We'll cover using it as a desktop computer as well as the fun of physical computing and connecting your Raspberry Pi to the outside world. So, grab your knapsack of essentials (snacks) and let's go.

A tour of Raspberry Pi 5

So you've taken it out of the box. That's a good idea and a positive step forward, but what are you now looking at? Here are the essentials you need to know

Here is your USB-C power connector; without energy, this particular jewel is worthless

This small connector is a Raspberry Pi connector for PCIe Expect to see exciting peripherals very soon

If you want to see what's going on, you'll need to connect a HDMI cable to either of these ports. You'll need a micro-HDMI to HDMI cable and yes, you can run two displays at 4K if you want!

SD cards act like a hard drive for your Raspberry Pi. You slot them in under here. The new on/off button sits alongside

These more delicate connectors allow you to add one or two Raspberry Pi cameras to your setup or the official 7-inch touchscreen

The unique GPIO is one of the jewels in Raspberry Pi's crown. It provides a gateway to the outside world. Connect devices, LEDs, switches, sensors and more
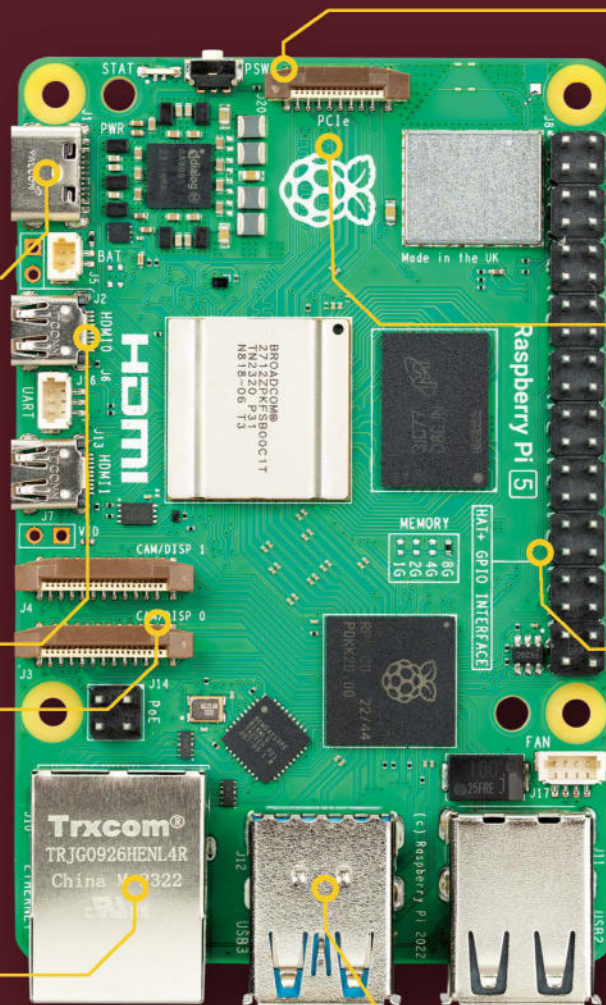
Raspberry Pi 5 has great Wi-Fi, but you can also use wired Gigabit Ethernet for rock-solid network connectivity

Lots of USB ports, including super-fast USB 3.0 (the blue ones). This is where you connect your keyboard and mouse

SETTING UP YOUR RASPBERRY PI 5

YOUR FIRST ADVENTURE IS THE MOST IMPORTANT! YOU CAN'T TAKE ON QUESTS WITHOUT A WORKING RASPBERRY PI

MAKER

PJ
Evans

When not on epic journeys and slaying dragons (actually befriending them), PJ is a writer, software engineer, tinkerer and level-15 wizard.

mastodon. social/@ mrpjevans

You'll Need

➤ Another computer for writing the OS to a microSD card (16GB or more)
magpi.cc/ microsdcard

➤ Official power supply
magpi.cc/ powersupply

➤ USB keyboard and mouse
**magpi.cc/ keyboard
magpi.cc/mouse**

➤ HDMI TV or monitor

➤ Micro-HDMI to HDMI cable
magpi.cc/ microhdmi

To the initiate, a Raspberry Pi can look a little intimidating. It lacks some of the friendliness of a traditional desktop. You've got a bare circuit board with little else, and that can seem a bit strange on your first encounter. Don't worry: everything can be explained and we can have you adventuring in no time. We'll get the software sorted out, the hardware plugged in, and get you on to the internet. Just remember to take your time, check everything twice, and learn as you go.

1 ### Acquire the spell book
OK, OK, we won't go overboard again on the D&D thing. What we mean is the first thing you need to do is prepare the operating system for your Raspberry Pi. An operating system (OS) is the foundation on which all applications run. But how to get it onto your Raspberry Pi? We need to get it written to an SD card that will then be inserted into the slot on the Raspberry Pi. Start by downloading Raspberry Pi Imager (**magpi.cc/imager**), which makes writing SD card images simple.

2 ### Incant the spell!
Sorry, we did it again. Never mind. Start Raspberry Pi Imager and make sure your microSD card is inserted into your computer, using an adapter if your machine does not have a microSD card slot. First, click on 'CHOOSE OS' and select the first option 'Raspberry Pi OS (64-bit)'. Now select 'CHOOSE STORAGE' and you should see your SD card (check the size to be sure). Now click 'Write'. You may need to enter your password at this point; that's normal. The image will be written to the microSD card and then verified to check everything went well. When prompted, you can remove the

microSD card. We have a more in-depth guide to using Imager on page 40.

3 ### Assemble the hardware
It's time to get everything plugged in. If you don't have a case, be very careful and only hold your Raspberry Pi by the edges. Do not place it on a metal surface or anything that might conduct electricity. Start by connecting the keyboard and mouse to the USB ports (it doesn't matter which). Now connect the micro-HDMI connector to either of the two available ports and the larger HDMI end to your monitor or TV. Finally, connect the unplugged USB-C power supply to your Raspberry Pi. Make sure your monitor is on and plug the power supply in.

4 ### Behold the life-giving spell!
Sorry, that's a slight overreaction. What you should see is a red & green flickering light on the Raspberry Pi as it comes to life. Your monitor should display some Raspberry Pi logos and a stream of text. Do not worry about this, it's nothing

▲ SD cards are very fragile. Insert the card gently into the slot with the gold contacts facing the underside of the board

Got some hard tasks planned for your Raspberry Pi? Get a Raspberry Pi Case or Raspberry Pi Active Cooler like this one

Raspberry Pi 5 features Gigabit Ethernet and USB 3.0 ports

you need to read if all is well. The Raspberry Pi may boot once or twice during this initial period. It's setting everything up and ensuring that all the space on your SD card can be used. Shortly, you'll see the desktop appear for the first time. Congratulations, your Raspberry Pi is ready for use.

5 Wait, youngling! It must be fed!

Well, not fed exactly, but updated. Raspberry Pi software is constantly being updated, almost daily. Before doing anything, we recommend you ensure your software is absolutely on the latest version. To do this, watch out for a symbol in the top-right corner of the screen with a downward-pointing arrow. This is an indicator that software updates are available. Give it a click and follow

the prompts to make sure the system is in tip-top shape. Whenever you see this symbol appear, we recommend you update as soon as possible.

6 Commune with the other beings

We mean networking. The best option is always wired. If that works for you, just connect an Ethernet cable between your Raspberry Pi and your internet router. Within a few seconds, you'll be good to go. If you prefer Wi-Fi, click the pair of arrows in the top-right of the screen and you can configure your connection there. You'll need your SSID (Wi-Fi network name) and the password. Once set, open Chromium (a bare-bones version of Chrome) and you can set sail across the internet. What now? Have a look at our side-quests!
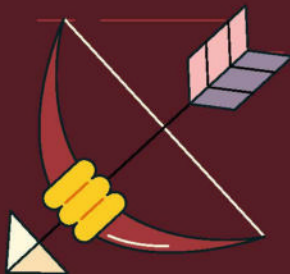
ACCESSORIES

It's dangerous to go alone, take these!

A s amazing as a Raspberry Pi 5 is, on its own, it won't do much. At the very least you need power. After that, there is a seemingly endless range of accessories so you can customise to your heart's content and build a perfect project. Considering its small size, you have a surprisingly wide range of connectors to make use of including USB 3.0, the versatile GPIO header, and for the first time, PCI Express. The choice can be overwhelming, so here are some of the most important accessories you should consider for your Raspberry Pi adventure.

PROTECT YOUR TREASURE

Your Raspberry Pi is going to need some protection from the elements, so a case should be your number one purchase. A change in the layout of Raspberry Pi 5 means that new cases are needed, but you can already get the official case (**magpi.cc/case**) and both Pimoroni and Argon have theirs on the way.

BEWARE THE DRAGON'S BREATH!

Recent Raspberry Pi models run faster than their older siblings. A Raspberry Pi 5 can work quite safely without any kind of assisted cooling provided, but if you want to get the most speed from it, cooling is useful. There is now the powerful new Raspberry Pi Active Cooler.

ENCODE THE ANCIENT RUNES

Want to use your Raspberry Pi as a desktop machine? You're going to need a keyboard and mouse. Luckily, the vast majority of USB keyboards and mice will work instantly with Raspberry Pi 5 and you can even use wireless and Bluetooth devices with ease. The official pairing is a great choice: **magpi.cc/keyboard**.

WIELD THE STAFF OF POWER

Up for some gaming? Then get a decent controller. From inexpensive USB controllers to Bluetooth powerhouses, there's a wide range compatible with Raspberry Pi. We like 8BiTDo's range, which is perfect for retro gaming and the full AAA experience using services like Xbox Games Pass (**magpi.cc/pro2**).

Hear the songs of the people

Get a DAC or 'digital analogue converter'. Raspberry Pi has found a solid niche in performant audio playback. These add-ons (known as 'HATs') plug into the GPIO header and allow your Raspberry Pi to produce audiophile-quality audio. Pair with an OS like LibreELEC and you have your own media centre: **magpi.cc/dacpro**.

Illuminate the darkness

Raspberry Pi 5 can be more than a desktop computer – it can interact with the world around you by connecting electronics to the GPIO pins. Play with LEDs! If you feel a little unsure about this, then there are some great kits to get you started. We're huge fans of the CamJam series, starting with the EduKit #1: **magpi.cc/edukit**.

Capture souls

Whether it's setting up a webcam or building your own camera, photography has always been well supported by Raspberry Pi. The new model adds an extra slot for supporting multiple cameras. You can choose the HQ Camera board with mounts for different lenses, or the third generation of the standard Camera Module, now with auto-focus.

Don your wizard's hat

Everyone looks good in a hat, especially Raspberry Pi! HATs (Hardware Attached on Top) are boards that extend Raspberry Pi's functionality. If you can imagine it, there's probably a HAT that does it: displays, air monitoring, GPS, radio, climate, and more. A great one to start off with is Pimoroni's Enviro HAT for monitoring temperature and humidity: **magpi.cc/enviro**.
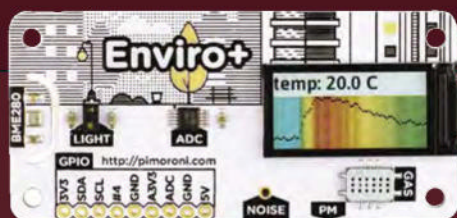
Enchant your memory

If you're looking for high-speed I/O and the microSD card is just not doing it for you, Raspberry Pi 5 is the first model to support the M.2 standard for SSD (solid-state drives) using its new Raspberry Pi interface for PCIe. The result will be a significant increase in speed. Coming soon!

10 Side quests for the rookie adventurer

Looking for inspiration? You have found your treasure. Consider these 10 quests you can undertake to truly begin to master the Raspberry Pi. All are within your reach, noble traveller…

Learn the Desktop

If you're completely new to Raspberry Pi, it's important to spend time learning the desktop environment. Raspberry Pi OS comes with some great software. Not only the usual office-type apps but programming environments, media players, and much more. You can add all of these from the Recommended Software app.

Write a game in Scratch

If you're new to programming, Scratch is the perfect introduction. It gives you a gentle introduction to the key concepts by using drag-and-drop 'blocks' to assemble code. It's a great learning tool, but most of all fun. It's already installed, so why not have a go at making a game! **magpi.cc/gettingstartedscratch**
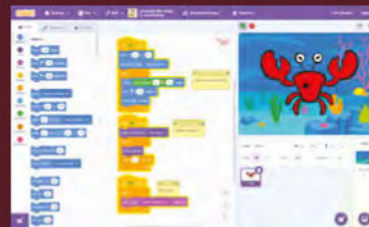
Blink an LED

It's hard to explain just how satisfying this first project is. Making an LED blink on and off is commonly everyone's first Raspberry Pi GPIO project and a gateway to greater things. You'll need a few electronic components (see the CamJam EduKit #1 mentioned earlier), then follow the guide at **magpi.cc/physcomputing**.

Build a robot

For the more ambitious, let your Raspberry Pi hit the road by mounting it on a robotic chassis. Learn about motors, servos, and sensors. Robotics is a hobby that never stops growing. One day you could enter Pi Wars, the fun competition for Raspberry Pi robots (**piwars.org**)). First, start here: **magpi.cc/buildbuggy**.

RETRO GAMING

As tiny as Raspberry Pi is, it is still an order of magnitude more powerful than its predecessors of the 1980s and '90s.

A thriving community has built up around emulating the classic consoles and home computers of that era. Check out the Recalbox project: **recalbox.com**.

MEDIA CENTRE

Why stop at music? Make your Raspberry Pi the centre of your media universe. LibreELEC (**libreelec.tv**) is a whole operating system based on Kodi. With it, your Raspberry Pi can be used to listen to music, view photos, and watch HD films. For streaming to various devices, check out Plex (**plex.com**).
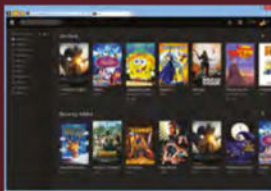
HOME AUTOMATION

Another popular use of our little computer is in home automation. The popular platform Home Assistant (**home-assistant.io**) is compatible with hundreds of smart home devices, including Philips Hue, Nest, Ring, and more. Create automations with scripting or build your own smart devices.

AUDIO PLAYER

If you want your Raspberry Pi to produce the best sounds around, get a DAC (digital to analogue converter) HAT to produce beautiful music. Pair it with software like Volumio to get a web-controllable playback interface. Here are lots of other options: **magpi.cc/mediaplayers**.
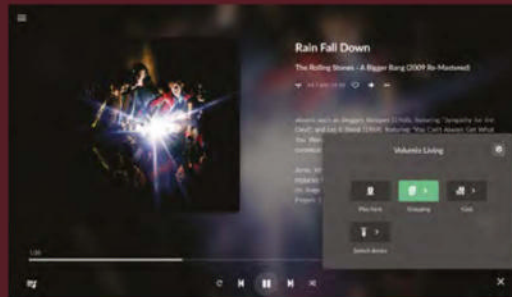
WILDLIFE CAMERA

Why not take a closer view of our feathered friends and other wildlife by setting up a Raspberry Pi wildlife camera? There are several ruggedised enclosures available that are suitable for life in the great outdoors. Add a camera and motion sensor and you're good to go: **magpi.cc/wildlifekate**.

MAGIC MIRROR

Another favourite of Raspberry Pi's community, the magic mirror takes a clear frame and adds a film of semi-transparent mirrored material. Place a screen behind it showing white-on-black images and the information looks to be hovering in thin air! Show calendar events, weather, news headlines, and more: **magpi.cc/buildmagicmirror**.

Ancient wisdom of the elders

We asked experienced Raspberry Pi users what they wished they had known when they bought their first one. Here's our favourites…

How to gain remote access

VNC allows you to see and control your desktop on a remote computer. You need to use SSH to connect your Raspberry Pi and enable VNC in Configuration. You can access Raspberry Pi OS desktop with TigerVNC (**tigervnc.org**). See The MagPi issue #136 (**magpi.cc/136**) for the in-detail solution!

Back up your OS

You can use SD Card Copier in Raspberry Pi OS to backup your Raspberry Pi to a second SD card, external disk drive, or PC. Then reset Raspberry Pi OS whenever you want.

How to get a history of commands

When using the terminal, you often have to enter long commands. Press **TAB** to autocomplete commands and file names, use the **UP** arrow to cycle through your history; enter 'history' to view everything, and **CTRL+R** allows you to search history and rerun a command with one keypress.
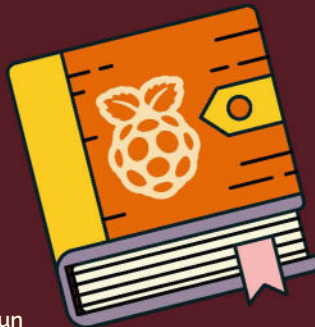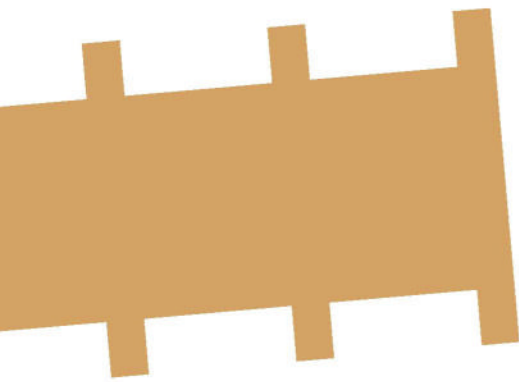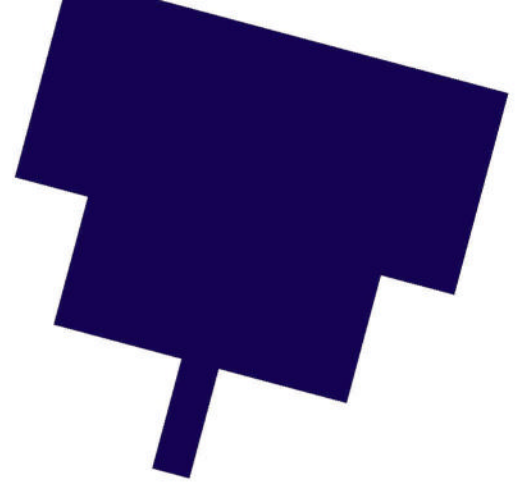
Making is moreish

You won't believe how moreish making can be, how much time it can take up, and how many new friends you will make along the way. Yes, Raspberry Pi enthusiasm can be incurable.

Not to use a cheap power adapter

This is one we sadly hear again and again. Always use a certified power supply. A phone charger is not the same thing, even if it has the same connector.

Install an operating system with Imager

Discover the new version of Raspberry Pi Imager with an updated installation process based on which Raspberry Pi board you use

MAKER

Alasdair Allan

Alasdair Allan is a scientist, author, hacker, and journalist. In the past, he has mesh-networked the Moscone Center, caused a US Senate hearing, and contributed to the detection of what was – at the time – the most distant object yet discovered in the universe.

magpi.cc/docs

You'll Need

> A Raspberry Pi computer
magpi.cc/products

> A microSD card and card reader
magpi.cc/microsdcard

magpi.cc/microsdcardreader

> A computer running an operating system: Linux, Windows, macOS, or a Raspberry Pi with Raspberry Pi OS working

To use your Raspberry Pi, you'll need an operating system. By default, Raspberry Pi computers check for an operating system on any microSD card inserted in the microSD card slot.

Depending on your Raspberry Pi model, you can also boot an operating system from other storage devices, including USB drives, storage connected via a HAT, and network storage.

To install an operating system on a storage device for your Raspberry Pi, you'll need:
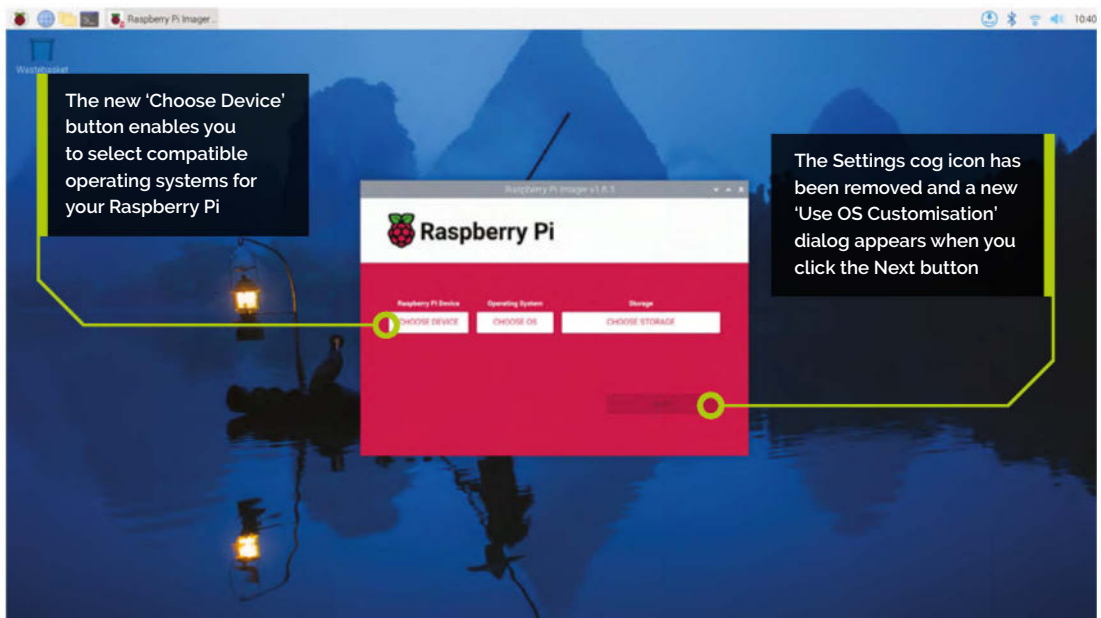- a computer you can use to image the storage device into a boot device
- a way to plug your storage device into that computer

Most Raspberry Pi users choose microSD cards as their boot device.

We recommend installing an operating system using Raspberry Pi Imager (**magpi.cc/imager**).

Raspberry Pi Imager is a tool that helps you download and write images on macOS, Windows, and Linux. Imager includes many popular operating system images for Raspberry Pi. Imager also supports loading images downloaded directly from Raspberry Pi or third-party vendors such as Ubuntu (**magpi.cc/ubuntu**). You can use Imager to preconfigure credentials and remote access settings for your Raspberry Pi.

Imager supports images packaged in the .img format as well as container formats like .zip. If you have no other computer to write an image

The new 'Choose Device' button enables you to select compatible operating systems for your Raspberry Pi

The Settings cog icon has been removed and a new 'Use OS Customisation' dialog appears when you click the Next button

to a boot device, you may be able to install an operating system directly on your Raspberry Pi from the internet (see 'Install over network').

You can install Imager in the following ways:
- Download the latest version from **magpi.cc/imager** and run the installer.
- Install it from a terminal using your package manager, e.g. `sudo apt install rpi-imager`.

Once you've installed Imager, launch the application by clicking the Raspberry Pi Imager icon or running `rpi-imager`.

Click 'Choose Device' and select your Raspberry Pi model from the list.

Next, click 'Choose OS' and select an operating system to install. Imager always shows the recommended version of Raspberry Pi OS for your model at the top of the list.

Connect your preferred storage device to your computer. For example, plug a microSD card in using an external or built-in SD card reader.

Then, click 'Choose Storage' and select your storage device. Next, click 'Write'.

In a pop-up, Imager will ask you to 'Use OS customisation'. We strongly recommend configuring your Raspberry Pi via the OS customisation settings. Click the 'Edit' button to open OS customisation.

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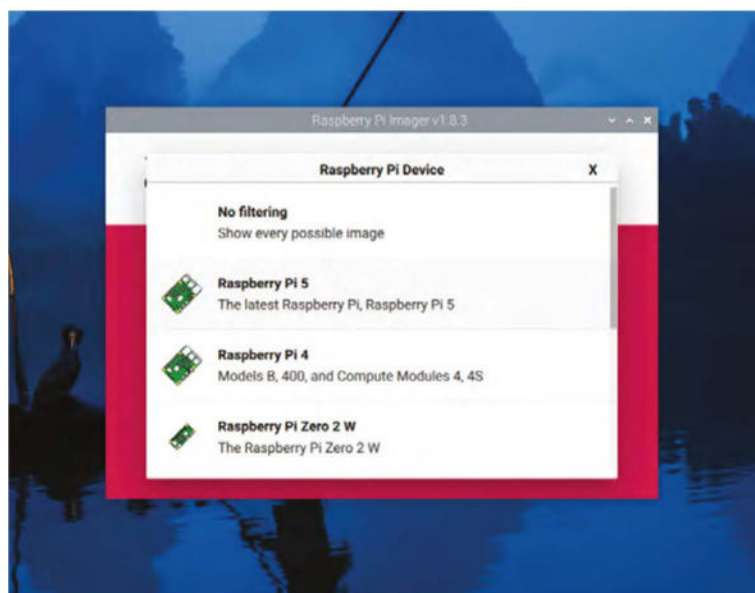
(**magpi.cc/configuration**). You can click the No button to skip OS customisation.

OS customisation

The OS Customisation menu lets you set up your Raspberry Pi before first boot. You can preconfigure:
- a username and password
- Wi-Fi credentials
- the device hostname
- the time zone
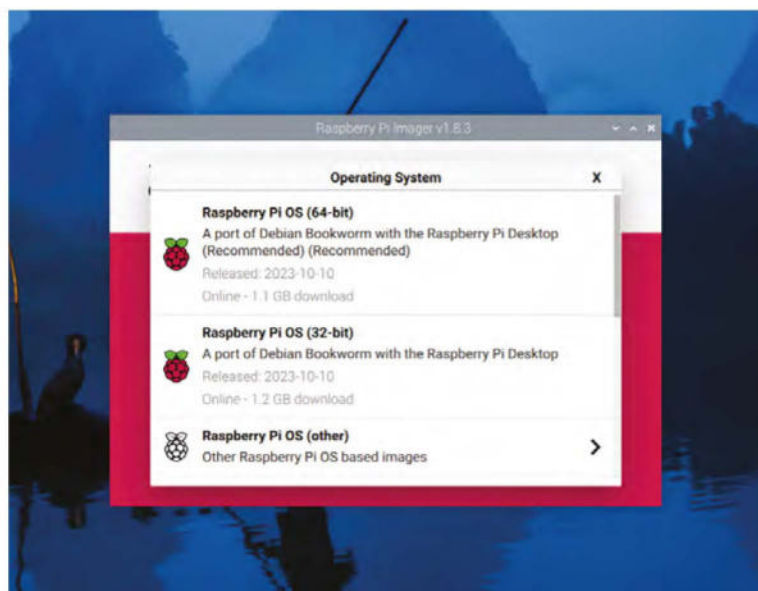- your keyboard layout
- remote connectivity

When you first open the OS customisation menu, you might see a prompt asking for permission to load Wi-Fi credentials from your host computer. If you respond 'Yes', Imager will prefill Wi-Fi credentials from
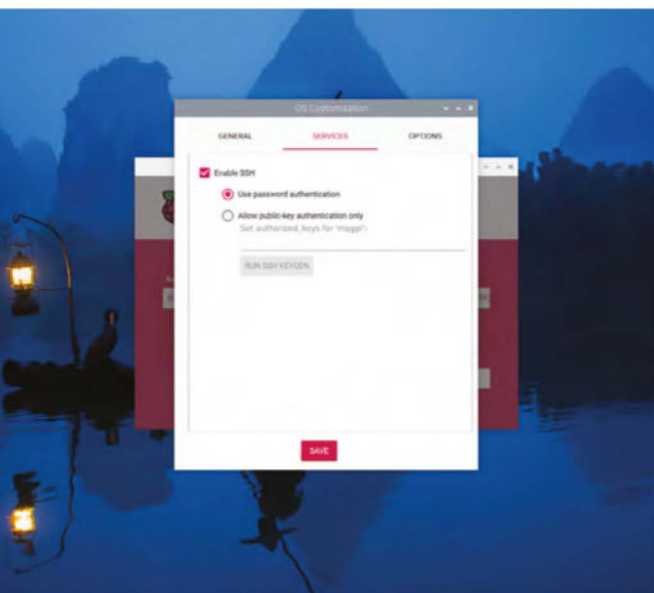

▲ The 'Raspberry Pi Device' dialog window is used to select the target device, and operating system options will match that model of Raspberry Pi

> **"** We recommend configuring your Raspberry Pi via the OS customisation settings **"**

the network you're currently connected to. If you respond 'No', you can enter Wi-Fi credentials manually.

The 'hostname' option defines the hostname your Raspberry Pi broadcasts to the network using mDNS (**magpi.cc/mdns**). When

◀ The 'Operating System' window offers Raspberry Pi OS (64-bit) as the recommended operating system on Raspberry Pi 5, 4, and 400, and Raspberry Pi OS (Legacy) for Raspberry Pi Zero 2 W, and older models

A new 'Use OS customisation' dialog window enables you to edit installation settings, and apply previously edited settings

Top Tip 👍

WARNING!

If you have more than one storage device connected to your computer, be sure to choose the correct device! You can often identify storage devices by size. If you're unsure, disconnect other devices until you've identified the device you want to image.

▼ The 'OS Customisation' window enables you to set hostname, username and password, and configure the Wi-Fi settings

you connect your Raspberry Pi to your network, other devices on the network can communicate with your computer using **<hostname>.local** or **<hostname>.lan**.

The 'username and password' option defines the username and password of the admin user account on your Raspberry Pi.

The 'wireless LAN' option allows you to enter an SSID (name) and password for your wireless network. If your network does not broadcast an SSID publicly, you should enable the 'Hidden SSID' setting. By default, Imager uses the country you're currently in as the 'Wireless LAN country'. This setting controls the Wi-Fi broadcast frequencies used by your Raspberry Pi. Enter credentials for the wireless LAN option if you plan to run a headless Raspberry Pi.

The 'locale' settings option allows you to define the time zone and default keyboard layout for your Raspberry Pi.

The 'Services' tab includes settings to help you connect to your Raspberry Pi remotely.

If you plan to use your Raspberry Pi remotely over your network, check the box next to 'Enable SSH'. You should enable this option if you plan to run a headless Raspberry Pi.

- Choose the 'password authentication' option to SSH into your Raspberry Pi over the network using the username and password you provided in the general tab of OS customisation.
- Choose 'Allow public-key authentication' only to preconfigure your Raspberry Pi for passwordless public-key SSH authentication using a private key from the computer you're currently using. If you already have an RSA

▲ Clicking the Services tab enables you to access SSH settings

key in your SSH configuration, Imager uses that public key. If you don't, you can click 'Run SSH-keygen' to generate a public/private key pair. Imager will use the newly generated public key.

OS customisation also includes an Options menu that allows you to configure the behaviour of Imager during a write. These options allow you to play a noise when Imager finishes verifying an image, to automatically unmount storage media after verification, and to disable telemetry.

Write

When you've finished entering OS customisation settings, click 'Save' to save your customisation.

The, click 'Yes' to apply OS customisation settings when you write the image to the storage device.

▲ After clicking 'Choose Storage', you should see your attached microSD card, which can usually be identified by its size

Finally, respond 'Yes' to the 'Are you sure you want to continue?' pop-up to begin writing data to the storage device. If you see an admin prompt asking for permissions to read and write to your storage medium, it's safe to proceed.

When you see the 'Write Successful' pop-up, your OS image has been completely written and verified. You're now ready to boot a Raspberry Pi from the storage device! M

Install over the network

Network Install enables a Raspberry Pi to install an operating system on a storage device using a version of Raspberry Pi Imager downloaded over the network. With Network Install, you can get an operating system installed on your Raspberry Pi with no separate SD card reader and no computer other than your Raspberry Pi. You can run Network Install on any compatible storage device, including SD cards and USB storage.

Network Install only runs on Raspberry Pi 4 or 400 (not yet on Raspberry Pi 5, see 'Top Tip' box). If your Raspberry Pi runs an older bootloader, you may need to update the bootloader to use Network Install. Network Install requires the following:
- a compatible Raspberry Pi model running firmware that supports Network Install
- a monitor
- a keyboard
- a wired internet connection

To launch Network Install, power on your Raspberry Pi while pressing and holding the **SHIFT** key in the following configuration:
- no bootable storage device
- attached keyboard
- attached compatible storage device, such as an SD card or USB storage

If you haven't already connected your Raspberry Pi to the internet, connect it with an Ethernet cable.

Once you're connected to the internet, your Raspberry Pi will download Raspberry Pi installer. If the download fails, you can repeat the process to try again.

As soon as you finish downloading Raspberry Pi Installer, your Raspberry Pi will automatically start Raspberry Pi Imager.

Part 01

Beepy: Make a DIY palmtop computer

Turn a Beepy handheld computer kit into a fully functional palmtop PC with our guide to ultimate terminal-based productivity

MAKER

K.G. Orphanides

KG is a developer and writer who desperately wants lighter-weight applications with worse graphics for less overpowered hardware.

twoot.space/ @owlbear

▶ WordGrinder provides a clean, unobtrusive and elegant pocket writing environment, with quality-of-life features such as autosaving and document sets

You'll Need

▶ SQFMI Beepy kit or equivalent
beepy.sqfmi.com

▶ 3D printed case (optional)
magpi.cc/slimflat

I f you've ever missed the golden age of palmtop computers, PDAs (personal digital assistants), and phones with physical keyboards, Squarofumi's Beepy might be the kit for you: just add a Raspberry Pi Zero W.

We've picked out a suite of software to turn Beepy into a portable productivity powerhouse. Squarofumi is preparing another production run of the Beepy kit, due to go on sale in early 2024, priced at $79. From Step 3 onwards, the applications in this tutorial will also work well on other handheld computer kits, but Beepy's 400×240 mono display combined with a Raspberry Pi Zero W makes it a particularly compact and power-efficient choice.

01 Set up your handheld computer

Detailed software and hardware setup instructions for the SQFM Beepy can be found at **magpi.cc/beepystarter**. Ensure that you're running the latest firmware and drivers, as keyboard mappings differ between versions. If you have a Beepy from the initial 'Beepeberry' release batch, it's a very good idea to fully reinstall it, as there have been significant changes to the keyboard maps. However, if required, a driver upgrade path exists (**magpi.cc/beepykeyboard**). If you're using another handheld computer kit, ensure your device is fully up-to-date. Before following this tutorial, open a Terminal and enter:

```
sudo apt update
sudo apt install git
```

02 Classy intro, extra sessions

To add virtual screen-switching functionality and a cute duck to Beepy, we're going to use youngoris's custom Tmux and Neofetch setup scripts (**magpi.cc/beepytmux**). SSH into Beepy and follow the Installation and Neofetch Configuration guides to configure Neofetch with a customised display for Beepy.

Then follow the Tmux configuration steps. Now, pressing the berry button will move to your first Tmux session. This means you can have multiple applications running, each in its own session. To create a new session hold the berry button, press **ALT**+**H** to display the prompt symbol ":" and type the word 'new'. Use **BERRY**+ **ALT**+**(** or **)** to cycle between sessions. See the Tmux Cheat Sheet (**tmuxcheatsheet.com**) for more shortcuts.

Finally, follow the Fbterm configuration instructions. Fbterm is a framebuffer terminal

emulator with improved support for font and graphical elements. Note that the fbterm config file referred to in the instructions is **.fbtermrc**, found in your home directory.

03 Install a word processor

While some might be happy using vim or Emacs for their word processing needs, we're getting that authentic retro PDA feel with the WordGrinder word processor, available from the Raspberry Pi OS repositories. Type:

```
sudo apt install wordgrinder
wordgrinder
```

When you launch WordGrinder, the first thing you'll see is a message telling you to press **ESC** to open the menu. On Beepy, the **BACK** button is mapped to **ESC**. You then press the initial letter of the menu option you wish to access. You can also navigate using **ESWD** as **UP**, **DOWN**, **LEFT** and **RIGHT** arrow keys by activating meta mode with a click of the **CENTRAL** button.

04 Working with WordGrinder

You won't need to spend much time in the menus, though, as this is an old-school, distraction-free writing environment. While it's not as fast as typing on a computer keyboard, Beepy's keyboard lends itself to accuracy – thumb size allowing.

However, if you're working on your magnum opus, you could probably enable auto-saving on your document by opening the menu with **ESC**/ **BACK** and going to File > Document Settings > Autosave, then pressing **SPACE** to enable the option and enter to confirm it.

WordGrinder saves in its native .WG format by default, but also supports the standard OpenDocument Text (.ODT) format, among others.

To quit WordGrinder, press **CTRL** (mapped to the **CALL** button) and **Q** or **X** in the File menu.

Full documentation is available at **magpi.cc/wordgrinder**.

05 Read your mail with Mutt

Mutt is an outstanding, highly configurable, and distraction-free email client for any system.
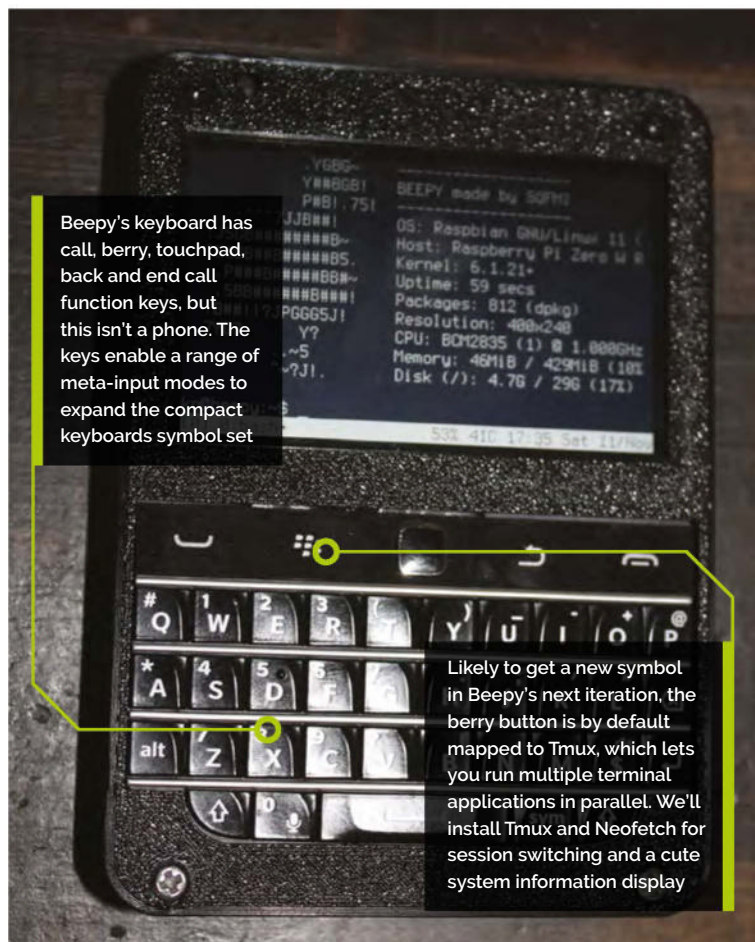
Beepy's keyboard has call, berry, touchpad, back and end call function keys, but this isn't a phone. The keys enable a range of meta-input modes to expand the compact keyboards symbol set

Likely to get a new symbol in Beepy's next iteration, the berry button is by default mapped to Tmux, which lets you run multiple terminal applications in parallel. We'll install Tmux and Neofetch for session switching and a cute system information display

We'll install, run and then configure it to access our IMAP email server. We host our own mail, but popular services such as Outlook and Gmail also support IMAP.

Make sure that you're in the root of your home directory, type:

```
sudo apt install mutt
nano .muttrc
```

You'll find our sample Mutt IMAP config in the code box. Enter your config, exit and save it with **CTRL**+**X**, and give it whirl:

```
mutt
```

When prompted to create a mail directory, say yes. When finished, press **Q** to quit.

Mutt's full manual lives at **magpi.cc/muttman**.

06 Everyone loves a spreadsheet

There are a surprising range of ncurses-based ('new curses', **magpi.cc/ncurses**)

Top Tip 👍

Board shorts

All of Beepy's keyboard modes and maps can be found at **magpi.cc/ beepykeyboardman**.

▲ The sc-im spreadsheet is inordinately powerful, even supporting multi-sheet Excel 365
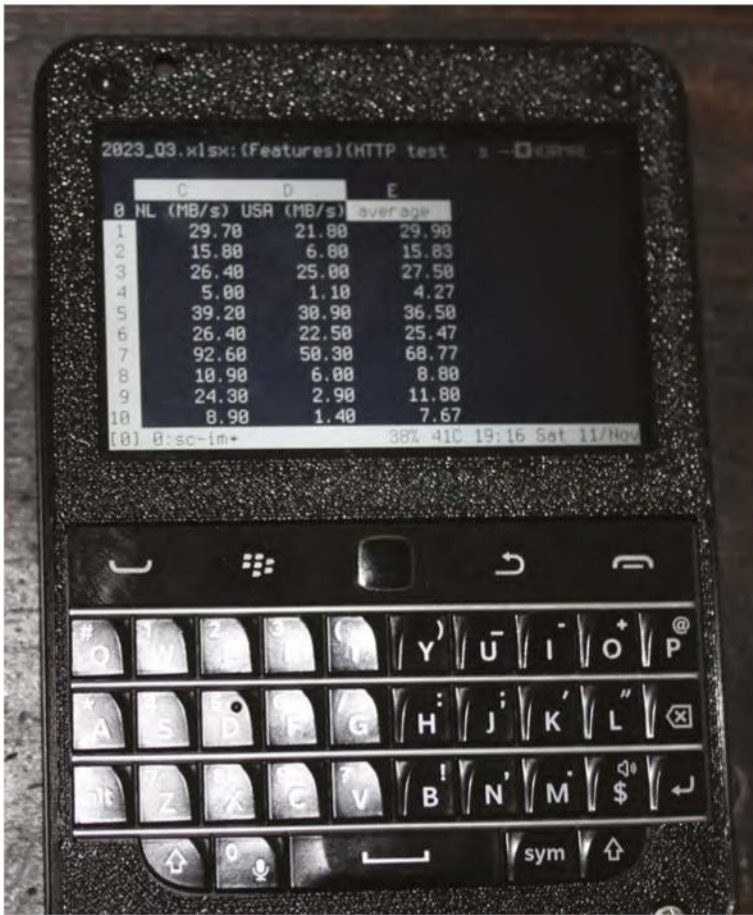
spreadsheets around, with a broad divide between those that use Emacs-style keybinds, such as Oleo, those that use vim-style bindings, like teapot and sc-im. We'll be using sc-im, with Excel XLSX file support via libxlsxwriter. Open Terminal and enter:

```
sudo apt install libzip-dev libxml2-dev
bison libncurses5-dev libncursesw5-dev build-
essential git
git clone https://github.com/jmcnamara/
libxlsxwriter.git
cd libxlsxwriter
make -j4
sudo make install
sudo ldconfig
cd
git clone https://github.com/andmarti1424/
sc-im.git
cd sc-im/src
make -j4
sudo make install
sc-im
```

See the quickstart guide (**magpi.cc/scimqs**) for navigation keys. Type **:q** to exit.

▲ A live Matrix chat feed on Beepy might not look pretty, but is both useful and extremely cyberpunk

07 What todo?

From project management to shuffling around the supermarket, todo lists are essential. We're going to use Taskwarrior (**taskwarrior.org**), a simple and effective command-line list tool.

```
sudo apt install taskwarrior
task add beans
```

Answer 'yes' when asked if you'd like to create a sample .taskrc file. To add a task, type 'task add' followed by the task; for example:

```
task add Start using Taskwarrior
```

To list your tasks, just type:

```
task
```

And to remove a task, provide its number and mark it done:

```
task 2 done
```

Find the full documentation at **taskwarrior.org/docs**.

08 Browse the web

What's the point of a portable device if you can't while away time on the internet? Time to install a web browser.

```
sudo apt install w3m
w3m -M ddg.gg
```

…w3m will open the DuckDuckGo search engine in monochrome mode (the `-M` option). Tab to the search bar by pressing **ALT**+**ENTER**, type your query, press **ALT**+**ENTER** again to go to the Search button, and press **ENTER** to search. The quickest way to navigate your results is by tabbing. You can just hold down **ALT** and press **ENTER** every time you wish to tab. See the w3m manual (**magpi.cc/w3mman**) for more navigation keys.

09 Jack into the Matrix

The Matrix encrypted messaging protocol is supported via the matrix-commander terminal tool. If you don't have a Matrix account, create one via the Element client at **magpi.cc/matrixreg**, find

▲ Mutt provides a more configurable IMAP and POP3 mail interface than most of its graphical counterparts. Online configuration guides are available for Gmail and Outlook

" Turn Beepy into a portable productivity powerhouse "

a server at **joinmatrix.org**, or host your own. SSH into Beepy and type:

```
sudo apt install python3-pip python3.11-venv
libolm-dev
python3 -m venv /home/YOUR-USER-NAME/matrix-
commander
cd matrix-commander
bin/pip install matrix-commander
```

Now let's put that in our path.

```
nano ~/.bashrc
```

Now add the following to the bottom of the file:

```
export PATH="$HOME/matrix-commander/
bin:$PATH"
```

Save and quit with **CTRL**+**X** and then reload the bashrc settings for your session:

```
source ~/.bashrc
echo $PATH
```

Save and exit Nano (**CTRL**+**O**, **CTRL**+**X**).

Top Tip

SSH is your friend

When setting up Beepy as your PDA, it's easiest to install and configure everything via SSH, and then it's ready to use on the move.

10 **Home command**

While in your SSH session, enter:

```
matrix-commander --login password
```

Enter the URL of your home server when prompted (that'll be **https://matrix.org** for most people), then your username and password as prompted. You'll also be asked to set a default room, formatted as **!RoomIDString:YourMatrixServer.tld**. I used my household's group chat room.

Confirm, and you're ready to verify. Type:

.muttrc

> Language: **mutt**

```
001.   set imap_user = "username"
002.   set imap_pass = "password"
003.
004.   # SMTP server. 587 is a common port, but your provider may
       use another
005.   set smtp_url = "smtp://user@domain.tld:587/"
006.   set smtp_pass = "password"
007.   set ssl_starttls = yes
008.   set ssl_force_tls = yes
009.
010.   set from = "your@email.address"
011.   set realname = "Your name"
012.
013.   # 143 is a common IMAP port but yours may differ
014.   set folder = "imap://subdomain.domain.tld:143"
015.   set spoolfile = "+INBOX"
016.   set postponed="+Drafts"
017.
018.   set header_cache=~/.mutt/cache/headers
019.   set message_cachedir=~/.mutt/cache/bodies
020.   set certificate_file=~/.mutt/certificates
021.
022.   # Keep mail on server
023.   set move = no
024.
025.   # Check for new messages once a minute
026.   set mail_check = 60
027.
028.   # Reverse chronological mail listing
029.   set sort = "reverse-date-received"
030.
031.   # Offer to save unsent messages as drafts
032.   set postpone=ask-yes
```

```
matrix-commander --verify
```

After a short while, you'll be informed that "matrix-commander is ready and waiting for the other party to initiate an emoji verification with us by selecting 'Verify by Emoji' in their Matrix client."

11 **Identify yourself**

On your other client, you'll be asked to confirm that the login was you. However, that's not enough to complete verification. To force emoji verification, in your non-Beepy Matrix client, open the room you set as default.

On the room's top bar, click the round 'i' icon to open the info panel, then click People, select your user, select your matrix-commander device, which will be marked as 'Not trusted', then click 'Interactively verify by emoji'. You'll be shown matching sets of emoji in both your SSH session to Beepy and the Matrix client you're using for authentication. Confirm that they match, and your matrix-commander session will be verified.

Close your verification session by pressing **CTRL**+**C**.

12 **Connected communications**

Now we can move from SSH to Beepy itself. To send a message to your default room, type:

```
matrix-commander -m "Beepy says hi!"
```

The output can look cluttered on Beepy's small screen due to excessive logs. To eliminate these, append `--log-level CRITICAL` to your command.

To see any new messages since you last connected, including your own, type:

```
matrix-commander --listen once --listen-self
--log-level CRITICAL
```

If you're using Tmux, you can leave a session open and listening:

```
matrix-commander  --listen forever --listen-
self --log-level CRITICAL
```

Further instructions can be found in the **manual.txt** file packaged file packaged with the application (**magpi.cc/matrixcommander**). M

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Part 11

Design a circuit
with KiCad

Design an electronic circuit for controlling high-power
LED lights or model railway lighting

MAKER

**Stewart
Watkiss**

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

penguintutor.com

**twitter.com/
stewartwatkiss**

Warning!
Electrical Safety

Whilst 12 V will not
cause electrocution, it
can cause a fire. Ensure
power supplies have
over-current protection
and consider adding
a fuse.

**magpi.cc/
electricalfires**

T his tutorial will provide guidance on how to
design your own circuit using KiCad. It will
show how you can design a circuit that can
be used with Raspberry Pi Pico. This will include
choosing suitable components and designing a
schematic diagram. This will then lead to creating
your own custom printed circuit board (PCB) in
the next tutorial.

This circuit is to control three sets of lights
using buttons on the PCB or through a web
interface. The design can be used for 5 V or
12 V lights, making it suitable for either home
automation or model railway lighting.

01 Design idea

All projects start with an idea. When
creating a breadboard circuit, you have an
opportunity to experiment and change the design
as required. Creating a custom PCB involves
additional time and cost, so it is important to
spend additional time in the design phase to get
the circuit just how you want it.

It is often useful to create a design specification
that lists the features that you want, anything you
want to avoid, and any restrictions it needs to be
designed for. There may be restrictions on size, or
you may want to provide additional flexibility to

▲ The schematic diagram shows how the components will be wired together when designing the PCB layout

A Pico is mounted onto the PCB, which is used to control external LED lights

Copper tracks in the PCB are used to connect the electronic components

that amount of power for simple switching. Without the overhead of an operating system, Pico is more responsive, more reliable, and cheaper. A Pico W can be used to provide Wi-Fi access.

The plan is to switch high-power LEDs which are more than can be powered just using the GPIO pins on a Pico, so this is going to need MOSFET switch circuits.

It also needs to use switches for input, and these can be wired between GPIO pins and ground, using the internal pull-ups in Raspberry Pi Pico.

add extra features. Sometimes these may conflict with each other, in which case you may need to make some compromises. Listing these up-front helps to keep your design on track.

02 Creating the initial design

With the idea and specification ready, you can start to make basic decisions about the circuit. Our first decision was to use a Raspberry Pi Pico. This project could be made using a Raspberry Pi computer, but it doesn't need

03 Flexible design

One thing to consider when designing a PCB is whether it will be used for a single circuit or whether it can be used for multiple purposes. It can be useful to include additional flexibility as that helps justify the cost of having a PCB made, but adding extra features will increase the size and cost of the PCB.

You'll Need

> 470 Ω resistors
> **magpi.cc/470ohm**

> 1N5817 diode
> **magpi.cc/1n5817**

> Switches
> **magpi.cc/ 12x6switches**

> PCB screw terminals
> **magpi.cc/ pcbterminal**

> IRLB8721 MOSFET
> **magpi.cc/mosfet**

> 5V COB LED light
> **magpi.cc/cobled**

> Power adapter
> **magpi.cc/ jacktoscrew**
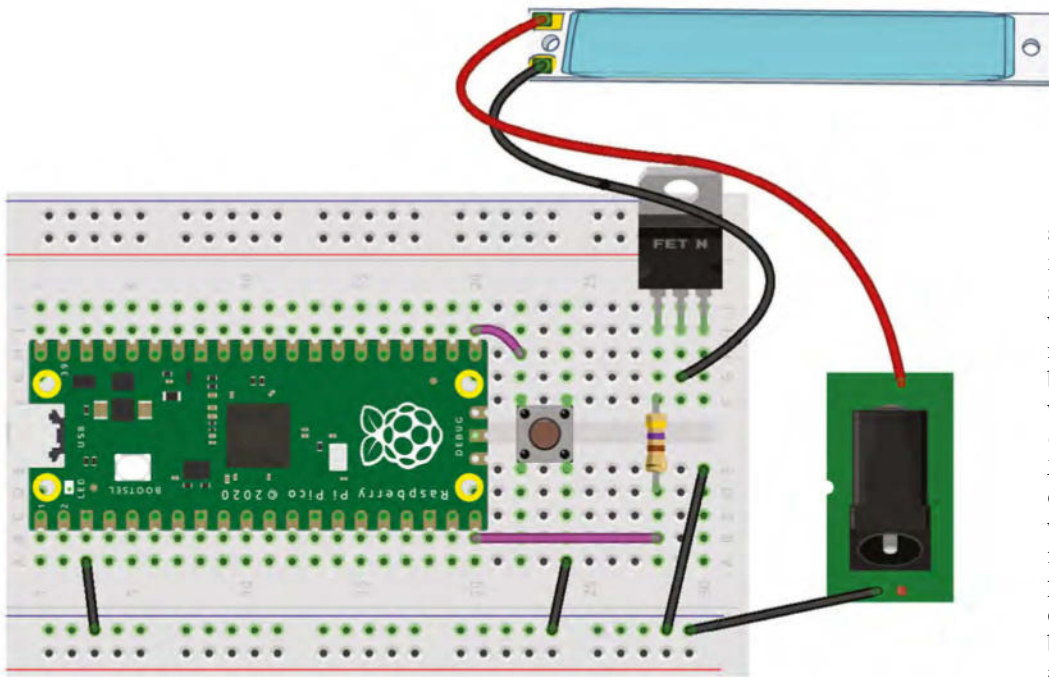
Figure 2: A breadboard prototype with a COB LED light strip and a connector for a 5V power supply

A typical MOSFET for switching LEDs is the 2N7000. This MOSFET can switch up to 200 mA, which will likely be sufficient for model railway lights, but not for the light strips which can draw up to 600 mA. Looking at what MOSFETs are available, you can find the IRLB8721PBF which supports up to 62A, more than we need with plenty to spare. It is more expensive than the 2N7000, but the savings in having a single transistor type for different requirements means that we can make savings by using a single PCB design for multiple projects.

The main thing here is what LED lights are to be controlled. In the specification for this build, it was decided that the board should be capable of controlling both 12V or 5V LED lights. The 12V lights would be useful for camping lights or model railways, and 5V would be useful for COB (chip-on-board) lighting strips. An appropriate voltage power supply is needed to match the LEDs used.

05 Prototyping

The next stage is to test if your design will actually work. This is where the breadboard comes in useful because it allows you to try out

> **❝ The next stage is to test if your design will actually work ❞**

different circuits and values. You may want to use a multimeter, or even an oscilloscope to check that the outputs are what you expect.

In this case, the electronics are made up of common circuit configurations, but as it's a different MOSFET than before, you may want to test it to see if it behaves in the way that you expect. The diagram in **Figure 2** shows an example using single switches and a single COB LED light strip to test the main components.

Figure 3: To include a Pico in the design, add the RPi_Pico.lib library through the Manage Symbol Library menu option

04 Component selection

Having decided on the LEDs, you can now choose a MOSFET that is sufficient for controlling them.

06 Moving to KiCad

In the design so far, you've hopefully been making notes about the decisions you've made. Now it's time to convert those to create a schematic diagram. The schematic diagram is
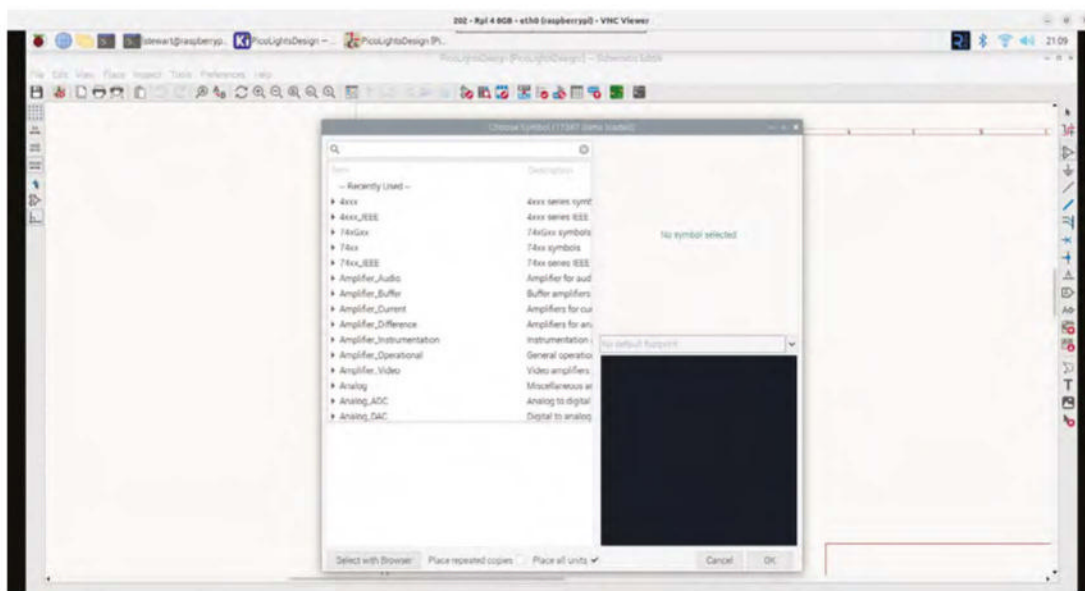
useful because it shows each of the components wired together without the difficulty of trying to follow individual wires.

The tool used here is KiCad, which is open-source software capable of creating professional circuits. You can run KiCad on most computers, including Raspberry Pi. To install on a Raspberry Pi, use the terminal command:

```
sudo apt install kicad kicad-packages3d
```

07 Creating the schematic diagram

After launching KiCad, you should see the project window. There should be no project selected and the right-hand side of the window shows the various tools which make up KiCad. This is shown in **Figure 1** (previous page). Create a new project by clicking on the new project icon and giving it a name, such as PicoLights. It will create a new directory and create a KiCad project file. You can then click on the Schematic Editor on the right to start a new schematic diagram.

You are presented with a blank drawing area. You can move around using a mouse with the right button pressed, and zoom using your mouse scroll wheel.

08 Adding a Pico footprint to KiCad

Whilst various models of Raspberry Pi are included in KiCad's component library, it does not currently include a Pico. To add a Pico symbol, first download the file from **magpi.cc/kicadzip** (note: direct download).

This file is a complete PCB design, but within the zip file are the files **RPi_Pico.lib** and **RPi_Pico_SMD_TH.kicad_mod**. Copy both files to a suitable directory (eg. KiCadLibraries) and choose Tools > Manage Symbol Libraries.

Click on the '+' icon to create a new library, name it 'RPiPico', then click on the folder icon in the Library Path column and select the lib file. It will add it as a Legacy library. This is shown in **Figure 3**. That .kicad_mod file will be used later when creating the PCB.

09 Adding components to the schematic

You can now add components by choosing Add Symbol from the Place menu, or by using the icon on the right-hand side of the schematic editor. Click the screen to bring up the symbol selector dialog, search for Pico, and select the one inside
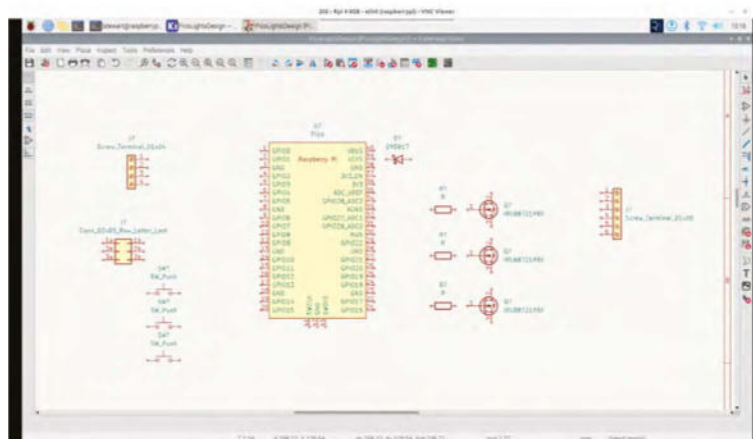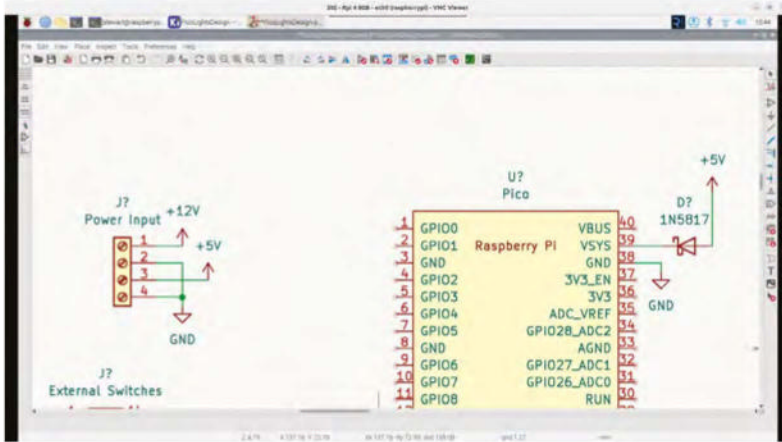
▲ Figure 6: Power label symbols are used to indicate the power supplies. Labels with the same name are treated as though they are connected

10 Powering the circuit

To provide power, a screw terminal is used. This needs two power supplies: one for your LEDs (12V or 5V depending upon LEDs) and one for the Pico (5V). These will be supplied using a 4-way terminal connector, Screw_Terminal_01x04. A 1N5187 diode is also needed to allow either the USB or screw terminal to be used.

The output will also be provided through screw terminals to connect to your choice of LED. Choose 'Screw_Terminal_01x06'.

The components can be moved into an appropriate position and rotated or mirrored using the right-click menu. Arrange the components so that they are similar to **Figure 5**.

the RPiPico library, then click OK to add it to the schematic diagram. The symbol selector is shown in **Figure 4**.

For the button switches, use SW_Push. This will also provide headers which can be used to connect to an external switch that can be added as 'Conn_02x03_Odd_Even'.

The MOSFET is the IRLB8721PBF and add gate resistors (search for 'R' for the resistor symbol).

11 Adding power connections

The value of the components can be changed using the 'Edit' value from the right-click menu. Change the resistors to 470R and rename the connectors to represent their purpose.

Rather than having to wire up all the different places where power is needed, power symbols can be used. Use +12V, +5V, and a common ground for both supplies' GND. If you place multiple power symbols with the same reference (you can use duplicate from the right-click menu) then they will all be connected together, reducing the number of wires needed. Connect the power symbols to the various components using 'Add wire' from the Place menu. The power connections for the input and Pico are shown in **Figure 6**.

simple-lights.py

DOWNLOAD THE FULL CODE:
magpi.cc/picolights

> Language: **MicroPython**

```
001.  from machine import Pin
002.  import utime
003.
004.  sw1 = Pin(3, Pin.IN, Pin.PULL_UP)
005.  sw2 = Pin(4, Pin.IN, Pin.PULL_UP)
006.  sw3 = Pin(5, Pin.IN, Pin.PULL_UP)
007.
008.  out1 = Pin(20, Pin.OUT)
009.  out2 = Pin(19, Pin.OUT)
010.  out3 = Pin(18, Pin.OUT)
011.
012.  while(1):
013.      if (sw1.value() == 0):
014.          # Toggle out1
015.          out1.value(1-out1.value())
016.          utime.sleep (0.5)
017.      if (sw2.value() == 0):
018.          out2.value(1-out2.value())
019.          utime.sleep (0.5)
020.      if (sw3.value() == 0):
021.          # Toggle out3
022.          out3.value(1-out3.value())
023.          utime.sleep (0.5)
```

12 Wiring

The rest of the components can be wired together to complete the circuit. When joining wires, there will be a circle over the connection to show that they are connected. If there is no circle, then crossing wires are not electrically connected.

You should also annotate the components by giving each a unique reference. You could do this manually using the properties of each component, changing 'J?' to 'J1' etc., or use 'Annotate Schematic' from the tools menu.

Code is provided (**simple-lights.py**) to allow you to test the prototype using the button LED. In the next tutorial, you will use the schematic to create a professional printed circuit board. M

Making music on Pico

Use CircuitPython to create complex sounds

Ben Everard

Ben's house is slowly being taken over by 3D printers. He plans to solve this by printing an extension, once he gets enough printers.

Most microcontroller programming environments have a way of making beeps, and even if there's not an in-built method, it's a pretty simple thing to do – just flick a pin on and off quickly (but not too quickly) and you have an audio signal that you can send to a speaker, headphones, or other audio devices.

CircuitPython, however, has just gained a complex audio synthesis module called synthio. This lets you not just create beeps and boops, but control these sounds in a variety of ways. Let's take a look.

You'll need a board that supports synthio. RP2040 boards, such as Pico and Pico W, are a great option for testing things out and having a play using headphones; however, a board with dedicated audio hardware (such as the Adafruit RP2040 Prop-Maker) will make it easier to connect a speaker.

Before we dive into the code, let's take a look at the hardware. If you're using a board without dedicated audio hardware (such as a Pico), you just need to connect a pair of headphones between one of the GPIO pins and ground. The easiest way to do this is to clip crocodile clips onto the headphone jack.

You can probably get away without adding a resistor in there as well, but it's a bit safer to put a 220 Ω resistor between the GPIO pin and the headphones. This stops the current from getting too high (especially if you are using crocodile clips that can accidentally touch).

Ideally, you should have a capacitor between the GPIO pin and ground. This is because the signal coming from the GPIO pin isn't an audio signal, but a high-frequency PWM signal that, when averaged out, becomes the audio signal. The capacitor creates a low-pass filter that does this averaging out. We find that this isn't generally necessary because the rest of the circuit tends to act as a low-pass filter, so it works fine without it.

We used GPIO0, but you can adjust this to any you want.

Let's take a look at a really simple example:

Above
You can use a jack socket if you want, but crocodile clips are great for prototyping
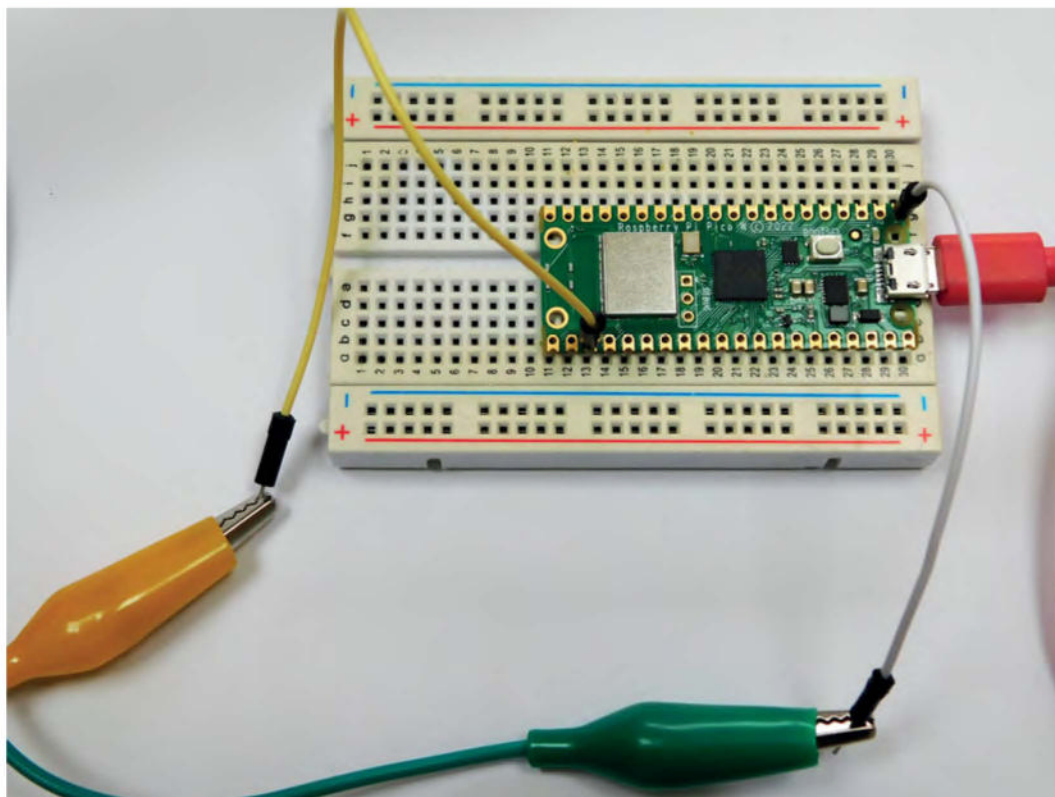
```
import time
import board
import digitalio
import synthio
import audiopwmio
import audiomixer

audio = audiopwmio.PWMAudioOut(board.GP0)
mixer = audiomixer.Mixer(channel_count=1, sample_
rate=22050, buffer_size=2048)
synth = synthio.Synthesizer(sample_rate=22050)

audio.play(mixer)
```

```
mixer.voice[0].play(synth)
mixer.voice[0].level = 0.1

while True:
    synth.press(65)
    time.sleep(0.5)
    synth.release(65)
    time.sleep(1)
```

Here, we use three objects. There's a `PWMAudioOut` which handles the output. There are other output options if you have additional hardware, for example, if you want to use an I2S DAC. There's a `mixer`. Technically, we could get away without this, in which case, the audio would play at full volume, but this can be a bit loud on headphones, so we prefer to always use a mixer to enable us to keep control over how loud we go. In future examples, you'll also see how a mixer can be used to combine sounds. Finally, there's a `synth` which is used to generate the sound.

In this case, we just loop through, pressing and releasing note 65. The notes are given numbers in the MIDI system, and 65 is F#.

When we press it, it goes on full; when we release it, it goes off instantly. This is OK, but it sounds a bit harsh. Wouldn't it be better if we could fade the sound in and out? Synthio has a solution to this – it's called envelopes:

```
import time
import board
import digitalio
import synthio
import audiopwmio
import audiomixer


audio = audiopwmio.PWMAudioOut(board.GP0)
mixer = audiomixer.Mixer(channel_count=1, sample_
rate=22050, buffer_size=2048)
synth = synthio.Synthesizer(sample_rate=22050)
audio.play(mixer)
mixer.voice[0].play(synth)
mixer.voice[0].level = 0.1

amp_env = synthio.Envelope(
                          attack_time=0.05,
                          sustain_
level=0.2,
                          release_time=0.5
)

while True:
    synth.envelope = amp_env
    synth.press(46)
    time.sleep(1.25)
    synth.release(46)
    time.sleep(1.25)
```
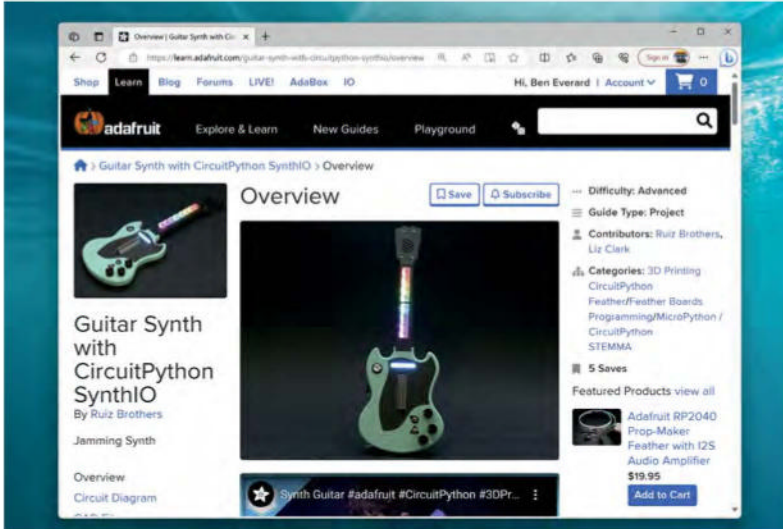
Above
There's an example guitar created by the Ruiz Brothers at hsmag.cc/synthioguitar

Envelopes are a way of controlling the volume over time using the parameters: `attack_time`, `attack_level`, `sustain_time`, `sustain_level`, `release_time`, `decay_time`.

At first, the volume will ramp up to `attack_level` over the period of `attack_time`. Then it will drop down to `sustain_level` volume over `decay_time`. It will then stay at the same volume for `sustain_time`, and finally drop down to zero volume over `decay_time`. All times are in seconds, and volumes are between 0 and 1.

Now we can play notes that sound a bit more natural, let's take a look at combining them. The following code uses two `synth` objects to play notes at different times:

```
import time
import board
import digitalio
import synthio
import audiopwmio
import audiomixer

audio = audiopwmio.PWMAudioOut(board.GP0)
mixer = audiomixer.Mixer(channel_count=1, sample_rate=22050, buffer_size=2048)
synth1 = synthio.Synthesizer(sample_rate=22050)
synth2 = synthio.Synthesizer(sample_rate=22050)

audio.play(mixer)
mixer.voice[0].play(synth1)
mixer.voice[0].level = 0.1
mixer.voice[1].play(synth2)
mixer.voice[1].level = 0.05

amp_env = synthio.Envelope(
```

```
            attack_time=0.05,
            sustain_level=0.3,
            release_time=0.3
)

amp_env2 = synthio.Envelope(
                attack_time=0.05,
                sustain_level=0.5,
                release_time=0.5
)

beat = 0
synth1.envelope = amp_env
while True:
    if beat % 2 == 0:
        synth1.press(60)
    if beat % 2 == 1:
        synth1.release(60)
    if beat % 4 == 0:
        synth2.press(46)
    if beat % 4 == 2:
        synth2.release(46)
    time.sleep(1)
    beat += 1
```

We can't use a simple repeating loop here because that wouldn't let us play notes at different rates, so we've created a beat loop, then we can detect which beats we want to start and stop different notes at.

ON ANOTHER NOTE
So far, we've set the volume structure of the note, but we've still been playing the same sound – a square wave beep. We can create far more complex

> **Now we can play notes that sound a bit more** natural, let's take a look at combining them

sounds than this. Synthio uses a wavetable function to create the audio signal. This basically means that you can create an array of volumes that define the shape of the audio signal for a note. This could go abruptly from 0 to 1 as in a square way; it could go up linearly like a triangular wave; it could have a curve like a sine wave, or just about anything else. Each wave shape produces a very different sound.

```
import time
```

```
import board
import digitalio
import synthio
import audiopwmio
import audiomixer
import ulab.numpy as np

audio = audiopwmio.PWMAudioOut(board.GP0)
mixer = audiomixer.Mixer(channel_count=1, sample_
rate=22050, buffer_size=2048)
synth1 = synthio.Synthesizer(sample_rate=22050)
synth2 = synthio.Synthesizer(sample_rate=22050)

audio.play(mixer)
mixer.voice[0].play(synth1)
mixer.voice[0].level = 0.2
mixer.voice[1].play(synth2)
mixer.voice[1].level = 0.05

amp_env = synthio.Envelope(
                    attack_time=0.05,
                    attack_level = 1,
                    decay_time = 0.1,
                    sustain_level=0.3,
                    release_time=0.3
)

amp_env2 = synthio.Envelope(
                    attack_time=0.05,
                    attack_level = 1,
                    decay_time = 0.1,
                    sustain_level=0.1,
                    release_time=0.1
)

SAMPLE_SIZE = 512
SAMPLE_VOLUME = 32000  # 0-32767
half_period = SAMPLE_SIZE // 2
wave_sine = np.array(np.sin(np.linspace(0, 2*np.
pi, SAMPLE_SIZE, endpoint=False)) * SAMPLE_VOLUME,
                    dtype=np.int16)

note1 = synthio.Note(synthio.midi_to_hz(60),
waveform=wave_sine, amplitude=1)

beat = 0
synth1.envelope = amp_env
while True:
    if beat % 2 == 0:
        synth1.press(note1)
    if beat % 2 == 1:
        synth1.release(note1)
```



```
    if beat % 4 == 0:
        synth2.press(46)
    if beat % 4 == 2:
        synth2.release(46)
    time.sleep(1)
    beat += 1
```

We've only really scratched the surface of what you can do with synthio here. It's a hugely powerful system for creating music using microcontrollers. There's a more in-depth introduction online at **hsmag.cc/synthiofundamentals**.
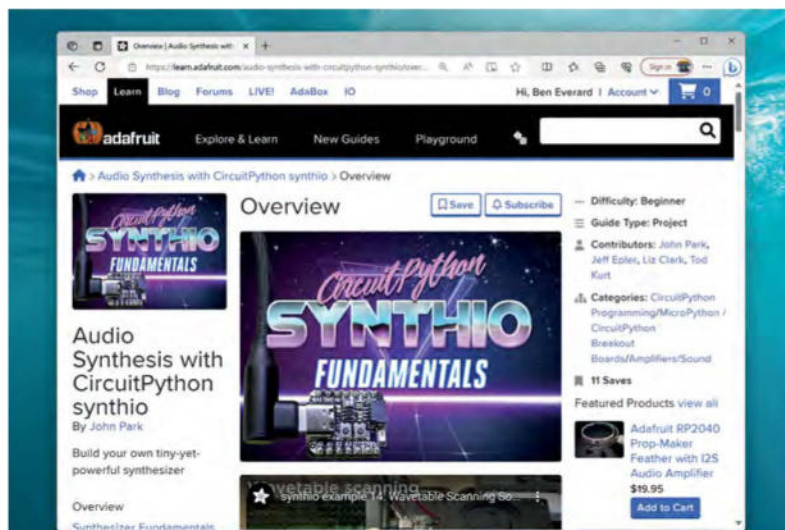
Above
How far do you want to disappear down the synth rabbit hole?

SYNTH TERMINOLOGY

Synthio uses similar terminology to many other synthesizers. You'll come across envelopes and mixers similar to those we've used in this article in many other bits of software and hardware. Here are a few other things that synthio provides that you will also find elsewhere:

- Low-frequency oscillator (usually known as an LFO) is a special type of oscillator that unsurprisingly runs slowly, or at least slower than typical audio frequencies. The purpose of this isn't to generate audio sounds directly but to influence other audio. For example, you can use it to bend a note in a vibrato-like effect.

- Filters block some audio signals while allowing others to pass through. The type of filter defines what frequencies are allowed to pass through. Synthio Synthesizer objects have the following methods to create filters: high_pass_filter, low_pass_filter, and band_pass_filter. Once they are created, they can be attached to notes or synthesizer objects.

THE *Official*
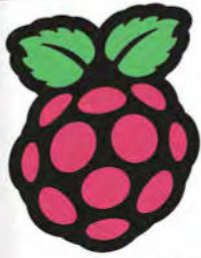
RASPBERRY PI
HANDBOOK

2024
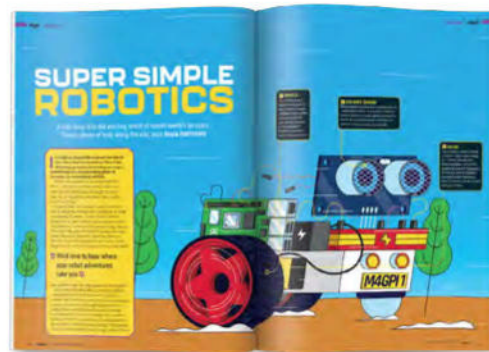
Serious fun with
electronics

Retro gaming with
Raspberry Pi

Upcycling
Big Mouth Billy Bass

Recreate
Doctor Who's K-9

Super Simple
Robotics

Build Iron Man's
Arc Reactor

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FROM THE MAKERS OF *MagPi* THE OFFICIAL RASPBERRY PI MAGAZINE

Raspberry Pi
BEGINNER'S
PROJECTS

We all need to START somewhere. Here's some of those wheres...

While there are many questions that have and have not been answered by science and research, the question 'what do I do with Raspberry Pi?' largely comes down to... well, what would you like to do with it? Some people have a vision of their first Raspberry Pi project to get themselves started, but other folks need more of a push.

This is where we come in. There are a huge number of options for newbie Raspberry Pi owners to choose from, and we've collected an excellent selection that will hopefully inspire you. **Let's get stuck in.**

BY EX-NOVICE

ROB ZWETSLOOT

Programming PROJECTS

START CODING WITH THESE GREAT PROJECTS

ADA'S POETRY GENERATOR
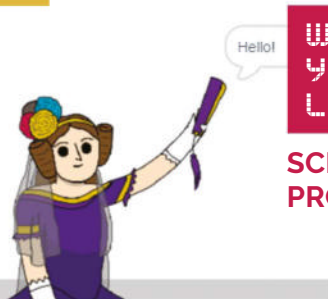
WHAT YOU'LL LEARN

SCRATCH PROGRAMMING

Ada Lovelace is a computing pioneer – and using this block programming language, you can have her tell you different poems from her Analytical Engine. It's a perfect way for younger folks to get their heads around the flow of coding by using variables it compares and filling up lists to use at random.

This project can also be completed in the browser from **scratch.mit.edu**, and can be used between Raspberry Pi and another computer.

→ **MAGPI.CC/ ADAPOETRY**

Projects website

Our colleagues over at the Raspberry Pi Foundation have a site full of beginner-friendly programming (and electronics!) projects for Raspberry Pi and standard PCs. Head to **magpi.cc/projects** to see more.

PROJECT

DON'T COLLIDE! PYTHON GAME

WHAT YOU'LL LEARN

→

PYTHON, GAME PROGRAMMING

PROJECT

PASSWORD GENERATOR

WHAT YOU'LL LEARN

PYTHON, INFOSECURITY

A good password is essential these days, and thanks to powerful password managers you can easily store them so you don't always have to remember them each individually either. This project shows you how to create a simple Python script to generate a random list of characters for passwords of varying lengths and complexity.

Always remember to turn on two-factor authentication when you can as well, though.

→ **MAGPI.CC/ PASSWORDGEN**
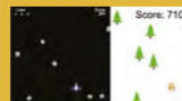
A great way to learn programming is to make a game! This endless runner-style game is made completely in Python with some simple graphics so you can understand not only how the programming loops in games work, but also how to display them and make them playable.

For more game coding in Python, Pygame is a great library to look into for streamlining the experience.

→ **MAGPI.CC/ DONTCOLLIDE**

Electronics PROJECTS

MAKE YOUR FIRST CIRCUITS WITH THESE ELECTRIFYING PROJECTS

PYHSICAL COMPUTING WITH PYTHON
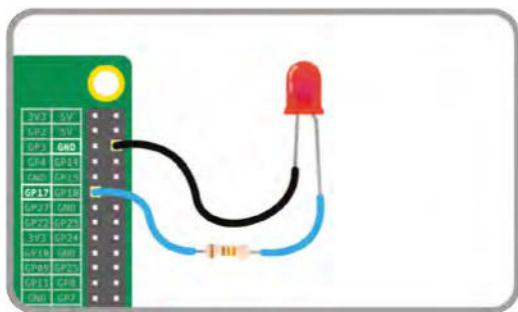
WHAT YOU'LL LEARN → CIRCUITS & GPIO PINS

This introduction to creating circuits on Raspberry Pi covers how to program a load of components connected to the GPIO pins on a Raspberry Pi. This includes LEDs, sensors, buttons, etc., and is a great way to get acquainted with what you can do with programmable circuits.

You'll need to get some electronics components for this – check out *The MagPi* issue 136's buyer's guide for advice on where to get them if you don't already.

→ MAGPI.CC/ ELECINTRO

GPIO MUSIC BOX

Raspberry Pi Pico Advanced Kit

Want to make circuits with a Raspberry Pi Pico? This set of projects includes 32 different components and teaches you how to start with lighting an LED and ends with you building a robot. You can find out more at **magpi.cc/advpicokit**

WHAT YOU'LL LEARN ↓ PYGAME PROGRAMMING, AUDIO
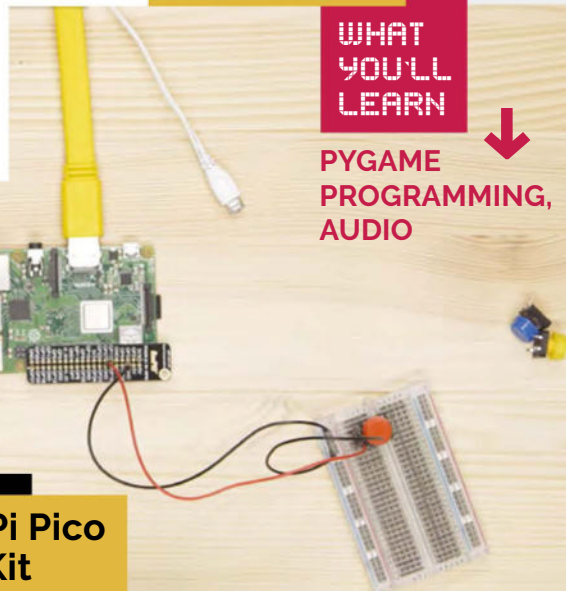
This fun project allows you to create sweet music with a series of buttons and Raspberry Pi. The basic concept is that you start a loop in the code that keeps an eye on the buttons to see when they're pressed. When each button pressed, it will trigger a specific sound.

Pygame is great for circuits and code that is in continuous use, which is why it tends to be used for video game projects too.

→ MAGPI.CC/ GPIOMUSICBOX
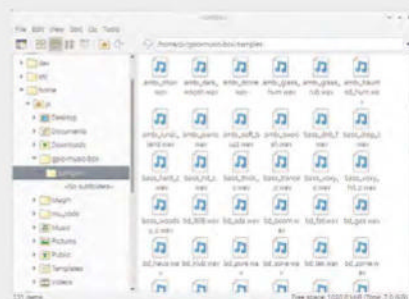
Robotics
PROJECTS

CREATE AN AUTOMATON WITH THESE EXCELLENT ROBOT PROJECTS

PROJECT

AUTONOMOUS ROBOTICS PLATFORM FOR PICO

WHAT YOU'LL LEARN

ROBOTICS WITH RASPBERRY PI PICO

Similar to the EduKit #3, this is the Pico equivalent that allows you to quickly and easily build your own rover that can be programmed to work autonomously. It even comes with a chassis. Pico is great for robotics even if it it's not as powerful as a full-sized Raspberry Pi.

The kit comes with line-following sensors, an ultrasonic distance sensor, and a little buzzer you can use as a horn in case you need the cat to get out of the way.

➔ **MAGPI.CC/ AUTOROBOT**

Pi Wars

Want to get serious about your robotics? Pi Wars is a regular robot competition where people show off just how good their robot is by getting it to avoid walls, survive an obstacle course, and pop balloons. Apply to the next one at **piwars.org**

Pi Wars
THE RASPBERRY PI ROBOTICS CHALLENGE COMPETITION

PROJECT

MEARM

WHAT YOU'LL LEARN

ROBOTICS & TIMING
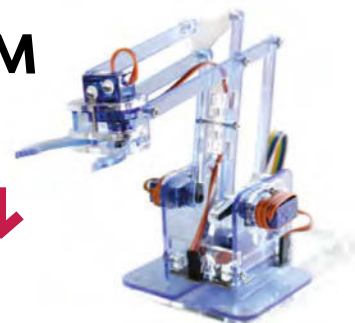
A classic robot designed used in factories the world over, a robotic arm is a nice and simple type of robot where you don't have to worry about locomotion but do have to worry about precise movements and grip. This MeArm kit works with many types of microcontroller as well, and we suspect could also work with Pico with enough jiggery-pokery.

It comes with decent servos, though, which will be ripe for reuse in future projects too.

➔ **MAGPI.CC/ MEARM3**

CAM JAM EDUKIT #3

Our go-to kit for beginner robotics, this easy-to-use kit will help you build your first robot and can easily be reused to make future robots down the line. It can be used in remote control mode as well as in autonomous mode with line followers, ultrasonic distance sensors, and proximity sensors.

It doesn't come with a chassis, but you can either turn the box into one or 3D-print your own.

➔ **MAGPI.CC/ EDUKIT3**

WHAT YOU'LL LEARN

ROBOTICS WITH RASPBERRY PI

PROJECT

Media Centre
PROJECTS

IMPROVE HOW YOU GET YOUR MEDIA WITH THESE GROOVY PROJECTS

PROJECT

ULTIMATE MEDIA CENTRE
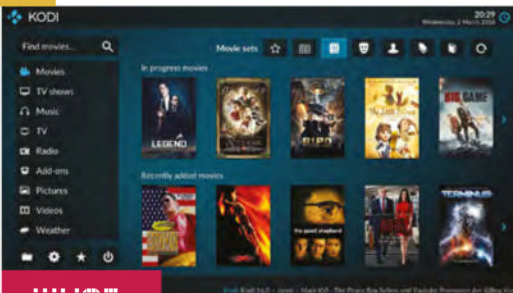
WHAT YOU'LL LEARN ➜ **NETWORKING**

The ultimate media centre is a hybrid network file-playing, media-streaming, and gaming machine that fits neatly inside a Raspberry Pi 4 (but can easily be upgraded to a Raspberry Pi 5) and slid under the big telly.

If you don't want the game aspect, you can also start it as just a Kodi machine without any of the RetroPie stuff. We've been using a similar setup for just that for years.

➜ **MAGPI.CC/102**
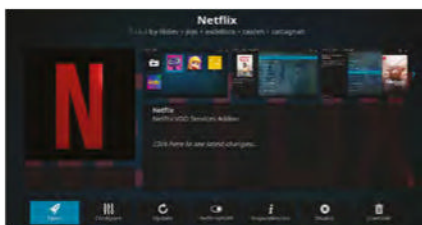
PLAY CLASSIC CONSOLE GAMES LEGALLY ON RASPBERRY PI

WHAT YOU'LL LEARN ⬇ **ALTERNATE OS INSTALLATION**

Emulating retro consoles can be easy. This guide takes you from setting up RetroPie – our favourite emulation operating system for Raspberry Pi – to looking up legally available ROMs to play on it!

Tired of playing just old games? Then we also show you the world of new homebrew games for these systems of the past.

➜ **MAGPI.CC/ LEGALCLASSICS**

Media centre book

For all your media centre needs, you can check out our free PDF, *Build a Raspberry Pi Media Player*, which includes reviews of media-related products and ways to play media on Raspberry Pi OS. Check it out at magpi.cc/mediaplayer
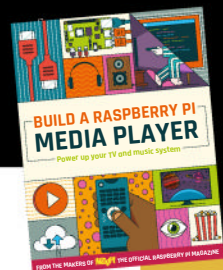
PROJECT

BUILD A HOME MUSIC SYSTEM

WHAT YOU'LL LEARN ⬇ **AUDIO WIZARDRY**

Make a Sonos-style system with a Raspberry Pi, an audio HAT, and some good speakers. This tutorial uses Mopidy, a server created for music listening. In this first part, you can build the music system, and part two allows you to stream the audio around your home.

It also makes uses of a touchscreen so you can control the music from the base station.

➜ **MAGPI.CC/HOMEMUSIC**

Home Automation
P R O J E C T S

AUTOMATE YOUR HOME WITH
THESE IOT PROJECTS

BUILD A HOME ASSISTANT WITH RASPBERRY PI
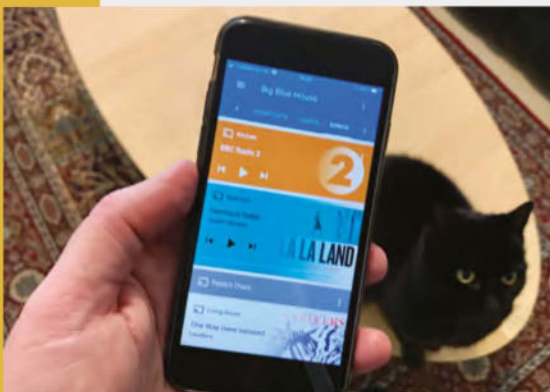
WHAT YOU'LL LEARN → APIs

Not only is this project a home assistant, the software is called Home Assistant. Try not to get confused by it, but either way it allows you to connect to standard Wi-Fi controlled lights and objects from a mobile phone app that connects to your Raspberry Pi. It's heavily customisable and can easily allow you to control multiple kinds of automated home appliances at the same time, so you don't need to stick to one brand or service.

→ **MAGPI.CC/ HOMEASSIST**

DIY home automation

In *The MagPi* #129, we did a big feature on different home automation projects, from beginner to advanced. Check it out and see if there's anything else there that piques your curiosity: **magpi.cc/129**

BUILD A RASPBERRY PI PICO SMART HOME
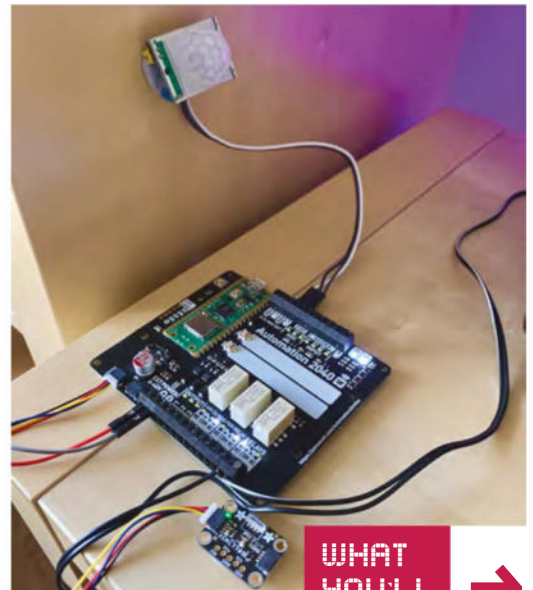
WHAT YOU'LL LEARN → APIs

From issue 123 of the magazine, this is a slightly different way of doing home automation, this time with a Raspberry Pi Pico! It's easier than you might think with the right bits of kit. There are garage door sensor projects, weather stations, and a fancy way to automate the lighting in your home! Pico is much more powerful than people think, and can do a lot with enough tweaking.

→ **MAGPI.CC/123**

MyCobot 280 **Pi**

▶ Elephant Robotics ▶ **magpi.cc/mycobot280** ▶ From £651 / $799

This high-quality, robust robot arm has a range of optional attachments. By **Phil King**

▶ The MyCobot 280 Pi robot arm extends to 350 mm at full height, but can also tuck up into a compact 'ball'

With a working rotation arc of 330° and radius 280 mm from its base joint, the MyCobot 280 is a high-quality robot arm with a long reach.

Powered by a built-in Raspberry Pi 4, it has six degrees of freedom (6DOF) thanks to half a dozen joints (equipped with bearings) controlled by large servos, all enclosed in protective plastic casings. Between two horizontal joints for the base and 'head' are three vertical ones; by varying the angles of the joints, each of which has a range of 330°, the arm can flex into pretty much any position as it moves smoothly.

A sixth joint rotates the end of the head, to which you can attach various accessories using tiny LEGO connectors inserted into its grid of holes and those on the accessory, making them easy to fit and remove.

A similar LEGO connection system is used on the bottom of the robot to attach a base. Several options are available; we were supplied with the G-Base 2.0 (£58), which attaches the arm securely to the edge of a desk (so long as it's not too thick).

Robot connections

With the robot arm secured to a desk, it's time to power it up. A DC supply connects to a barrel jack on the base with a red power switch next to it. Raspberry Pi 4's USB and Ethernet ports are exposed, along with its GPIO pins via a breakout header just above. On the opposite side of the base are a micro-HDMI port, headphone jack, USB-C port, and microSD card slot.

The inserted microSD card is pre-installed with a special version of Ubuntu MATE featuring a built-in development environment for MyCobot and several apps and tools. An extensive Python library enables you to quickly start positioning the arm by setting one or more joint angles or co-ordinates – you can also read the current
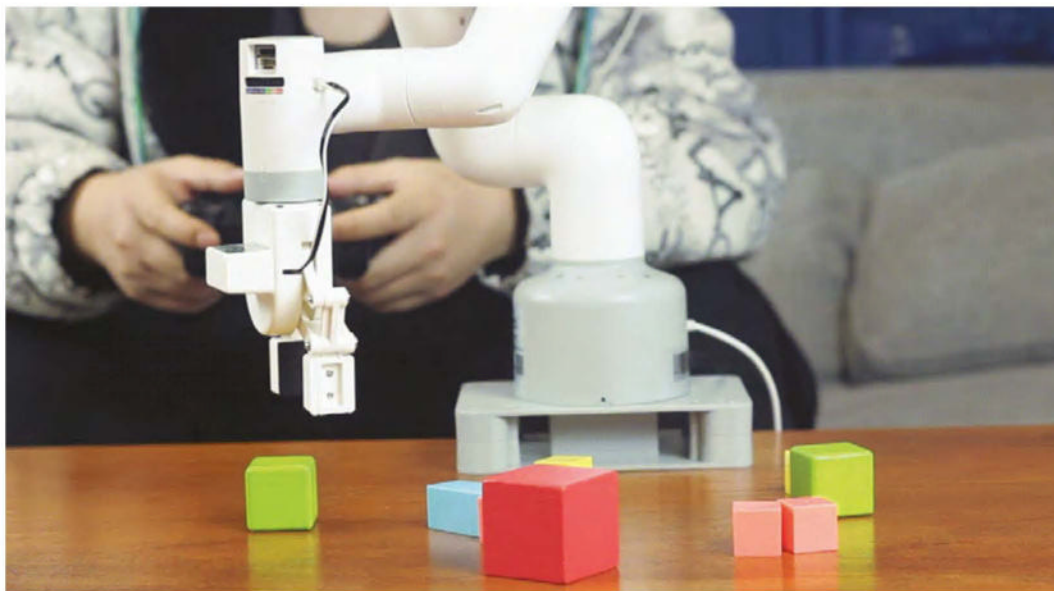
◀ With an adaptive gripper attached to the head, you can pick up objects by opening and closing it

▼ A pen holder accessory enables the arm to draw shapes and letters on paper

values. So you can manually move the arm into different positions and read the values to help you program it to shift between positions.

Another coding option is the myBlockly app in which you drag and drop Scratch-style blocks, including dedicated ones for MyCobot to set joint

> **A sixth joint rotates the end of the head, to which you can attach various accessories using tiny LEGO connectors**

angles/co-ordinates and light up the RGB LED matrix on the head. Make sure you set the Baud value in the init block to 1000000, however, otherwise it won't move. The arm also works with the commonly used ROS (Robot Operating System) 1 and 2.

The MyCobot written documentation could be clearer and better organised, but several videos help you to get to grips with it.
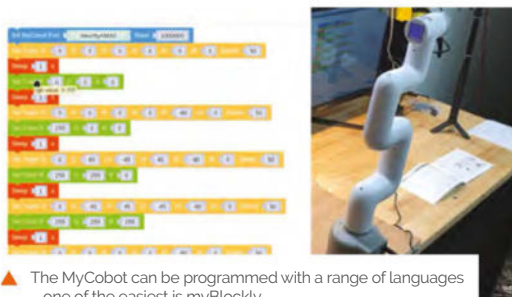
▲ The MyCobot can be programmed with a range of languages – one of the easiest is myBlockly
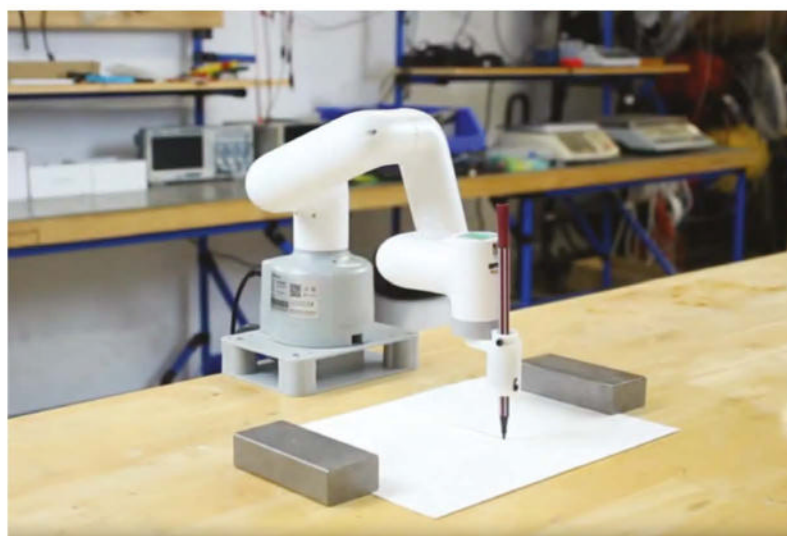
Attaching accessories

Our MyCobot arm was supplied with a couple of optional accessories: an adaptive gripper (£106) and a pen holder (£58). The gripper has a connector that plugs into a servo port on the head. It worked well and we soon had it picking up and dropping items on the desk with good repeated positioning precision.

The head also features a Grove connector, USB-C, and mini GPIO breakout, so there are plenty of connection options. You could even add a camera to give the arm computer vision.

While considerably more expensive than other Raspberry Pi robot arms we've tested, even without the addition of accessories, the MyCobot 280 is more robust and stylish. It has more powerful servos, while the joints have bearings for smoother movement and improved precision. ▨

Verdict

It's not cheap, but it does include a Raspberry Pi 4 and is a robust and stylish robotic arm with smooth and accurate movement.

9/10

10 Amazing:

Raspberry Pi Pico projects

You can do incredible things with Raspberry Pi Pico and RP2040

Raspberry Pi 5 is here, and it is excellent, but we've not forgotten about Raspberry Pi Pico. We still see excellent builds using it and the RP2040 chip that powers it on a regular basis and we do not expect that to let up any time soon. If you're after some inspiration for your own Pico build, here are ten excellent ideas… **M**
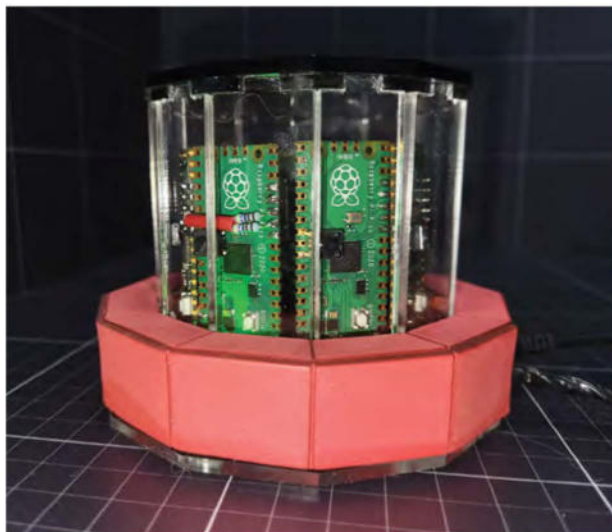
▲ PicoCray

1/50 supercomputer

Distributed computing on a Pico may not really be practical, but it is very fun and a cheap little project.

magpi.cc/picocray

▲ Pico Held

Pico Mega Drive

This very impressive project is a handheld that is able to emulate the Sega Mega Drive/Genesis on just a Pico. It's quite a feat.

magpi.cc/picoheld

◀ Pico headphones

3D-printed cans

While you wouldn't normally think of great audio when you think of Pico, these custom 3D-printed headphones are a great DIY project that shows off Pico's power.

magpi.cc/picophones

▶ Raspberry Pi beret

Traffic fashion

Used at a convention to signal to people when the maker was going to turn, this beret features a Pico that runs a web server and controls NeoPixel LEDs via a smartphone.

magpi.cc/picoberet

▶ BurgerBot

Pico robot

Kevin McAleer's Pico robot can also draw like the turtle robots of old. It has a cool, unique design and Kevin also offers a course to show you how to make one.

magpi.cc/burgerbot

▲ PicoStepSeq

RP2040 music maker

This MIDI sequencer build on Pico includes a little display and a diminutive 3D printed, retro-styled case that is quite fetching.

magpi.cc/picostepseq
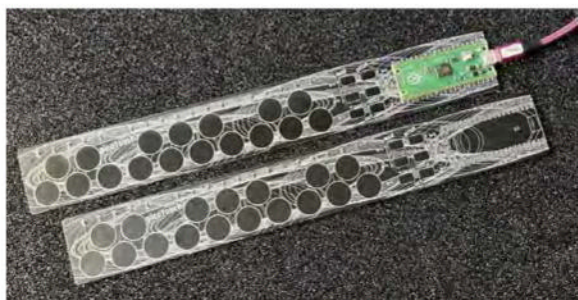
▲ PicoTouch synthesiser

Capacitive touch synthesiser

Another musical Pico project, this time a MIDI synth using a capacitive touch strip. Buttons can be used to control the scale on the synthesizer, with C major as the default one.

magpi.cc/ptsynth

▶ Roboat

Recycled robot boat

Take three empty plastic bottles, a bottle cap, and a motor, and you have all you need for a Pico-powered remote-control boat.

magpi.cc/picoroboat
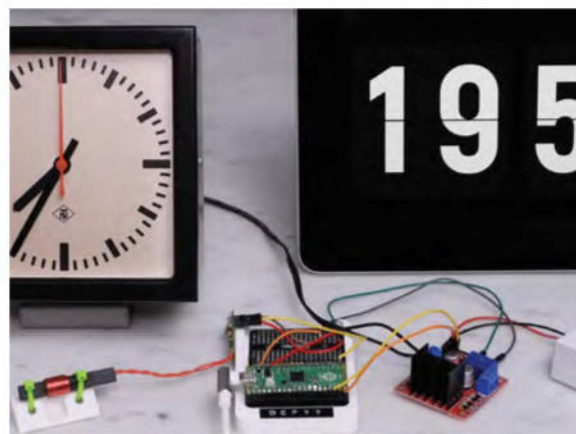
▲ Pico railway clock

Signalling Pico

If you ever pick up an old railway clock at a car boot sale and wonder why it's not working properly, you might need a Pico to send a signal to it, naturally.

magpi.cc/picorwclock
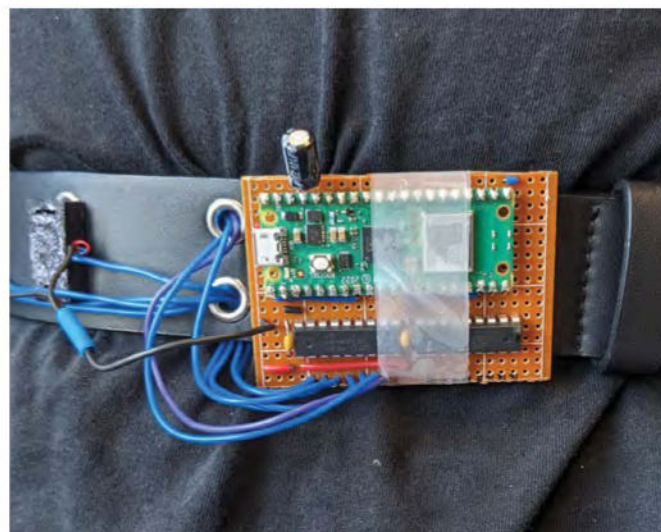
▲ Pico-powered belt

Waist compass

How can a belt be Pico-powered? Well, this one uses a series of vibration motors to tell the user which way is north. Perhaps you can convert it to give directions?

magpi.cc/picobelt

Learn C
with Raspberry Pi

The C coding language may seem daunting at first, but these resources will help you. By **Phil King**

Learn-C.org

AUTHOR

Interactive Tutorials

Price:
Free

learn-c.org

Want to just dive straight in a get coding with C? This free interactive website enables you to do that, with no need to install any software on your computer. For each tutorial, you read through the instructions and then use the online code editor to create your program and run it. Get the expected output correct and you can advance to the next step. It's a fun way to learn. There's also an equivalent site for learning C++ (**learn-cpp.org**).

The 'basics' section of the Learn C site guides you through key concepts such as variables and types, arrays, conditions, strings, loops, and functions. Once you've mastered those, you can move on to an advanced set of tutorials covering topics such as pointers, structures, dynamic allocation, recursion, linked lists, binary trees, unions, function pointers, and bitmasks.
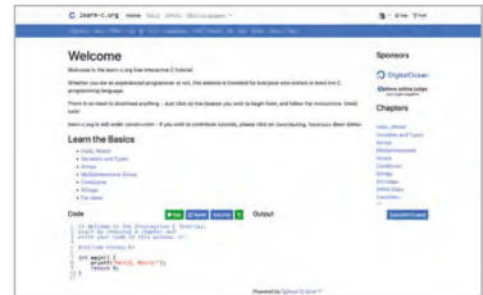
Further reading

Books to help you learn more about C/C++
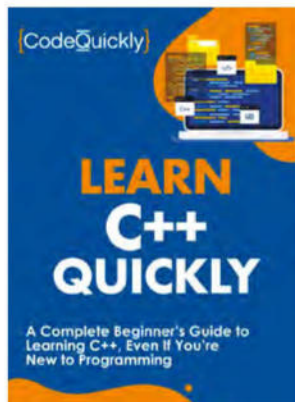
LEARN C++ QUICKLY

An enhanced version of C, the extensible C++ adds many improvements, plus support for object-oriented programming (OOP). With simple explanations and bite-size steps, this book helps you get to grips with it..
▶ **magpi.cc/cplusquickly**

C PROGRAMMING: A MODERN APPROACH

Many C coders swear by KN King's 824-page tome, which serves as a weighty introduction with good examples to follow. Just be aware that it's based on the earlier C99 version of the language, not C11 or C17..
▶ **magpi.cc/cmodern**

AN INTRODUCTION TO C & GUI PROGRAMMING 2ND EDITION

The first half of the book is an introduction to C with Raspberry Pi. The second half shows how to use the GTK user interface toolkit create feature-rich GUI applications.
▶ **magpi.cc/cgui**

C Programming Absolute Beginner's Guide

AUTHOR

Que

Price:
£22 / $24

magpi.cc/cprogabg

One of the most powerful and widely used programming languages, C – along with its C++ and C# spin-offs – is a mid-level language that's packed with useful functions and is known for its speed. The downside is that it's a little harder to learn than interpreted high-level languages like Python.

Fear not, as this introductory guide is designed with newbies in mind. Its 352 pages take readers step-by-step through all the key concepts, explaining them with great clarity and numerous code examples. By the end, you'll have a good grasp of the language.

Topics covered include variables, #include and #define statements, maths, logical operators, functions, conditionals, text strings, and loops. Perhaps most importantly, it explains data arrays and memory pointers, which beginners often find confusing, in easy-to-understand terms. Memory efficiency and code structure are also covered in the book, helping you to write faster and more effective programs. **M**
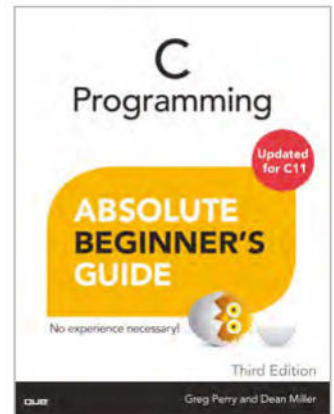
Online courses

Enrol in a C coding web course

C PROGRAMMING FOR BEGINNERS
Subtitled 'Master the C Language', this well-structured Udemy course is one of best resources for C newcomers, taking you through all the fundamentals. Everything is covered in great detail and you can learn at your own pace.
▶ **magpi.cc/udemyc**

LEARN C FROM SCRATCH
Aimed at complete newcomers, this free Educative course covers all the fundamental concepts, as well as some advanced topics, with clear explanations and editable code examples that can be run in the browser.
▶ **magpi.cc/cfromscratch**

C FOR EVERYONE
Subtitled 'Programming Fundamentals', this free UC Santa Cruz course is aimed at beginners and takes around 15 hours to complete. Its six modules cover aspects such as data types, functions, plus arrays and pointers.
▶ **magpi.cc/cforeveryone**

Allie
Weber

Young maker prodigy Allie holds patents and was a host
on Myth Busters Jr – what's in her future?

> Name **Allie Weber** | > Occupation **Student, content creator**
> Community role **Content creator** | > URL **@RobotMakerGirl**

Allie Weber is 18, which means that she was about seven years old when Raspberry Pi came out. While Raspberry Pi probably can't take all the credit for her incredible success, it's an interesting milestone to keep in mind when considering her many accomplishments.

"Ever since I was little, I always had the desire to make things and be creative," Allie says. "I won the science fair in first grade with a robot made out of recycled materials and continued coming up with invention ideas as I got older. After basically running out of science fairs in my hometown, I started entering online engineering competitions. My inventions include my patented Frost Stoppers, temperature-sensing gloves that can warn you before you get frostbite, and the Blowdart Spirometer, a medical device that makes respiratory therapy more fun by letting you shoot foam darts with it. Through making, I have learned so many new skills, and met many good friends in the maker community."

How did you become a *MythBusters Jr* host?
After hearing about some of my inventions, the production company reached out to me and asked me to try out. I actually ended up doing one of my auditions at space camp in my flight suit. Needless to say, they were excited to have me on board, and I had so much fun hosting all ten episodes of crazy experiments with my good friends and fellow co-hosts, along with our *MythBusters* mentor Adam Savage.

When did you learn about Raspberry Pi?
I started working with Raspberry Pi when I was quite young, using it in various projects starting from when I was around 10 or 11. Raspberry Pi was, and still is, one of the most powerful tools to use in making projects involving the combination of hardware and software elements.

▼ 3D printers are something every modern maker and inventor needs

▲ Dresses with lights are one of the coolest wearable ideas

▲ Sci-fi inspires a lot of people – Allie plans to make a Jurassic Park Jeep!

What have you made with Raspberry Pi?

Some of my favourite Raspberry Pi projects I have made are Pimoroni kits, which are awesome projects for beginners to learn with or experts to utilise in their projects. My favourites include Scroll Bot and OctoCam. One of my fellow *MythBusters Jr* hosts, Elijah Horland, also gifted me a *Jurassic Park*–themed PiGRRL handheld gaming device that I have worked on over the years, and really love.

What kind of projects do you like to make?

I love to make projects that solve problems, but I also love to make projects that are just for the fun of making them too. Lately, I have been making a lot of projects from games and shows I like. I have made some animatronics from *Five Nights at Freddy's*, and the Yellow Guy puppet from *Don't Hug Me I'm Scared*. I like how much I can learn from different projects, and how I can combine those skills, like sewing, programming, 3D printing, hardware, and more to make awesome things that I can use to teach others about those skills.

What's your favourite thing you've made?

Once, I took apart an RC car that I got for really cheap and turned it into a remote-control cow that can carry chocolate milk around for me. That was pretty fun. Sometimes my

> **"** Sometimes my favourite projects are ones that make me laugh **"**

favourite projects are the ones that just make me laugh.

Any future projects we should look out for?

I have a 1995 Jeep Wrangler that I have been wanting to turn into a Jurassic Park Jeep for years, so stay tuned for progress on that. When there are updates, I will be sure to post them for those who are interested! **M**

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 projects they've made.

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

01. This is a very serious setup! The ultimate home server stack

02. 'Synth-onna-stick' sounds like a 1980s product that annoyed parents, but we want one

03. *The MagPi*'s resident audiophile PJ is doing aural experiments, it seems

04. We love a good DIY laptop project, especially when you can 3D print your own parts

05. Unbottle your creativity with this very fun party piece

06. This is a very cool and practical build, perfect for classrooms

07. A fantastic art project using Pico

08. Kevin normally makes robots, but this month he's keeping our teeth shiny

09. We probably keep saying this, but: we need to make one for ourselves

10. Christmas decoration-based project? You've piqued our curiosity

Steven Cliff
Completed a couple of months long project to 3D prin RAC mount system for 6 x Pi 4's, with SSD and Oled stats displays. The pi's are clustered running OMV, Portainer, HA, OwnCloud, Grafana, Pi-hole and Homebridge. The cluster is connected to a Sabrent USB raid 5, 4TB Sata docking station. For cooling each Pi has a GeeekPi Ultra Thin ICE Tower and the rack has 3 x 120mm 5V usb 2000rpm fans at the back to blow through cool air to complement the cooling going on, on each Pi.

diyelectromusic
@diyelectromusic@mastodon.social

@themagpi I glued together a few off-the-shelf components, combined with a software update to #MiniDexed, to create a DX7-synth-onna-stick...

diyelectromusic.wordpress.com/...

#MagPiMonday

PJ Evans
@mrpjevans@mastodon.social

@themagpi Is this a Sonos Play:1? Nope, it's a #RaspberryPi powered Soma:1 which plays streams from SomaFM and can be controlled by Home Assistant over MQTT. Ambient choonz on demand.

04

PI-Learn-Tech · Follow
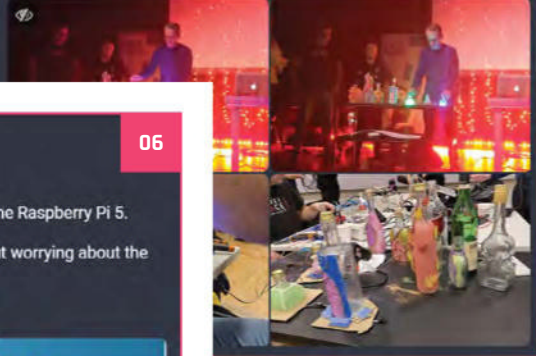
working on our 3D printed laptop that you build yourself as a kit powered by Raspberry Pi 5, comes with instructions and all parts to make a functional laptop... http://www.pi-learn.co.uk, our Raspberry Pi 5 being delivered this week, been a long project in the design stage 😊

2 w   Like   Reply   Hide

05

Piotr Gaczkowski
@DoomHammerNG@mastodon.social
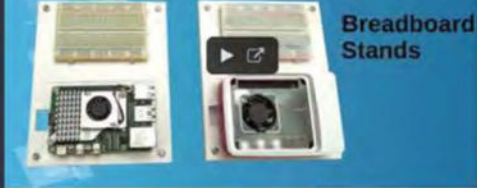
@themagpi Bottle Piano based on QT Pi RP2040 (original idea from Adafruit)

06

PenguinTutor (Stewart Watkiss)
@penguintutor@fosstodon.org

@themagpi
I've created some breadboard stands for the Raspberry Pi 5.

Now I can create electronic circuits without worrying about the wires falling out.

youtu.be/LYBTIVsWEHs?si=oy9Vel...

Raspberry Pi 5

Breadboard Stands

YouTube

Raspberry Pi 5 breadboard stand for electronic circuits RPi5
By Penguin Tutor

andypiper   1 w ...

Picoplot was on display at the Wimbledon Art Fair all weekend! #MagPiMonday - I learned some things that worked (and that didn't work so well!) and added them to the project log, link in qrcode.

07

kevinmcaleer

Yes! This weekend I built my own programmable toothbrush using a @raspberrypi Pico W! It's a project you can really sink your teeth into 🦷

08

raspberrypint   3 **09**

I started on a PICO W Pomodoro Timer after trying the Pomodoro technique via a webpage.

I recalled that @romilly.cocking had built a more advanced 'lazydoro', which is more automated using a time of flight(tof) sensor. Romilly kindly pointed me to his code, which I was able to modify for my design. I haven't incorporated a tof sensor yet, just a screen and buttons for now.

Thanks Romilly - getting started can be the hardest part.

github.com/romil...

The Pomodoro Technique

Select a single task to focus on | Set a timer and work continuously for 25 minutes | Take a productive 5 minute break | Repeat for 4 rounds | Take a longer break for 30 minutes and repeat

10

Pater Practicus
@paterpracticus@mastodon.world

@themagpi VERY early days, but I thought this year we might add some flashing signage lights for the #christmastree railway level crossing. #MagPiMonday #TMRGUK

Fabrication Fest

A fair for makers in Providence, Rhode Island, where folks could experience Raspberry Pi 5

While *The MagPi* is written in the UK, our benevolent director of publishing Brian Jepson resides in Rhode Island in the US. He's active in the maker scene in the area, so when the Rhode Island Computer Museum put on Fabrication Fest in his city, he went along and showed off Raspberry Pi 5 for the crowd.

01. Excellent books and magazines accompany an excellent new computer

02. Computer history is important, and fascinating

03. This is a very cool game working with conductive thread

04. A beautiful yet cold November day for Fabrication Fest, which had free entry

Best of the rest

Other great things we saw this month

BACKLIT LIGHTBOX

This very pretty box is made up of custom, 3D-printed layers over an 8×8 LED matrix controlled by Raspberry Pi to create excellent vistas.

▶ **magpi.cc/lightbox**

RASPBERRY PI HALLOWEEN COSTUME
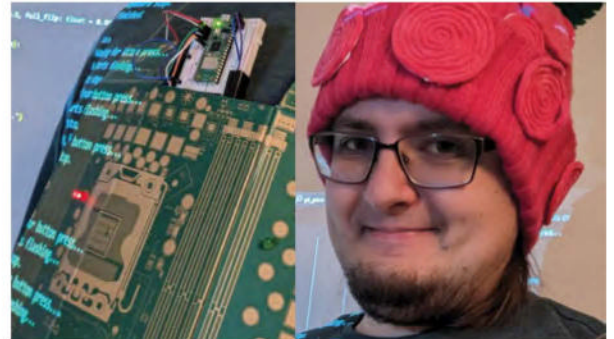
An amazing costume, complete with logo hat and a Pico controlling LEDs around the board graphic. We love it.

▶ **magpi.cc/rpcosplay**

Your **Letters**
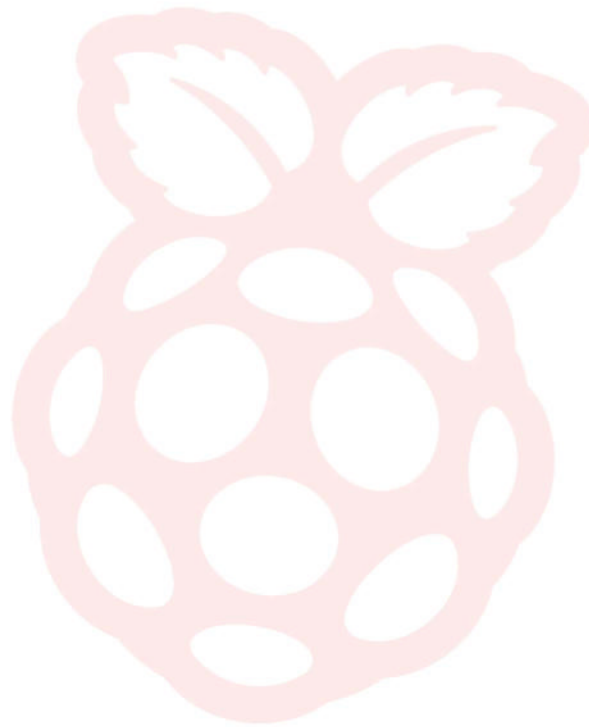
Essentially printed

Hi, I've been looking for *The MagPi Essentials Hacking and Making in Minecraft*. It is now sold out and I have the free PDF but would like a physical copy!

I have never found a copy of Hacking and Making in Minecraft for sale, so I wonder if it was ever actually printed? I am also interested in *Conquer the Command Line 2nd Edition*, but I can't find that either! Any help in this regard is much appreciated!
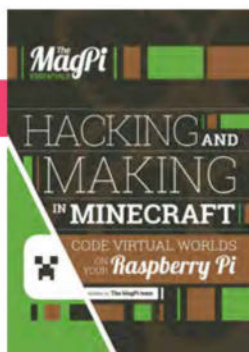
Paul via email

▲ The PDF for this book is still available – find it at **magpi.cc/books**

We did print *Hacking and Making in Minecraft*, but it was quite a while ago – same with *Conquer the Command Line 2nd Edition*. While we don't currently have plans to reprint them at the moment, we may reconsider it.

You can always get the PDFs printed yourself if you wish – it's all part of our Creative Commons licence for our releases.

Moving monitors

I've been a Raspberry Pi user since the very first one, which I pre-ordered as soon as I heard about it.

I've been the proud owner of a Raspberry Pi 5 for a month, but haven't used it as I want to get a portable monitor.

Have you ever reviewed portable monitors? If not, could you maybe do a review of a few so we know what is available and what works well with Raspberry Pi, specifically Raspberry Pi 5?

Terry via email

We've done a few reviews of more portable monitors over the years – recently CrowVision in issue 133 (**magpi.cc/133**) – but we've never done a comparison of them all. We can definitely see how the current and past monitors stack up in a future issue.

Terry also mentioned to us he was looking for bigger ones, at least 15-inch, so we'll see what it is out there.

▲ This is a bit smaller than 15-inch but it's a great little monitor
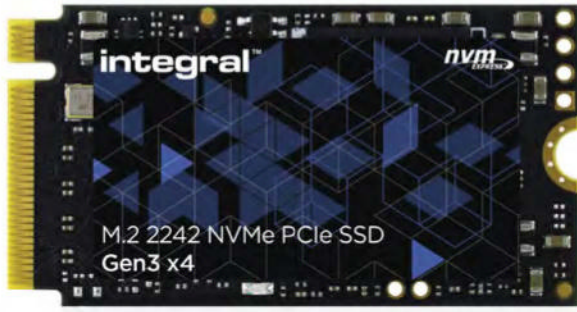
▲ You'll soon be able to add NVMe devices to Raspberry Pi 5

A matter of storage

I have a new Raspberry Pi 5 and I am awaiting another. I also have the new official Raspberry Pi case and new power supply.

Before I install Ubuntu, I would like to have additional storage (for data and swap); the OS can remain on the SD card.

When will the new [M.2] HAT be available? Will it hold more than one SSD device? Is there an extension for the case to accommodate the HAT?

Will these topics be covered in future editions of *The MagPi*?

Peter via email

We haven't heard of a time frame for the new M.2. HAT just yet. However, from what we understand, it will have room for just one M.2. SSD card.

As for whether it will fit in the case, we think that's still not confirmed, but we know it's a concern for the design. When we have more concrete news, we'll definitely have some information in the magazine – we're also very excited to see what we can do with the Raspberry Pi port for PCIe, storage or otherwise.

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. Microprocessor Showdown with Raspberry Pi 5

🗓 **Thursday 21 December**

📍 **Ann Arbor District Library, Ann Arbor, MI, USA**

▶ **magpi.cc/ms137**

In this self-guided demo, you can try out basic coding
and physical computing on several different platforms,
including the brand-new Raspberry Pi 5. Try your hand
at making wearable tech, solar-powered Morse code
transceivers, blackout poetry, computerised object
detection, animation with Scratch, live-coding dance
music, and much more.

02. Riverside Raspberry Jam

🗓 **Monday 8 January 2024**

📍 **ExCITE Riverside, Riverside, CA, USA**

▶ **magpi.cc/rrj137**

This month's topic is open, so if you have a topic you would
like to discuss, feel free to let them know in the comment
section on the event page.

03. Cornwall Tech Jam

🗓 **Saturday 13 January 2024**

📍 **FibreHub, Pool, UK**

▶ **magpi.cc/ctj137**

Cornwall Tech Jams are run by volunteers working in IT
and education throughout Cornwall. They are supported
by Software Cornwall, its members, and other local
businesses. Their volunteers give their own time and
expertise to plan each Cornwall Tech Jam and to the
regular maintenance of all the equipment.

04. Raspberry Pi Jam The Hague

🗓 **Saturday 27 January 2024**

📍 **Koninklijke Academie van Beeldende Kunsten, Den Haag, Netherlands**

▶ **magpi.cc/rpjth137**

This Raspberry Pi Jam will be held in the main galleries
of the Royal Academy of Art in The Hague. It will show
off what cool things are possible with our favourite
small computer.

FULL CALENDAR

Get a full list of upcoming
community events here:

magpi.cc/events

RASPBERRY PI 5 CAMERA TALK

03

Raspberry Pi 5 camera software and computer vision applications

> Where **Online**
> When **Thursday 14 December**

Raspberry Pi principal software engineer James Hughes joins element14's Phil Hutchinson for a discussion of Raspberry Pi 5 camera software and computer vision applications.

magpi.cc/RP5cameratalk
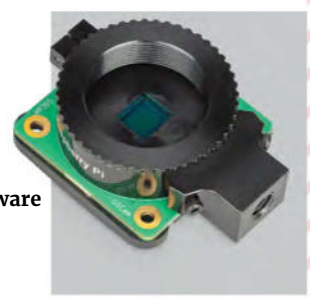
- Learn coding
- Discover how computers work
- Build amazing things!

5th Edition
Fully updated for
Raspberry Pi 5

The Official
**Raspberry Pi
Beginner's Guide**

How to use your new computer

Raspberry Pi
PRESS

Gareth Halfacree
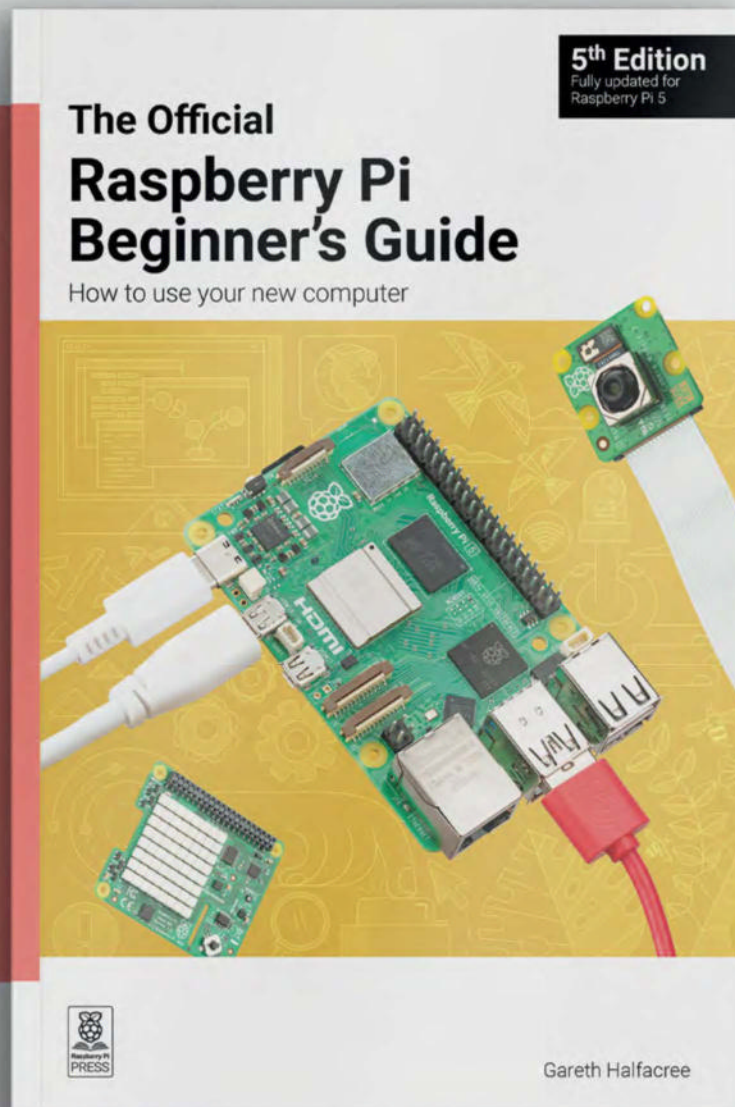
magpi.cc/beginnersguide

WIN ONE OF FIVE

U-MAKER BOX RASPBERRY PI CASES!

This cool and very modular case for Raspberry Pi allows you to modify the case depending on how you want to use it, with included parts and 3D printable add-ons. We've got five to give away...

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

NEXT-GENERATION RETRO GAMING

WITH
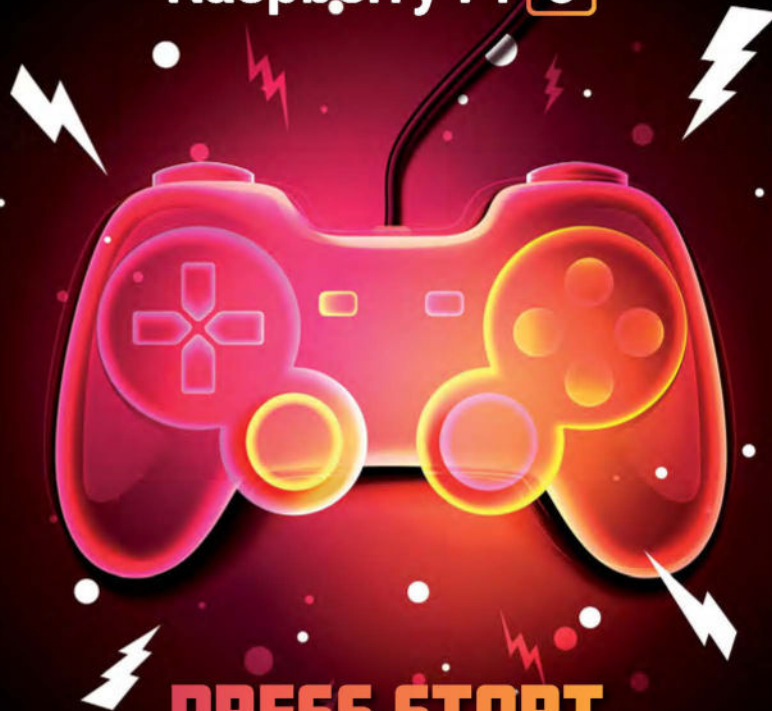
Raspberry Pi 5

PRESS START
ON A WHOLE NEW 3D WORLD OF VIDEO GAME SYSTEMS

THE MAGPI **#138**
ON SALE **25 JANUARY**

Plus!

Arts & crafts projects

Solar imaging

Raspberry Pi SCSI

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New year, new goals?

On planning out what to do in 2024, with perpetual procrastinator **Rob Zwetsloot**

I've definitely written before in this column about setting goals for a new year and what I had planned. Problem is, I'm very good at not always doing them. Yesteryear's goals become half of this year's goals – like perpetually saying at new year you'd go to the gym more, but based around hobby stuff.

I've learned to live with it. On the one hand, stuff happens and life can be unpredictable. I might have had time to work on a script or a model one evening, but then a friend hits me up to hang out or a parent calls or I'm very sleepy and need a nap. Should probably work a bit on that last one, to be honest.

I'm lucky that I get a lot of creative fulfilment by writing for the magazine as that's what I'm trying to get out of my hobbies anyway. Recently I've been taking part in a (relaxed) model building competition and said in passing I probably wouldn't meet the deadline. The organiser replied: "Don't worry about deadlines. Life has enough of those. Take your time and enjoy yourself". Words to live by.

Always next year

I'm enjoying making this model, so I'm just going to finish it at my own pace. It's a model of a Zaku mecha from the anime *Mobile Suit Gundam*, by the way. I've modified it so it looks like it's going fishing.

A good excuse I'm finding for finally doing some long-planned projects is the release of Raspberry Pi 5. We've been busy making excellent magazines for you in the run-up to Christmas, so I've not had

> **Being satisfied with what you've made with no deadlines is probably a lot more worthwhile**

a huge amount of time to play with mine yet. I definitely have plans for the new year, and hopefully I can get them in the magazine too.

One thing I'm planning is updating the gameshow buzzer system I made in 2021 by adding a screen for the contestants to watch stuff for the video round. Currently they have to twist around a lot to view a projector behind them, which probably isn't good for their necks

and I can't afford to pay for multiple chiropractor sessions.

While that project is a bit time-sensitive (the quiz happens on a certain date!), most maker projects and other hobbies are rarely time-sensitive, so they can wait. Perfect may be the enemy of good, but being satisfied with what you've made with no deadlines is probably a lot more worthwhile.

The MagPi in 2024

As the change in year is mostly arbitrary, not much will be differing anyway as we charge into 2024 with all 366 of its days (yes, that does mean Raspberry Pi will be four-slash-12 years old). We're always working behind the scenes to make sure the magazine is better to read and obtain, along with other bits and pieces. We'll still be the same excellent mag and we hope you enjoy the next year of them!

Oh, and if you have any cool new year project ideas, send them our way at **magpi@raspberrypi.com**. We're always interested to hear them!
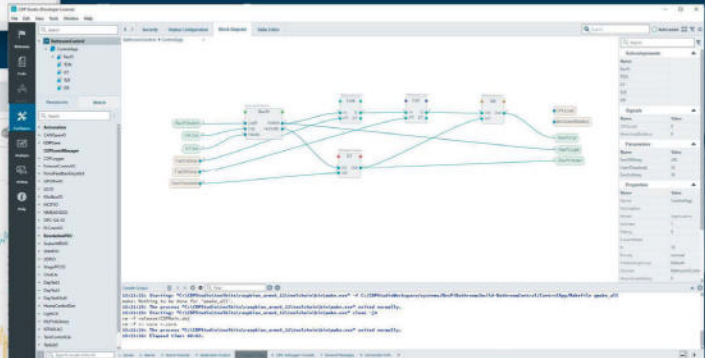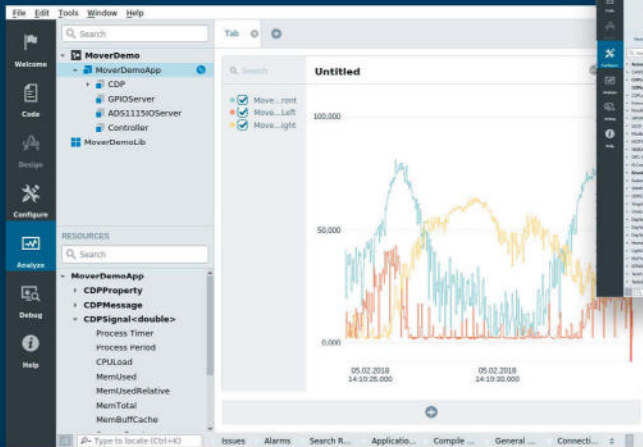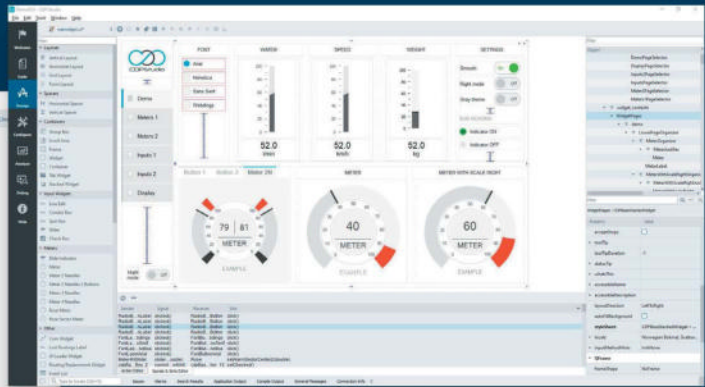
AUTHOR

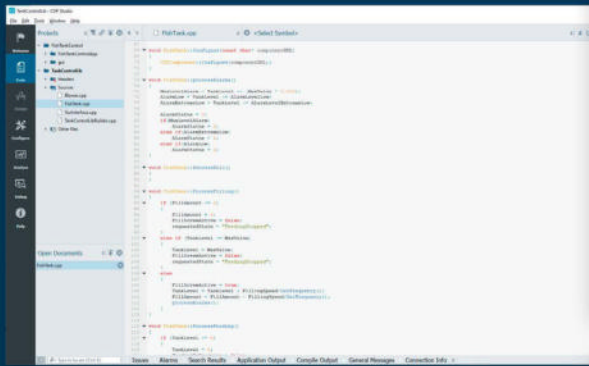### Rob Zwetsloot

Rob loves to write to-do lists and then not really follow through on them unless they're kind of urgent.

magpi.cc