

THE OFFICIAL RASPBERRY PI MAGAZINE

The MagPi + HackSpace

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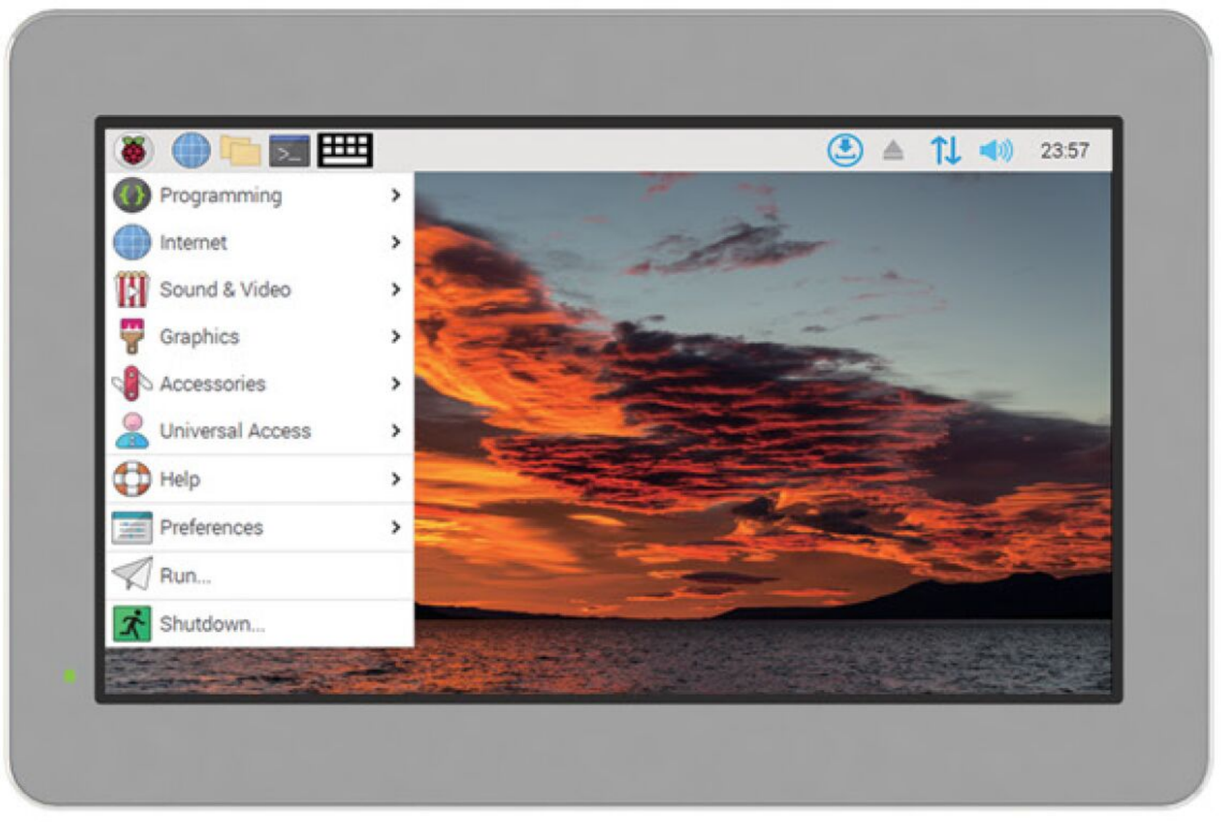
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& PEOPLE & PROJECTS

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WELCOME
to The MagPi 150

We've made it all the way to issue 150! This is a huge achievement and a testament to the strength of the Raspberry Pi community, the incredible team of writers, and the company itself.

I'm slightly in awe of you all!

I strongly believe in printed publications and physical products in general. Making hardware is tough; making print magazines is also hard. The stakes are high and you have to think about what you include; and what you leave out.

This month, the whole team came together to write about 150 People & Projects (page 42). This massive feature takes up almost a fifth of our magazine and was a labour of love. In it, you'll find all the biggest projects, best people, and brightest shining products of the last 13 years.

Raspberry Pi is the best computing platform of the modern age. With a Raspberry Pi in hand, and a magazine or book in the other, you will learn how computers work – an incredibly valuable skill.

Thank you for buying *The MagPi*, and thank you for supporting magazines. It really makes a difference.

Lucy Hattersley Editor



EDITOR

Lucy Hattersley

Lucy is editor of *The MagPi*, and believes in building physical things that hopefully work.

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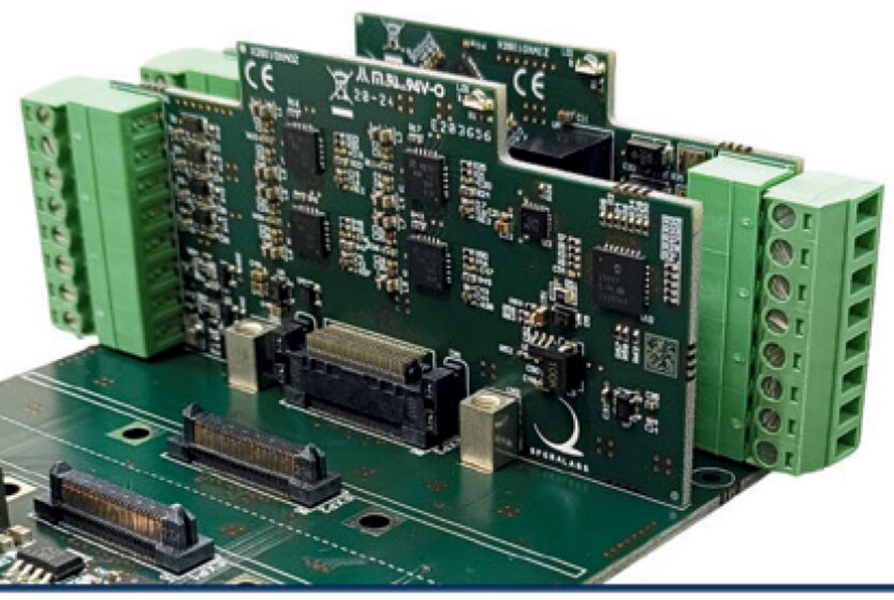


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Cave mapping



Floppy Disk Archiver

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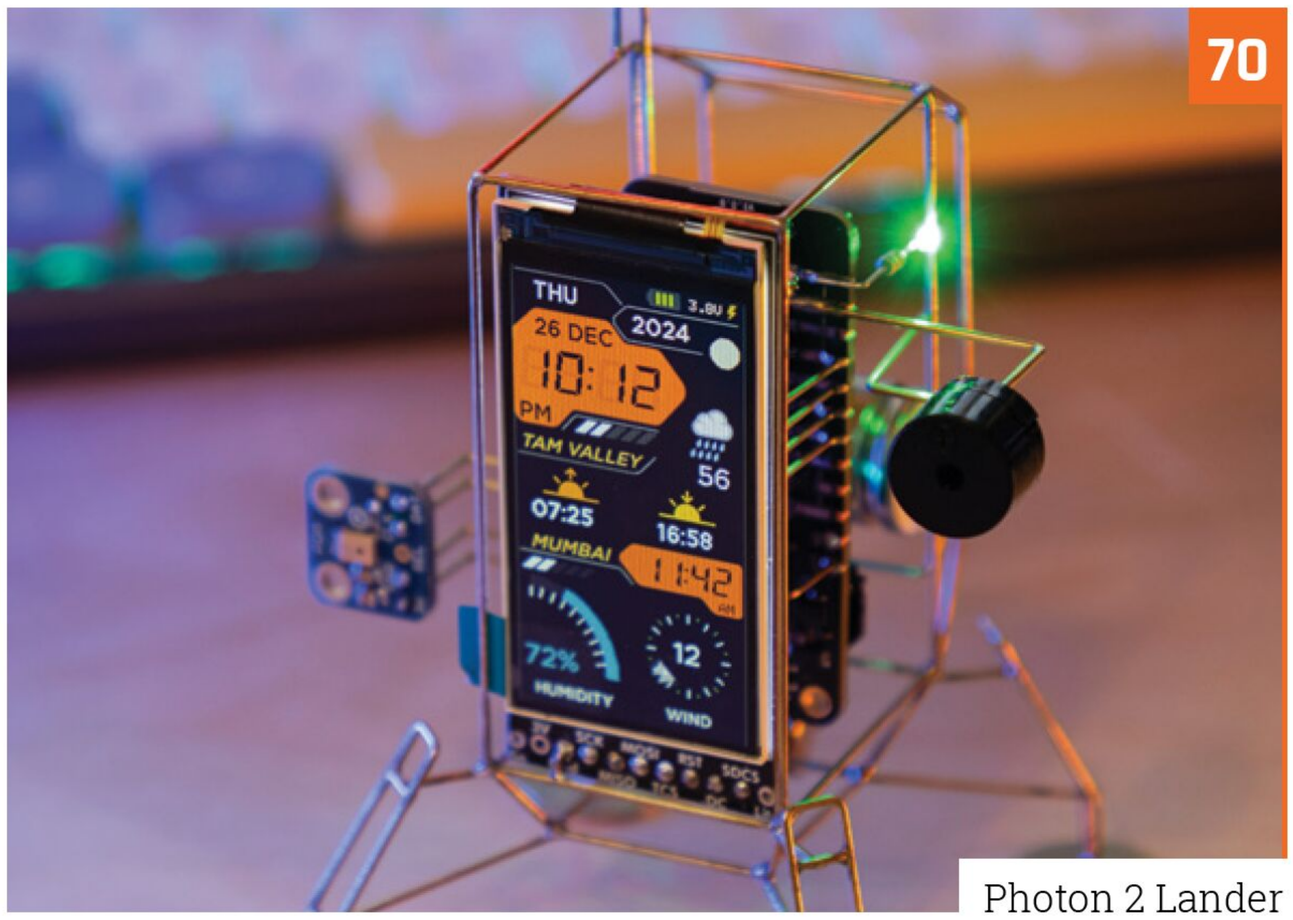
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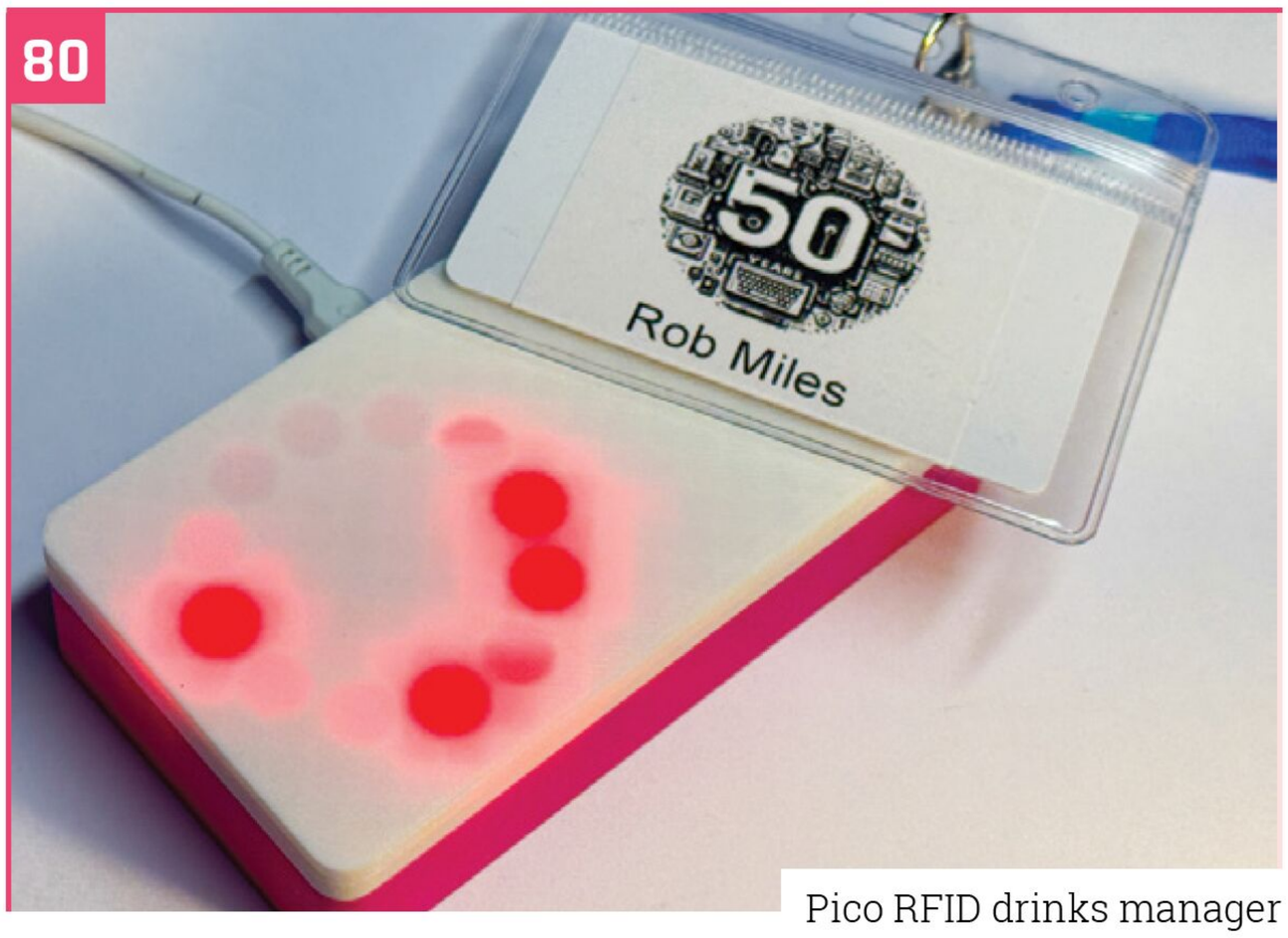
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E-ink clock



Photon 2 Lander



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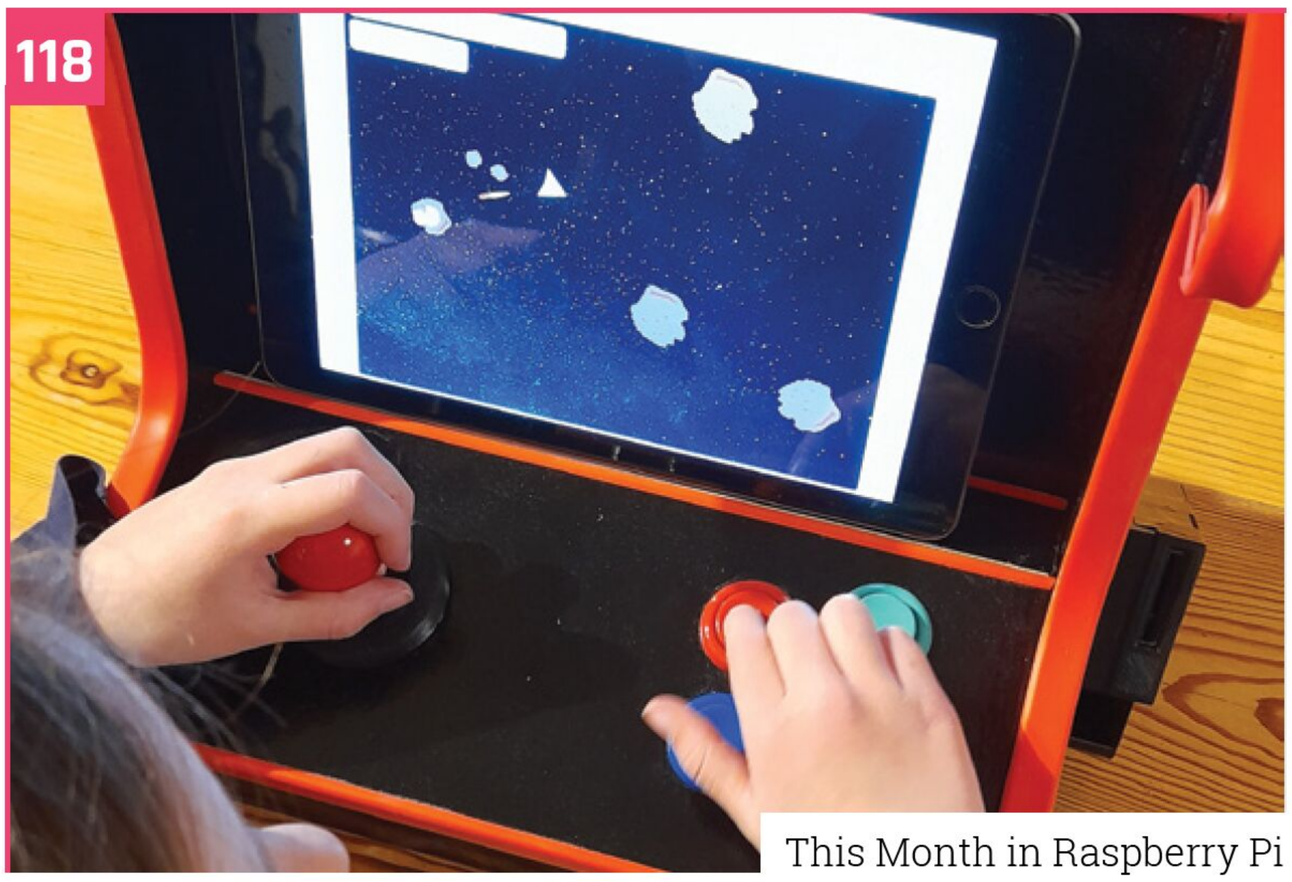
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This Month in Raspberry Pi

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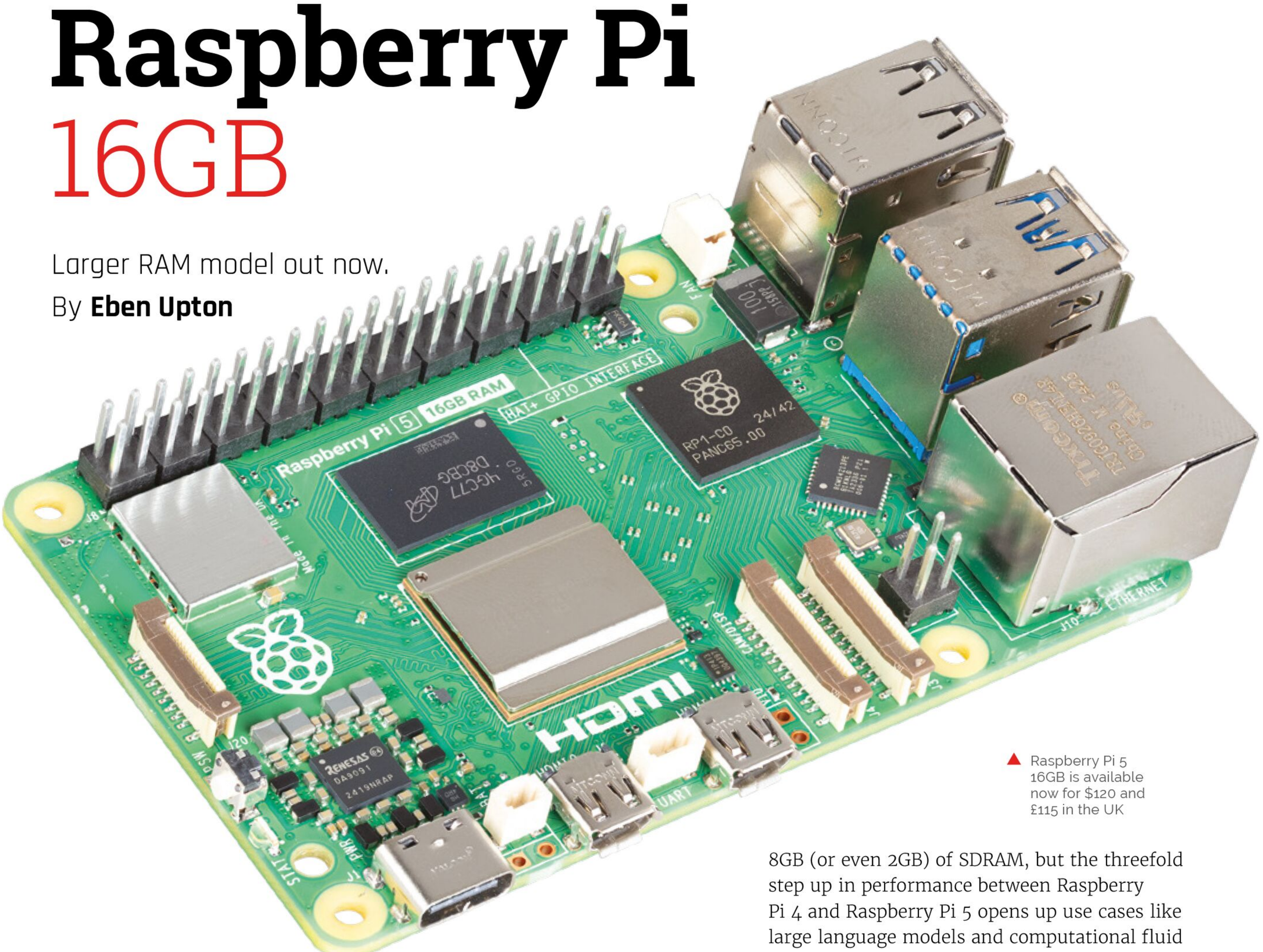
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Raspberry Pi 16GB

Larger RAM model out now.

By **Eben Upton**



▲ Raspberry Pi 5 16GB is available now for $120 and £115 in the UK

We first announced Raspberry Pi 5 back in the autumn of 2023, with just two choices of memory density: 4GB and 8GB. Last summer, we released the 2GB variant, aimed at cost-sensitive applications. And now we're launching its bigger sibling, the 16GB variant, priced at $120.

Why 16GB, and why now?

We're continually surprised by the uses that people find for our hardware. Many of these fit into 8GB (or even 2GB) of SDRAM, but the threefold step up in performance between Raspberry Pi 4 and Raspberry Pi 5 opens up use cases like large language models and computational fluid dynamics, which benefit from having more storage per core. And while Raspberry Pi OS has been tuned to have low base memory requirements, heavyweight distributions like Ubuntu benefit from additional memory capacity for desktop use cases.

The optimised D0 stepping of the Broadcom BCM2712 application processor includes support for memories larger than 8GB. And our friends at Micron (**micron.com**) were able to offer us a single package containing eight of their 16Gbit LPDDR4X die, making a 16GB product (**magpi.cc/raspberrypi5**) feasible for the first time.

> We're continually surprised by the uses that people find for our hardware

The extra 16GB RAM will be useful for large language models and desktop computing

Raspberry Pi 5 with a 16GB RAM package on the board

Carbon Removal Credits

New Raspberry Pi project supports carbon removal. By **Eben Upton**



▲ Enhanced rock weathering (ERW) is a nature-based carbon removal technology that permanently locks away CO_2

We're proud of the low environmental impact of Raspberry Pi computers. They are small and light, which translates directly into a small upfront carbon footprint for manufacturing, logistics, and disposal. With an idle power consumption in the 2–3W range, and a fully loaded power consumption of less than 10W, replacing a legacy x86 PC with a Raspberry Pi typically results in a significant reduction in operating power consumption, and thus ongoing carbon footprint.

But while our upfront carbon footprint is small, it is not zero. So we're launching Raspberry Pi Carbon Removal Credits (**magpi.cc/carbonremoval**), priced at $4, giving you the option to mitigate the emissions associated with the manufacture and disposal of a modern Raspberry Pi.

How does it work?

We commissioned Inhabit (**inhabit.eco**) to conduct an independent assessment of the carbon footprint of manufacturing, shipping, and disposing of a Raspberry Pi 4 or 5, which came to 6.5kg of CO_2 equivalent. When you buy a Raspberry Pi Carbon Removal Credit from one of our Approved Resellers, we pay our friends at UNDO Carbon (**un-do.com**) to begin capturing that quantity of CO_2 from the atmosphere using enhanced rock weathering (ERW) technology.

It's that simple.

What is enhanced rock weathering?

As rain falls through the atmosphere, it combines with CO_2 to form carbonic acid. When this weak acid falls on mountains, forests and grassland, the CO_2 interacts with rocks and soil, mineralises, and is safely stored in solid carbonate form. The natural process of weathering already accounts for the removal of one billion tonnes of CO_2 from the atmosphere every year.

ERW accelerates this natural process by spreading crushed silicate rock (in our case, basalt) on agricultural land, increasing the surface area of the rock and therefore increasing its contact with CO_2. Overall, this reduces the timescales involved from millions of years to mere decades. Once the reaction takes place, the CO_2 is permanently locked away for 100,000+ years.

In addition to capturing CO_2, spreading basalt on agricultural land also brings with it significant co-benefits. Silicate rocks are mineral-rich; as they weather, they release nutrients such as magnesium, calcium, and potassium, improving soil health and reducing the need for fertilisers. Trials with the University of Newcastle have shown an increase in crop yield following the application of crushed basalt rock. In addition, the alkaline bicarbonate ions captured during the ERW process



Spreading crushed silicate rock speeds up the natural process of carbon removal

are eventually washed out to sea, where they help to deacidify our oceans. You can find out more about UNDO's work at **un-do.com**.

Why capture carbon in the future, not the past?

Generally, when you buy carbon offsets, you are paying for carbon capture which has taken place in the past (for example by planting and growing trees). When you buy Raspberry Pi Carbon Removal Credits, UNDO spreads basalt now, which then captures the rated quantity of carbon over, roughly, the next 20 years.

> We believe it's a more rigorous, scalable, verifiable approach to carbon capture than traditional approaches like planting

We've chosen ERW because we believe it's a more rigorous, scalable, verifiable approach to carbon capture than traditional approaches like planting (or, more ridiculously, agreeing not to cut down) trees: quite simply, it's our best shot at drawing down a material fraction of humanity's carbon emissions in our lifetimes. But, as it is a relatively new technology, there is no pool of offsets corresponding to historical capture available for us to purchase.

So, we're doing the next best thing: paying UNDO to start an irrevocable process of carbon capture which will continue over the next two decades and beyond. We hope that our embrace of ERW will help raise awareness of this world-changing technology, and perhaps inspire others to take their first steps with it.



Each Raspberry Pi Carbon Removal Credit has a unique code printed on the card in order to protect against fraud

WOPR

We made our own WarGames computer for Pi Towers. By **Ashley Whittaker**

Ah, the WOPR – or 'War Operation Plan Response', for those who enjoy abbreviations that sound like a robot from the future, only less like a friend and more like an overzealous maths teacher.

The WOPR is the supercomputer from the 1983 movie *WarGames*. It doesn't understand sarcasm, it can't sense when it's being pranked, and it certainly doesn't know when it's been told to 'play a game' – much like our Maker in Residence, Toby, who built it to delight and entertain all visitors to the Pi Towers Maker Lab.

What's inside?

- Raspberry Pi 4 (**magpi.cc/raspberrypi4**)
- Raspberry Pi Touch Display 2 (**magpi.cc/touchdisplay**)
- 5V / 30A power supply (**magpi.cc/5v30a**)
- 615 Adafruit NeoPixels (**magpi.cc/neopixels**)
- Bluetooth speaker

A script runs on boot, which twinkles the NeoPixels in the traditional 1980s supercomputer colours: yellow and red.

Another script can be run to play a short clip from the film *WarGames* on the Touch Display 2



▼ WOPR (War Operation Plan Response) is the computer from the movie *WarGames*



The silver lettering was created using a Cricut cutting machine

screen, explaining the WOPR. At the press of a button on the Touch Display, our faux WOPR also parrots famous lines from the film, such as: "Shall we play a game?" and "How about a nice game of chess?"

For those who wish to linger a little longer in the Maker Lab, Toby devised a game in which clips from 1980s films and music videos flash (a little too fast, in our opinion) up on the screen, with your job being to enthusiastically shout out where each clip is from.

> WOPR is a combination of 3D-printed plastics and laser-cut MDF

Authentic enclosure

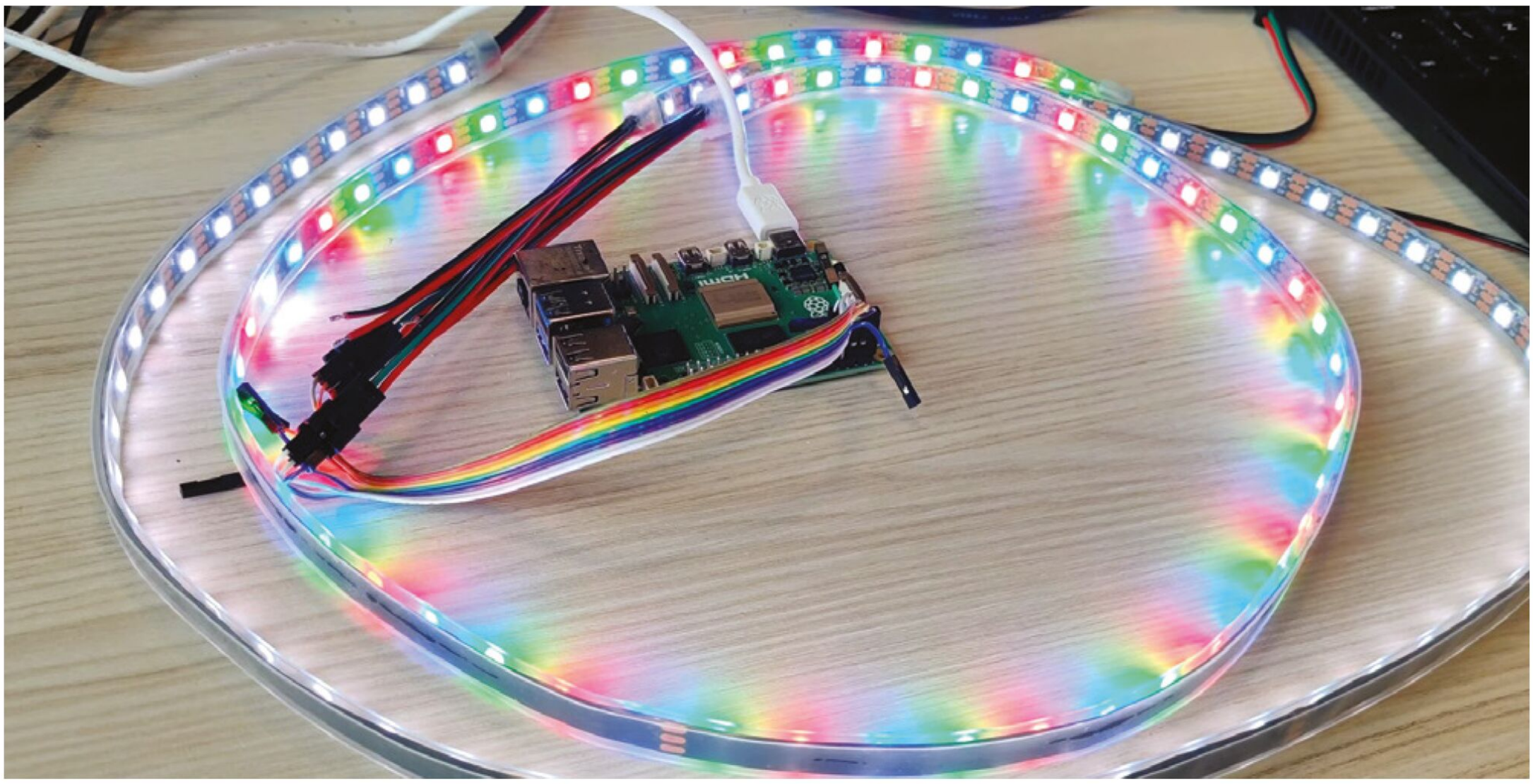
The body of the WOPR is a combination of 3D-printed plastics and laser-cut MDF painted in industrial grey, with Cricut silver lettering on the side. Everything is glued together, and a great deal of sanding was required to make it appear as though it is a sleek and very fancy contraption from the future.



A script on boot twinkles the 615 Adafruit NeoPixels

PIOLib: A user-space library for PIO control

Dip your toes into the world of PIO on Raspberry Pi 5 using PIOLib. By **Phil Elwell**

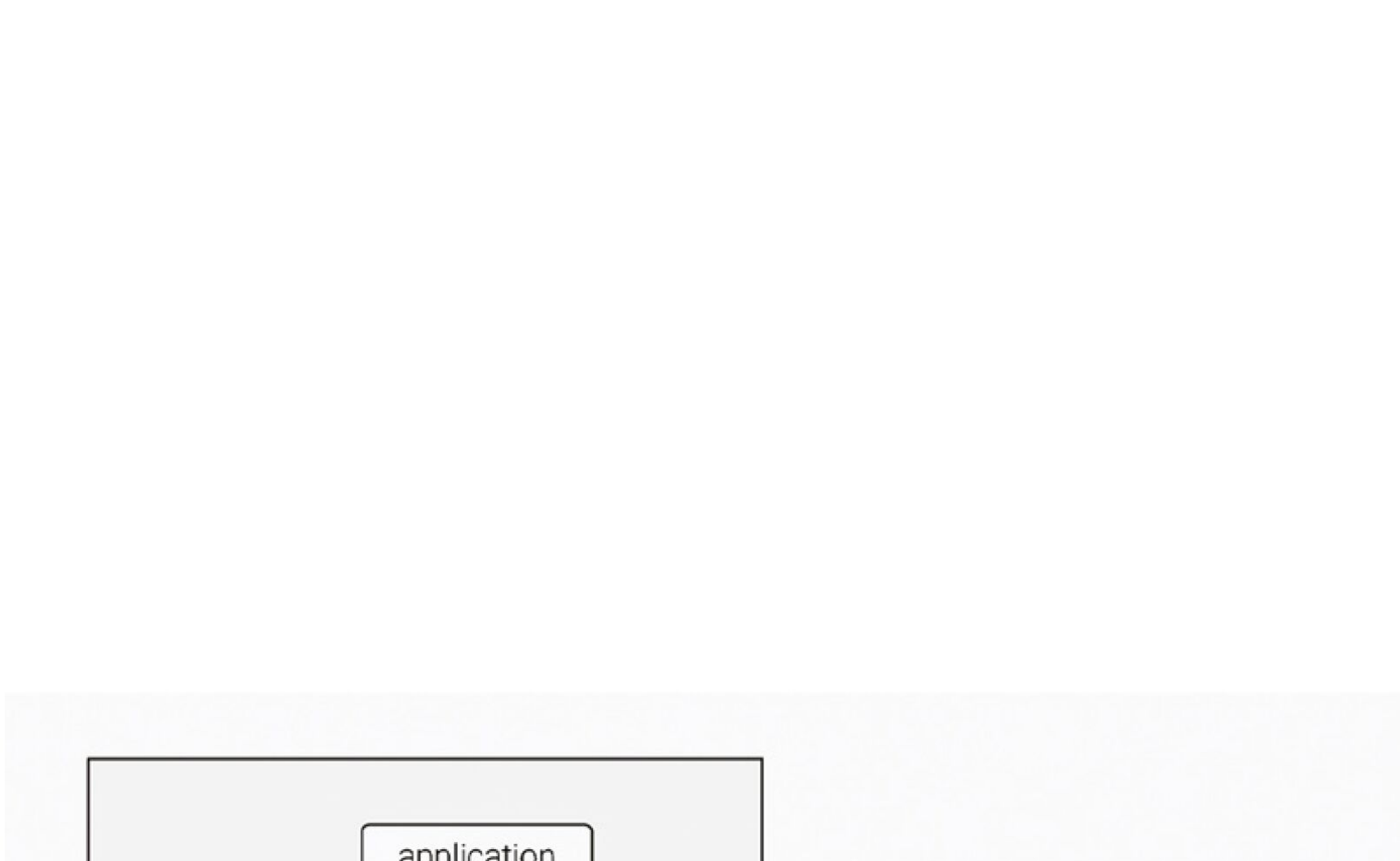


▲ WS2812 LEDs being driven by a Raspberry Pi 5

The launch of Raspberry Pi 5 represented a significant change from previous models. Building chips that run faster and use less power, while continuing to support 3.3V I/O, presents real, exciting challenges. Our solution was to split the main SoC (system on chip) in two – the compute half, and the I/O half – and put a fast interconnect (4-lane PCIe Gen 3) between them. The SoC on Raspberry Pi 5 is the Broadcom BCM2712, and the I/O processor (which used to be known in the PC world as the 'southbridge') is Raspberry Pi RP1.

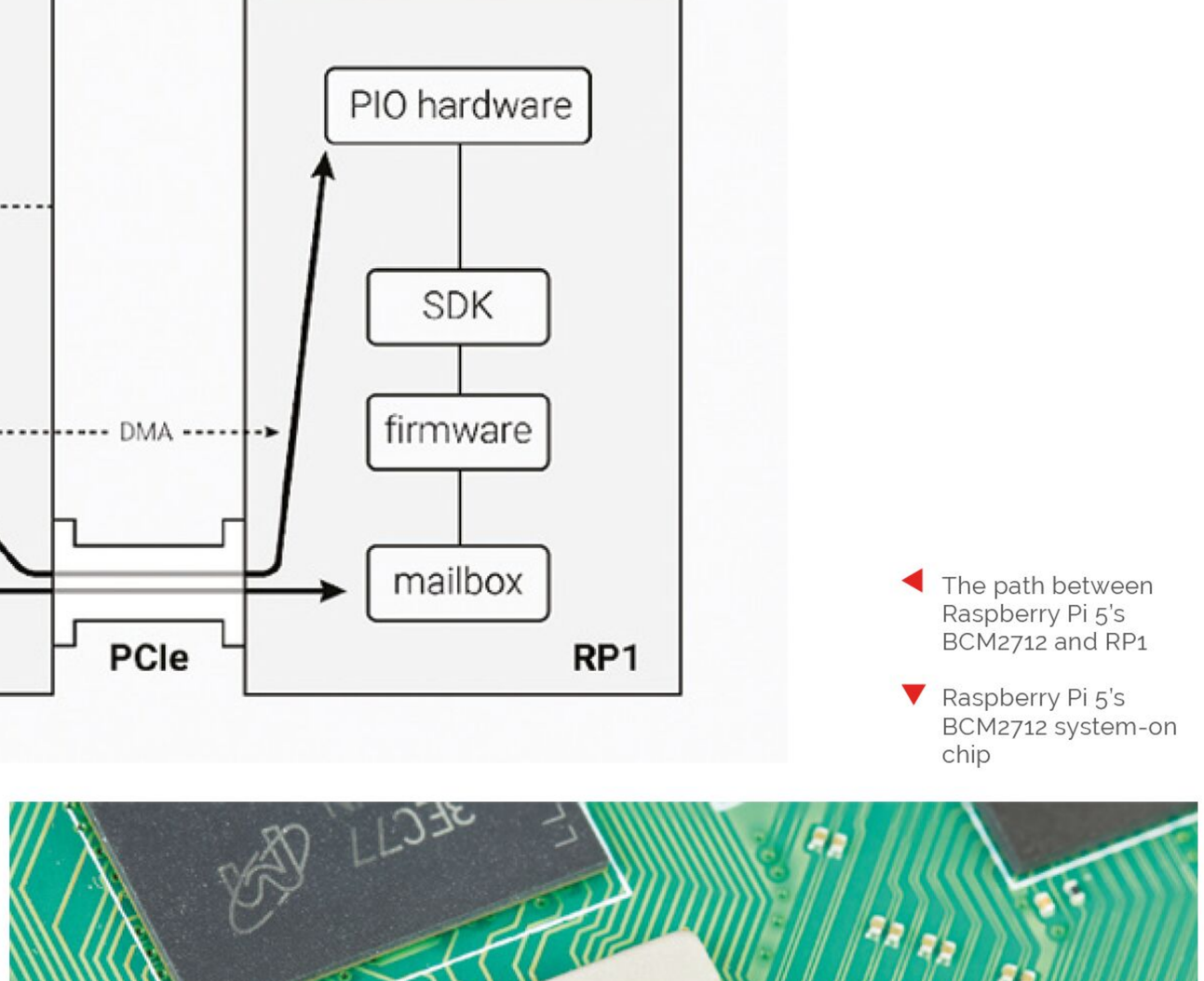
Along with all the usual peripherals – USB, I2C, SPI, DMA, and UARTs – RP1 included something a bit more interesting. One of RP2040's distinguishing features was a pair of PIO blocks, deceptively simple bits of Programmable I/O capable of generating and receiving patterns on a number of GPIOs. With sufficient cunning, users have been able to drive NeoPixel LEDs and HDMI displays, read from OneWire devices, and even connect to an Ethernet network.

RP1 is blessed with a single PIO block – almost identical to the two that RP2040 has – as well as



The path between Raspberry Pi 5's BCM2712 and RP1

four state machines and a 32-entry instruction memory. However, apart from a few hackers out there, it has so far lain dormant; it would be great to make this resource available to users for their own projects, but there's a catch.

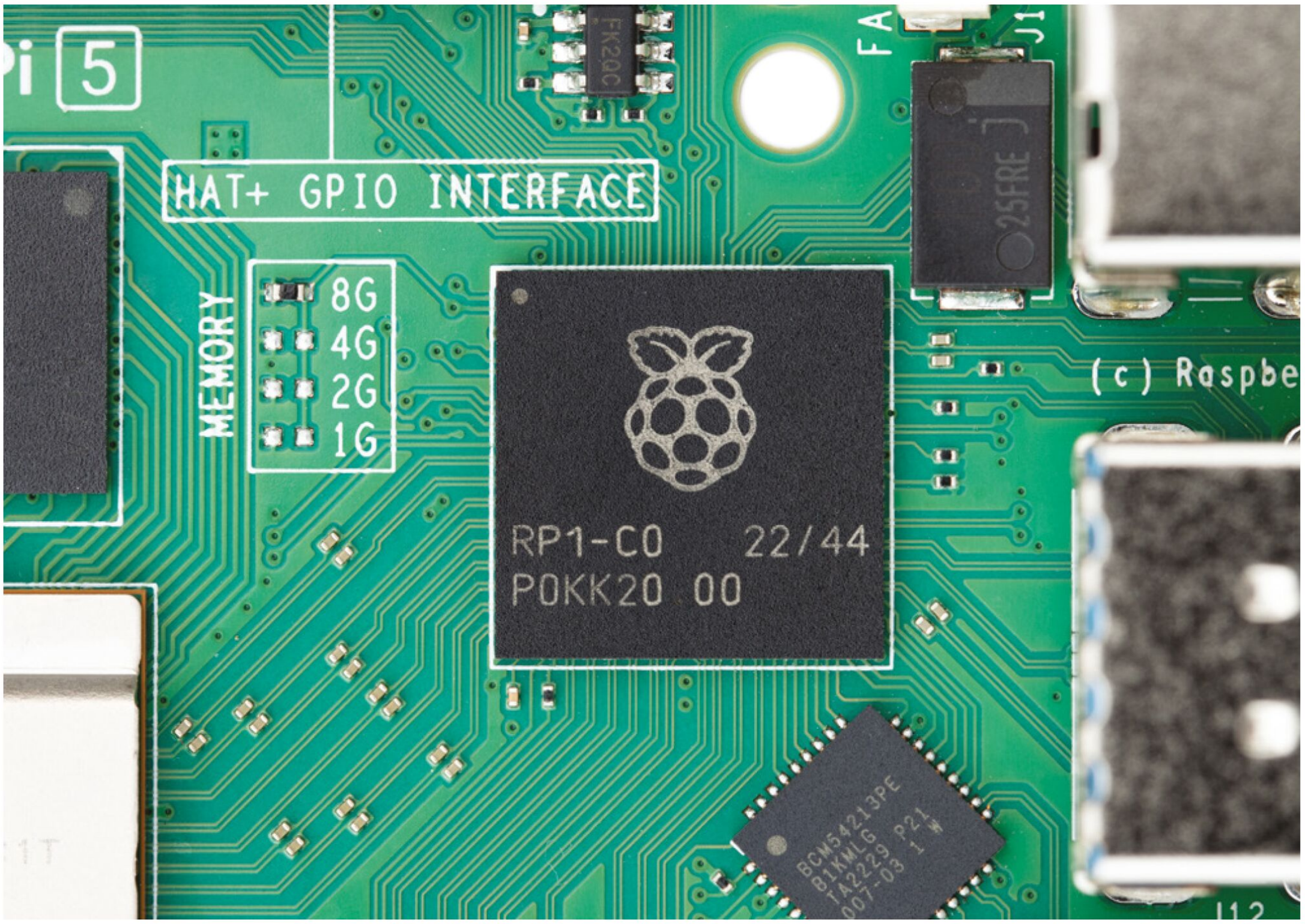


Raspberry Pi 5's BCM2712 system-on chip

Need for speed

The connection between RP1's on-board ARM M3 microcontrollers and the PIO hardware was made as fast as possible, but at the cost of making the PIO registers inaccessible over PCIe; the only exceptions are the state machine FIFOs – the input and output data pipes – that can be reached by DMA (direct memory access). This makes it impossible to control PIO directly from the host processors, so an alternative is required. One option would be to allow the uploading of code to run on the M3 cores, but there are a number of technical problems with that approach:

1. We need to 'link' the uploaded code with what is already present in the firmware – think of



▲ Raspberry Pi 5's RP1 input/output controller

it as knitting together squares to make a quilt (or a cardigan for Harry Styles). For that to work, the firmware needs a list of the names and addresses of everything the uploaded code might want to access, something that the current firmware doesn't have.

> Most of the PIOLib functions cause a message to be sent to the RP1 firmware, which performs the operation

2. Third-party code running on M3 cores presents a security risk – not in the sense that it might steal your data (although that might be possible…), but that by accident or design it could disrupt the operation of your Raspberry Pi 5.
3. Once the M3s have been opened up in that way, we can't take it away, and that's not a step we're prepared to take.

Not like that, like this

For these reasons, we took a different path. The latest RP1 firmware implements a mailbox interface: a simple mechanism for sending messages between two parties. The kernel has corresponding mailbox and firmware drivers, and an rp1-pio driver that presents an ioctl() interface to user space. The end result of adding all this software is the ability to write programs using the PIO SDK that can run in user space or in kernel drivers.

Latency trade-off

Most of the PIOLib functions cause a message to be sent to the RP1 firmware, which performs the operation – possibly just a single I/O access – and replies. Although this makes it simple to run PIO

programs on Raspberry Pi 5 (and the rest of the Raspberry Pi family), it does come at a cost. All that extra software adds latency; most PIOLib operations take at least 10 microseconds. For PIO software that just creates a state machine and then reads or writes data, this is no problem – the WS2812 LED and PWM code are good examples of this. But anything that requires close coupling between the state machine and driver software is likely to have difficulties.

The first official use of PIOLib is the new pwm-pio kernel driver. It presents a standard Linux PWM interface via sysfs, and creates a very stable PWM signal on any GPIO on the 40-pin header (GPIOs 0 to 27). You can configure up to four of these PWM interfaces on Raspberry Pi 5; you are limited by the number of state machines. Like many peripherals, you create one with a Device Tree overlay:

```
dtoverlay=pwm-pio,gpio=7
```

One feature absent from this first release is interrupt support. RP1 provides two PIO interrupts, which can be triggered by the PIO instruction IRQ (interrupt request), and these could be used to trigger actions on the SoC.

Over time, we may discover that there are some common usage patterns – groups of the existing PIOLib functions that often appear together. Adding those groups to the firmware as single, higher-level operations may allow more complex PIO programs to run. These and other extensions are being considered.

Let me play!

If you'd like to try PIOLib, you will need:

- The library and examples (**magpi.cc/piolib**)
- The latest kernel (`sudo apt update; sudo apt upgrade`)
- The latest EEPROM (see the 'Advanced Options' section of raspi-config)

In this YouTube video, you can see two strings of WS2812 LEDs being driven from a Raspberry Pi 5 (**magpi.cc/piolibYT**).



▼ Yes, you can use PIO on a Raspberry Pi 5

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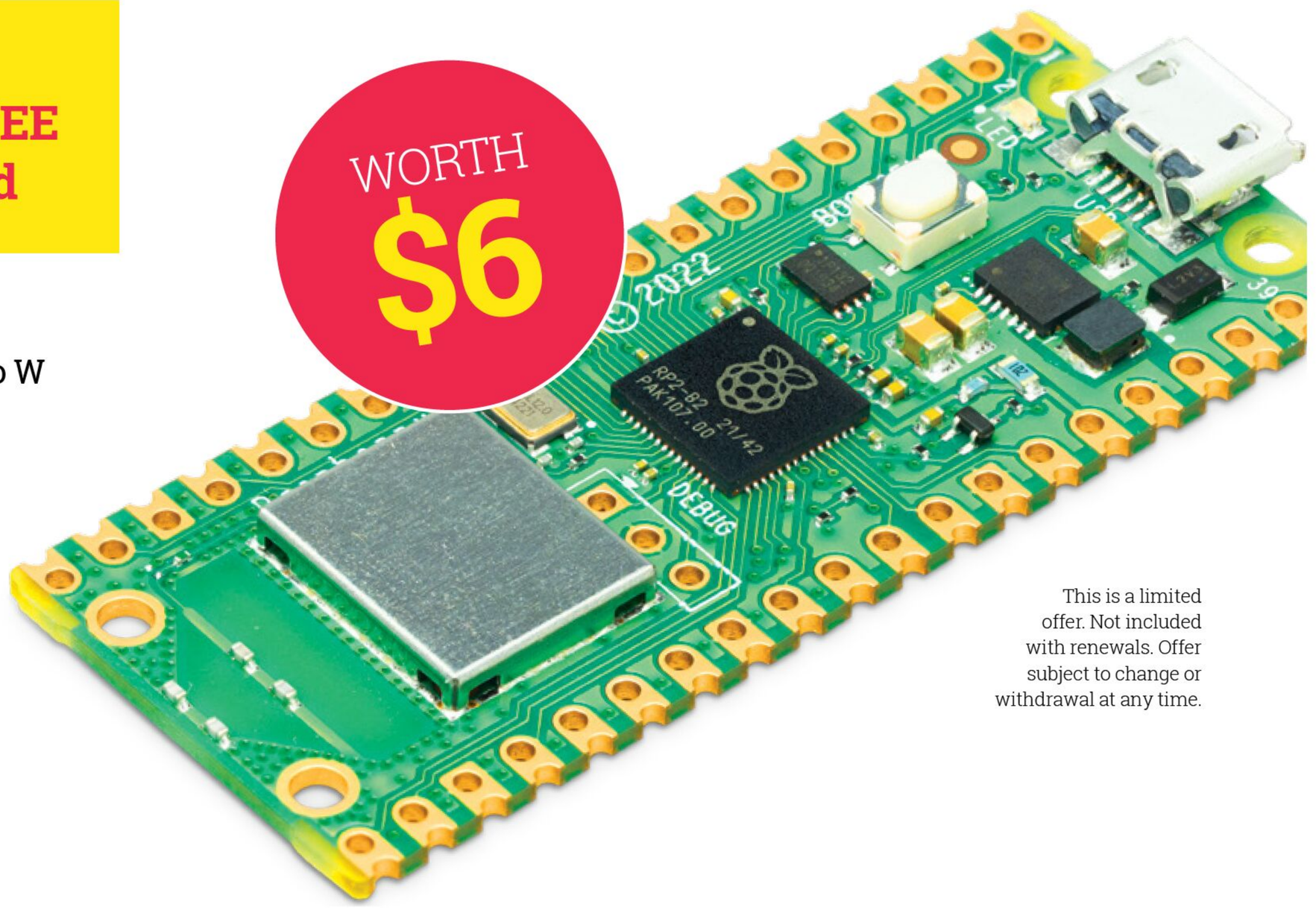
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Floppy Disk Archiver

Graham Hooley has converted an old floppy disk duplicator into an archiving machine that makes light work of preserving old files, as **David Crookes** discovers



MAKER

Graham Hooley

Graham Hooley – aka Graham Tinkers – loves to tinker and repair old 8- and 16-bit computers. He shares his passion for them via his YouTube channel.

youtube.com/c/grahamtinkers

As many computer archivists will confirm, floppy disks don't last forever. Although some will fare better than others, magnetic media generally degrades over time and disks can also fail due to dirt and dust if they're not stored properly. It's vital to archive them to a different media format as soon as possible to retain data. The trouble is that archival can be a cumbersome, long-winded process; unless you have an innovative device to hand.

Maker and developer Graham Hooley has created such a tool – a machine that allows a bunch of 3.5-inch floppies to be stacked and automatically read one at a time. The device uses parts from existing disk duplicators as well as a Raspberry Pi 3. It allows the disk images to be backed up to a USB drive. Not only that, a Camera Module snaps photos of the disks and these get archived as well. Not bad for a project that came about following a fortunate sequence of events.

"I'm a member of a maker space called Berlin Creators and we have a WhatsApp group chat," Graham explains. "One of the members said his brother had two 3.5-inch floppy disk duplicator machines in his cellar and he wanted to know if anyone wanted them before they ended up in waste recycling. I said I would take them, so he dropped them off at the maker space during our next Amiga meet-up. I had no idea what to do with them at first but, about two weeks later, I had a eureka moment."



The Raspberry Pi Camera Module v2 is used to capture a photo of each disk, saving it as the same name as the floppy disk image to make the archive easier to identify

Grease is the word

Graham had been testing the units and he was able to get one running and accepting serial commands from his PC. He then recalled seeing a video on YouTube by Shelby Jeuden [also known as Tech Tangents] about the Kryoflux and Greaseweazle solutions for preserving software on floppy disk.

Kryoflux, developed by the Software Preservation Society, and Greaseweazle, created by Keir Fraser, are small devices that sit between a floppy drive and a computer, allowing information to be harvested from disks. Using software, they can extract the raw flux transitions from a drive and

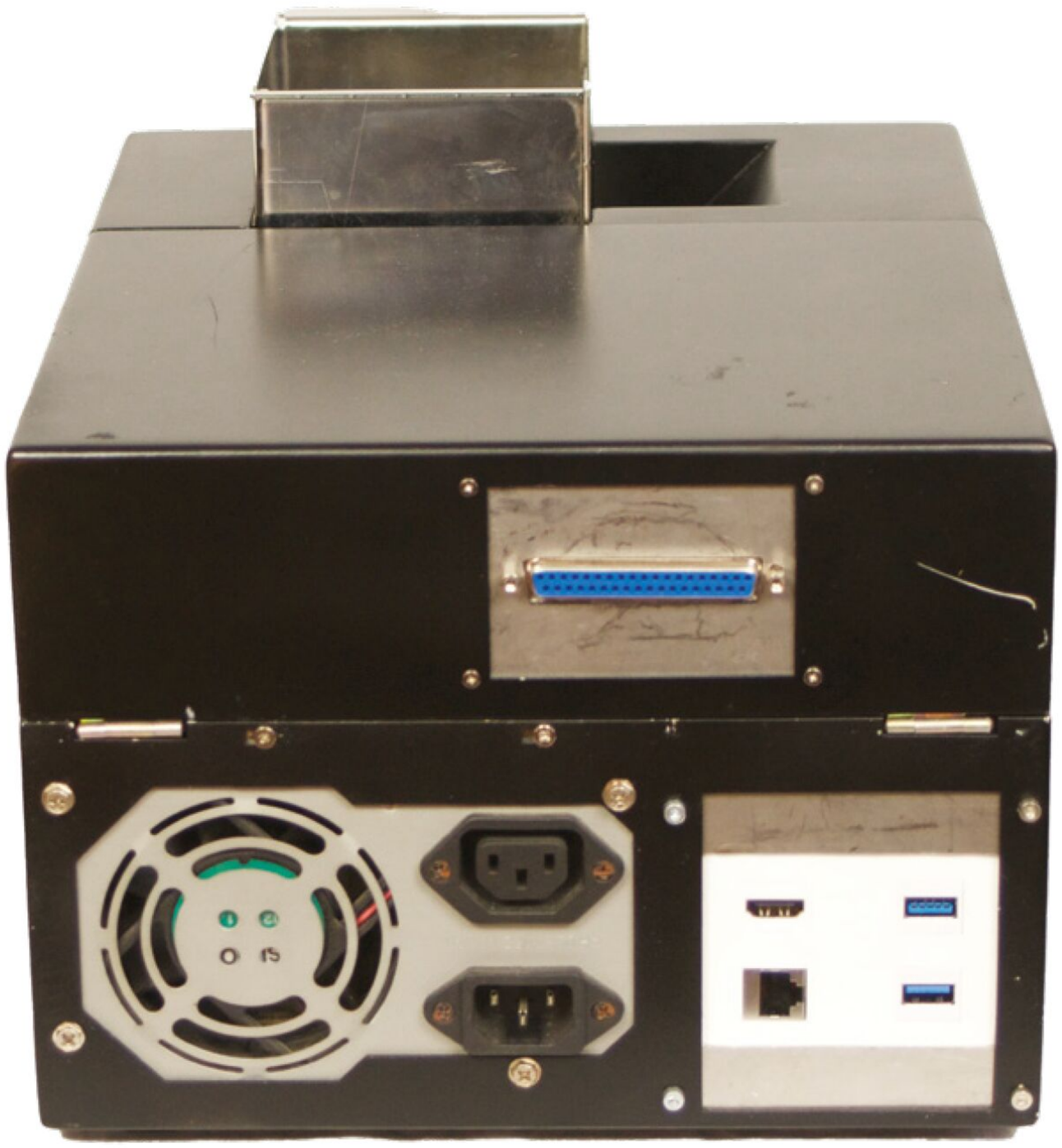
A Raspberry Pi computer is used to control the archiver and a Greaseweazle (the purple device to the right) reads the disks

Graham stripped back a 1990s LSK Data System GmbH disk duplication machine fitted with a Terra controller board and made use of its mechanical part

The device is capable of reading a host of disk formats, so you can dig out your old Commodore, Amstrad, Atari, and PC floppies (among others)

Quick **FACTS**

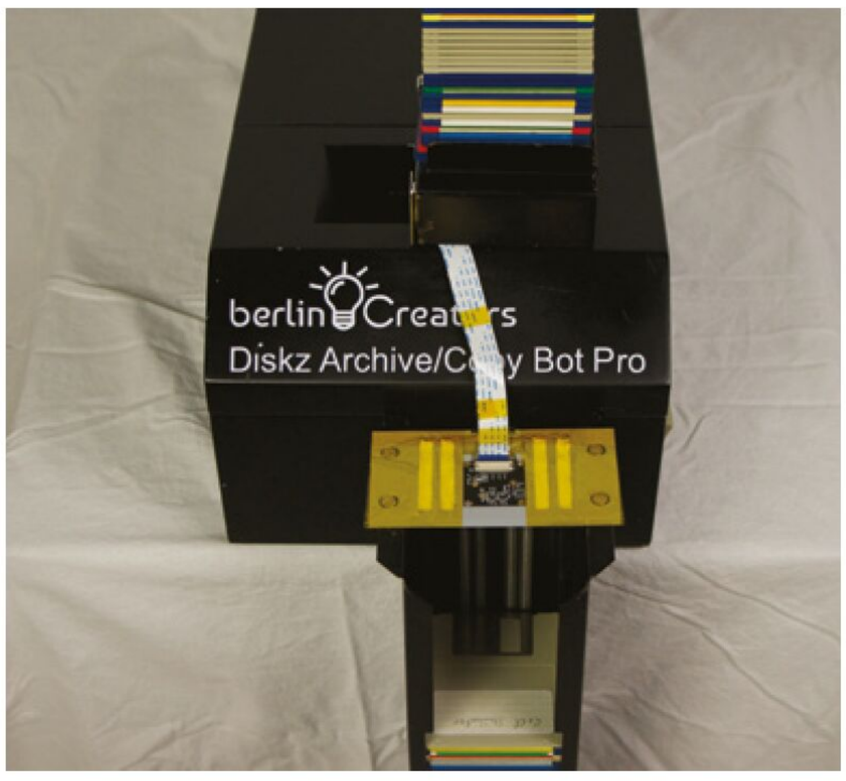
- The device quickly archives stacks of old floppies
- It uses the mechanical part from an old disk duplicator
- Raspberry Pi and a Greaseweazle device are connected
- Disk images are saved on a USB drive
- Graham is donating it to a Berlin maker space



▲ Graham has ensured that Raspberry Pi's modern ports are accessible from the back of the unit

allow binary image files to be built, preserving files that can then be read via emulators.

"I thought if I connected the floppy disk drive I'd been given to a Greaseweazle, I could load the disk using the serial interface, capture the image, eject, and repeat," Graham says. "I then decided to hook up a USB-to-serial adapter because most PCs don't have serial interfaces any more, but that didn't work. I quickly realised that the interface on the controller board was (true) RS232, not TTL RS232, so I added a level shifter and that worked."



▶ The camera is positioned over the output hopper so that it's able to take photos of the disks as they drop, saving them as jpg files.

Suddenly, Graham found that his setup could make light work of his 800-strong collection of disks for the Commodore Amiga, a computer he used for many years in the 1990s and 2000s having fixed a faulty used 16-bit A500 and progressed to a 32-bit A1200. His disk collection had grown stronger recently. "I've been collecting Amigas for the past five years and many have come with floppy disks," he says. Finding a way to archive them has, therefore, been timely.

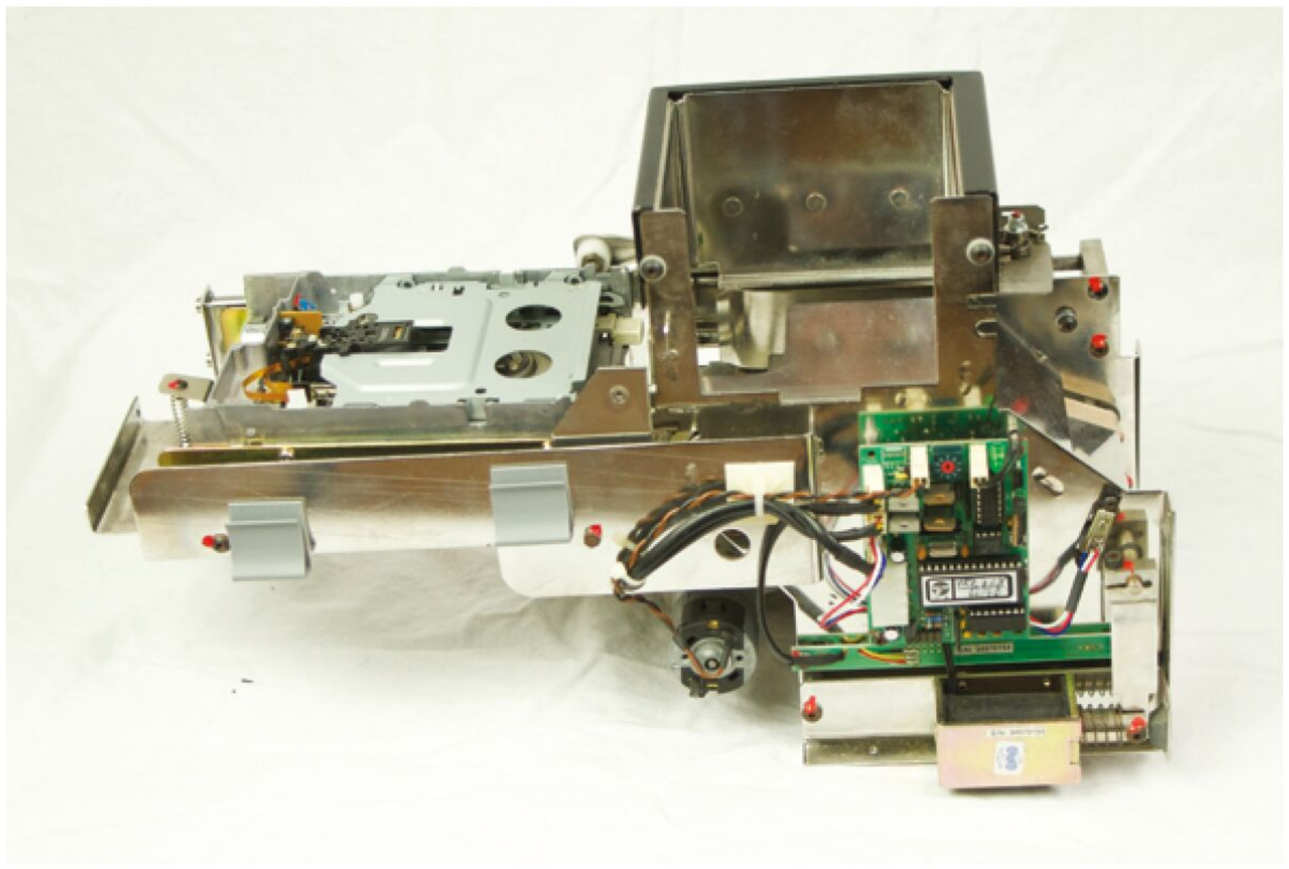
Flux capacity

Graham decided to use a Raspberry Pi computer for a couple of reasons. "I have several of them because I'm a big fan and I had a spare Raspberry Pi 3," he says. He also found that the build was rather straightforward once everything was in place. "It uses a Python script to control the Greaseweazle mechanism via its serial port by sending 'I' for Insert," he explains. "It then returns 'X' if successful and 'E' for an error."

If the script receives 'X' then it uses the Greaseweazle software to read the disk, returning '0' when done. "The disk is then ejected by sending 'A' for Accept on the serial port," Graham adds. "At this point, a photo of the disk label is taken and stored with the same file name as the disk image, adding '.jpg'. The camera came later in the design process. I wanted a way to identify which disk image belonged to which floppy disk, otherwise I would have to open each disk image to see what was on the disk."

Rather than save his Amiga disks in the popular Amiga Disk File (ADF) format which has long been used for backups and disk virtualisation, Graham decided to capture the raw flux data from the disks. "This results in a file size of about 27MB whereas an ADF file would be 880kB, but the flux image is more useful – if there are any errors on the disk, or if it's a copy-protected disk, it will still read the data," he explains.

By contrast, ADF doesn't support many copy protection schemes, so they can end up containing errors unless they're 'cracked' (which means the protection has been deliberately removed). "The flux images can always be converted to ADF files later if needed and the Greaseweazle can tag the files as being for the Amiga to aid format identification later," Graham says. Not they need to be converted, because the Amiga emulator WinUAE is capable of reading the flux images, so there's no problem as long as there is sufficient USB storage space.



▲ This is the disk duplicator mechanism being used by Graham, complete with a 3.5-inch floppy drive. Other size drives can be added.

Wide scope

Since Graham's device can read any 3.5-inch floppy disks supported by the Greaseweazle, archiving is not restricted to the Amiga. Indeed, since Graham repurposed a 37-way D-type connector on the back of the disk duplicator unit to allow 5.25-inch and 8-inch drives to be connected, it is compatible with pretty much any retro machine you can think of.

It has also been found to work very well, with very few issues. So far, the failure rate for reading disks is just one percent and any problems have been easily fixed. "In October, I unveiled the disk archiver at the Vintage Computing Festival Berlin and had it running continuously for about twelve hours in total as a soak test," he reveals.

> "With a 37-way D-type connector on the back, it is compatible with pretty much any retro machine you can think of"

"On the second day of the show, the Greaseweazle was unable to read the disks and I initially thought that the drive heads were dirty or the drive had failed. But the floppy drive is on a bracket that can easily be removed for maintenance, so I looked at the drive and there was a disk label on top of the drive spindle that prevented the disks from spinning. Once removed, everything worked again."

Graham is now busily going through the archived disks in the hope of finding some treasure among his collection – there's always a chance that disks obtained from others contain long-forgotten files. "I have not found anything rare or sought after at the moment, but I am checking the image files and there is still lots to do," he says.



Warning!
Moving parts

Be careful when handling this project because it has moving parts. Children should be supervised.

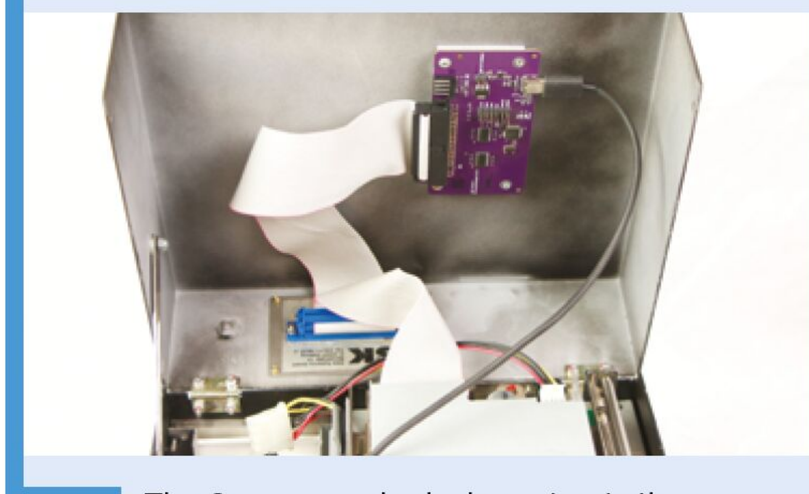
Floppy Disk Archiver



01 A Raspberry Pi 3 has been connected to the serial interface of an old disk duplicator. When it is turned on, the Raspberry Pi is able to issue serial commands via a Python script, but first it needs some floppy disks to work with.



02 The old disk duplicator came with two attachable hoppers, each capable of holding 50 floppies. The disks are stacked in the input hopper and the Raspberry Pi controls when a disk is inserted into the duplicator's built-in disk drive.



03 The Greaseweazle device extracts the raw flux transitions from a drive to capture the disk format and sends the data for storage on the Raspberry Pi. The disk is ejected and a spring-loaded mechanism in the output hopper limits its fall.

Open Cardiography Signal Measuring Device

Having looked to see how blood pressure monitors operate, Miloš Rašić has been hard at work trying to improve their accuracy, as **David Crookes** discovers



Warning!
Medical care

Be careful reading your own blood pressure and taking other measurements. You should not use home-made tools to diagnose medical problems.

magpi.cc/bpreading



MAKER

Miloš Rašić

Miloš Rašić is an electrical engineer specialising in robotics, biotech, and drone technology. He is passionate about open-source projects and creating innovative, functional designs.

magpi.cc/ocsmdevice

Keeping track of blood pressure is crucial for maintaining good health, especially when managing heart-related conditions. Electrical engineer Miloš Rašić knows this only too well. "Like most older people, my grandma suffers from elevated blood pressure, so a digital pressure monitor is something that is being used daily in the household," he says. But he also noticed the machines can be flawed.

"Different monitors have provided widely different measurements and their performance was highly dependent on their battery level, which is not a good thing," he explains. "So for my master's thesis project, I wanted to explore digital blood pressure monitors and discover how they work." This led him to develop a cardiography signal-measuring device based around a Raspberry Pi Pico W and which has the potential to save money and maybe even lives.

Conducting experiments

When Miloš approached his project, he had a list of requirements in mind, chief among them being safety. "The device had to have optical isolation when connected to a PC and be battery-powered or have an isolated power supply," he says.

As a priority, it needed it to measure blood pressure. "This included measuring the air pressure inside an arm cuff, controlling a small air pump and controlling an electromagnetic valve," he adds. Miloš also wanted the device to use a well-supported microcontroller unit with wireless capabilities, hence the use of a Raspberry Pi Pico W. "It provided everything I needed in



The main device casing as well as the PPG clamp have been 3D printed using a Creality K1C. The models can be downloaded from Printables

Lights are used to show which readings are being taken and live data is displayed on a monitor for clear viewing. All of the data is subsequently saved into a CSV file so that it can be further analysed

Besides the main PCB which is based around a Raspberry Pi Pico W, there is an air pump and valve, GX12 connectors, buttons, an 18650 battery, NeoPixel LEDs, an OLED display, and some other smaller parts

The GX12 ports for medical sensors are clearly marked using colours so that there can be no confusion over which component should be connected where. This ensures any experiments are more certain to be accurate

a small package with a large community which meant everything would be easy to troubleshoot," he says.

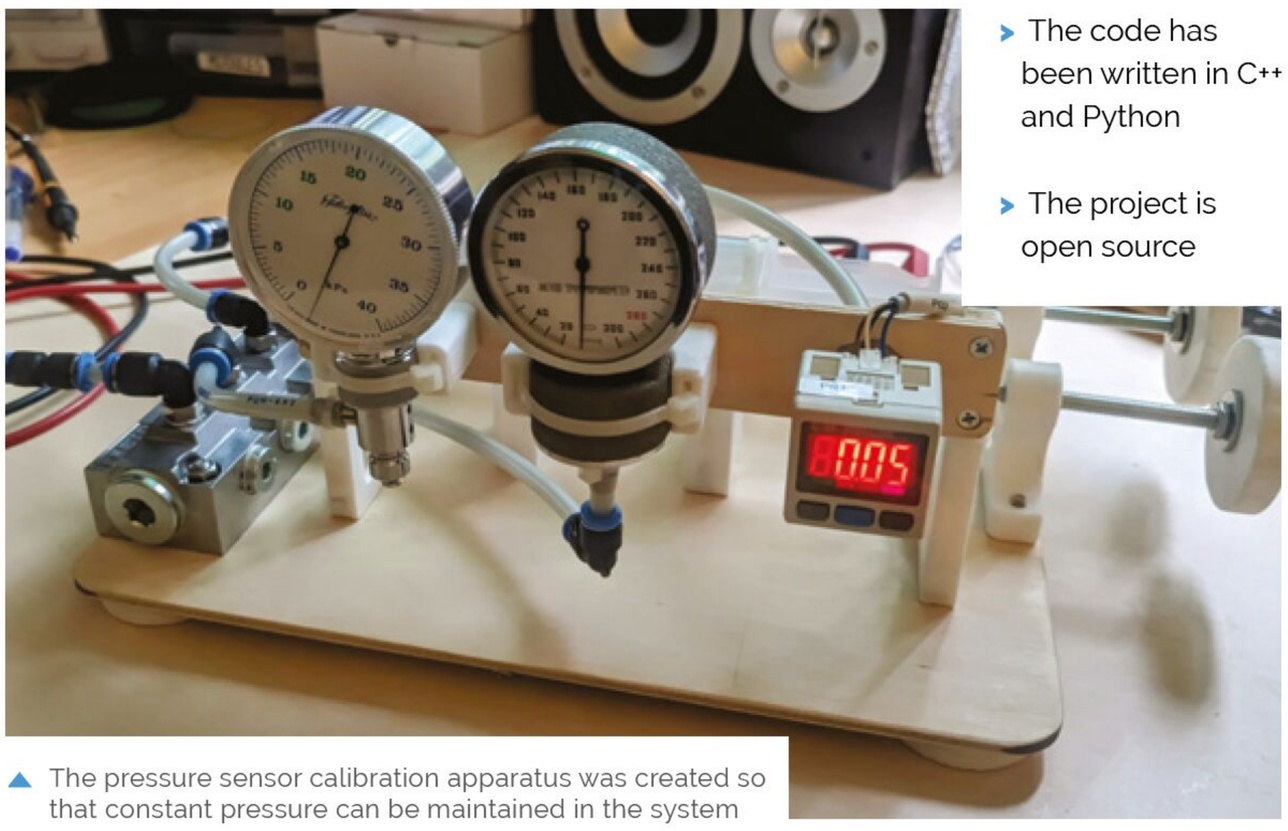
Along the way, Miloš began to add more features, including a stethoscope and the ability to take an ECG measurement. By using a photoplethysmography (PPG) clamp, he also figured the device could detect blood volume changes in the microvascular bed of tissue and, combined, these sensors would be able to give a better insight into a person's heart health.

And yet he was clear from the start that he wasn't going to create a medical device. Instead, the ultimate aim was to take readings and conduct experiments to discover an optimal algorithm for measuring blood pressure. "The whole area of blood pressure monitors was a curiosity for me and I wanted to demystify it a bit and generally have a platform on which other people can experiment with," he explains. "So I created a setup that can be used for experimenting with new methods of analysing cardiography signals."

Heart of the build

To fulfil his ambition, he got to work designing the PCB before looking at the other necessary components, such as the pump, valve, battery and connectors. Some parts were simple enough – for example, the air pressure cuff, which you've likely seen on a visit to a GP or hospital. "This is the only sensor most commercial devices use and the estimations using it are good enough for most cases," Miloš says. But others required more work.

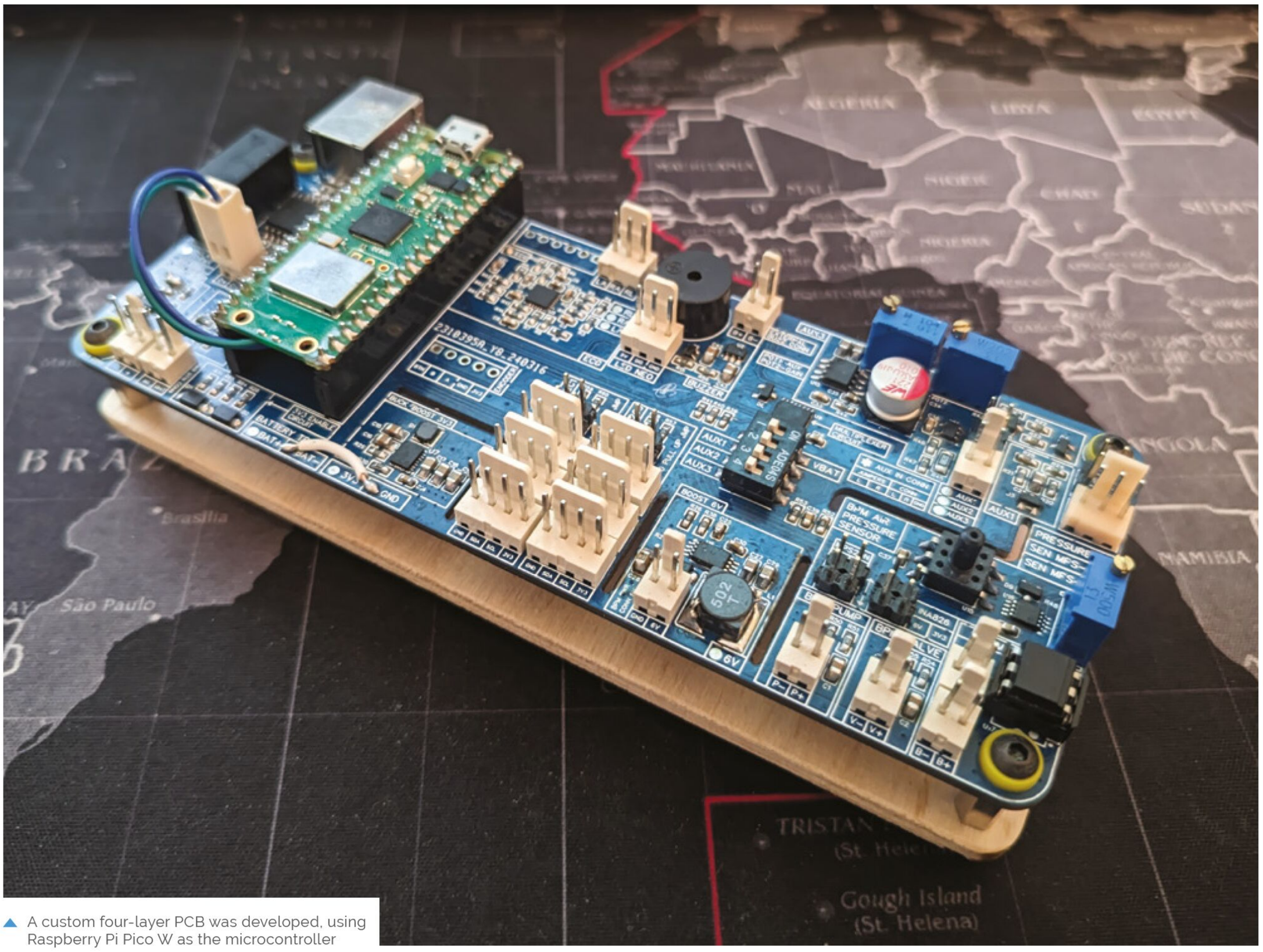
The ECG sensor to record heart activity was an important part of the build. "I wanted to extract



▲ The pressure sensor calibration apparatus was created so that constant pressure can be maintained in the system

Quick FACTS

- The device is able to monitor blood pressure
- It uses a variety of sensors, including a cuff
- It forms an experiment to find an optimal algorithm
- The code has been written in C++ and Python
- The project is open source



▲ A custom four-layer PCB was developed, using Raspberry Pi Pico W as the microcontroller

the pulses from the air pressure signal and for the ECG to be my reference measurement so that I knew the algorithm was working properly," he says. For this, Miloš included a custom layout of the AD8232 IC on the PCB (AD8232 is an integrated signal conditioning block for ECG measurement applications), allowing measurements to be taken.

> "To make sense of the data, Miloš decided the project would need a graphical interface"

Miloš also made a PPG clamp using a MikroE Oxi5 Click board that communicated with the rest of the system over I2C. "The PPG clamp is often used to measure blood oxygen saturation, but since it works by detecting the changes in blood flow in the finger, it's a very useful sensor when it's used in combination with the arm cuff," Miloš says. "Since the arm cuff cuts off circulation in the arm, and then slowly lowers the air pressure inside until the circulation is established again, using the PPG we can have a precise detection of when the laminar flow has been established again, which is the moment that the air pressure inside the arm cuff is equal to the diastolic air pressure."

Finally, an old analogue stethoscope was added. Miloš combined this with a small piezo microphone, turning the stethoscope into an electronic device. "A stethoscope is used when doing manual blood pressure measurements, and since [this] is still the gold standard for non-invasive methods, I wanted to see how the signal on the stethoscope looks during this process and if I could draw any conclusions from it," Miloš reveals.

Pressure's on

To make sense of the data, Miloš decided the project would need a graphical interface. "This would have a live view of all of the measured

signals and the capability of recording all of the data into a CSV file," he says. It required a hefty dose of programming. Python was used to code the GUI, handling the graphical interface, the communication with the device, as well as the data logging capabilities. Python was also used to analyse the recorded signals while the firmware was written in C++ "so that it runs as fast as possible on the Pico," Miloš explains.

With everything working, Miloš designed a case. "I needed to see the rough space required for everything, which allowed me to design a case with mounting points for each of those things," he says. "On the top, there is a lid that has NeoPixel LEDs and a small OLED display that can be programmed to show information to the user."

Since then, he's been using the project to conduct many tests and you can see the results of those on Miloš's GitHub page. The project has also been made open source because he hopes it will help others with their own projects. "It can give them a head start so they don't have to develop their electronics from scratch if all they want to do is, for example, do signal analysis," he says. "This is why I've also included some data that I've recorded with this device if anyone wants to use just that without ever having any contact points with the hardware!"



▼ To connect the stethoscope to the system, the earphones were removed and a small piezo microphone was then connected to an amplifier circuit

Taking accurate measurements

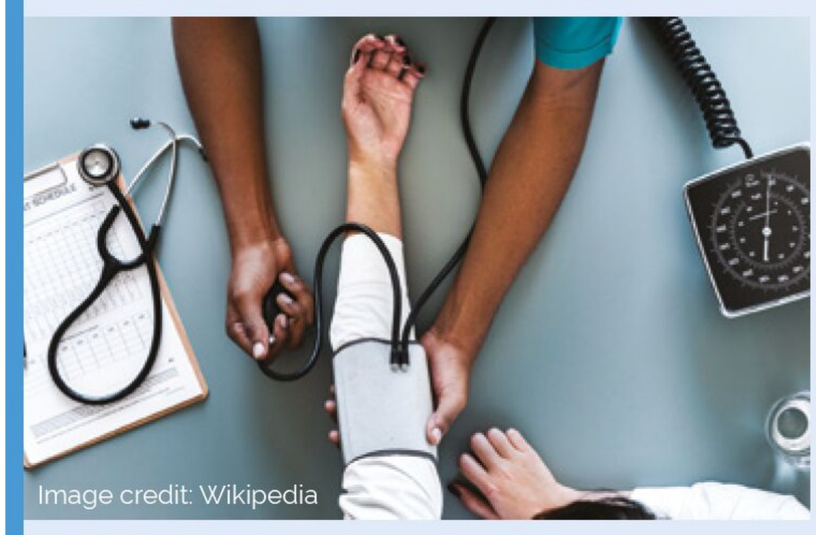
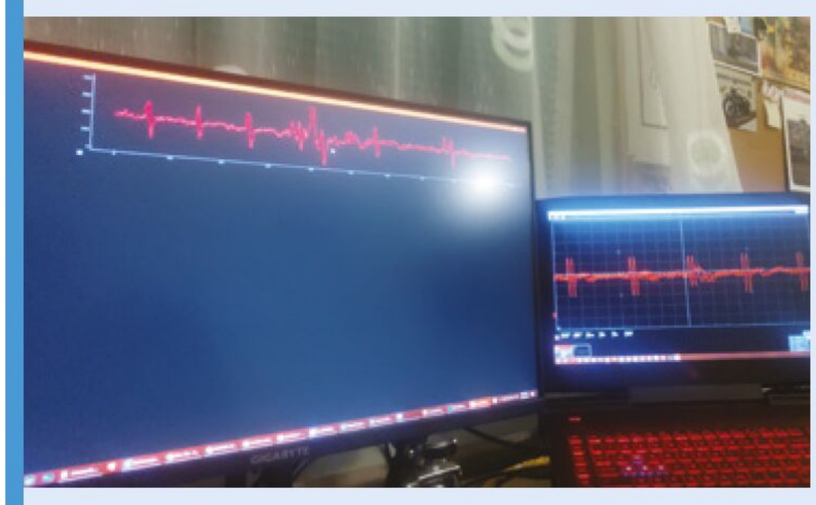


Image credit: Wikipedia

01 To validate and test the device, Miloš says the user first needs to get the blood pressure measurement of the subject using a commercial device. Ideally, this device would provide the measurement of the mean arterial pressure (MAP).



02 Without the subject getting up, ECG electrodes should be placed on the arms and a leg. The arm cuff should be put above the elbow, the stethoscope placed right underneath, and the PPG clamp should be put on the index finger on the same arm as the arm cuff.



03 A connection is established with the device and the data recording begins, followed by the valve and the pump. The pump needs to reach 200 mmHg, at which points it turns off. When the pressure decreases to below 40 mmHG, the data recording can be stopped.

Lawny

You can mow the grass remotely with this camera-equipped robot, as **Rosie Hattersley** discovers



MAKER

Eugene Tkachenko

Eugene Tkachenko is "an open-minded enthusiast" who enjoys designing and presenting videos about his various tech builds.

magpi.cc/lawnygit

Mowing the lawn is the sort of chore that lends itself well to automation. It also provides a focused outlet for those who prefer to find fixes to common problems rather than embrace the mindful qualities of repetitive back-and-forth mowing. Eugene Tkachenko is just such a maker: he has 15 years of project development under his belt using various types of technology and is also the guardian of a sizable lawn that requires plenty of attention. With Lawny, he wanted to find out whether there was a way to make lawn-mowing fun! See his video at **magpi.cc/lawnyYT**.

Makers gonna make

Eugene's previous projects include an underwater drone (**magpi.cc/80**), a translation platform, and several Android Studio plug-ins. Building on this experience, he set about building a reliable lawn-mower controlled by a mobile phone. "The Raspberry Pi perfectly covers all required features," he says. However, it needed an extra pair of PWM (pulse-width modulation) channels and relays so two H-bridges could be used. Once set up, Eugene added a camera to what was originally a Raspberry Pi 5-based setup so Lawny's user can see what's ahead. NodeJS allows Lawny



Warning!
Sharp blades

Lawny contains powerful blades that could cause significant damage or injury. Always keep it in sight while operating, remove any obstacles well in advance of its approach, and follow standard guidance on safely operating a lawn-mower.

magpi.cc/mowersafety



▲ Lawny tackles an overgrown lawn

A Raspberry Pi Camera Module 3 provides a first-person view of the grass to be tackled, so the user can work out where to mow next

Maker Eugene has successfully created Lawny models from Raspberry Pi 5 and Pi Zero 2W, using windscreen wiper motors to drive the three-wheel mower

Lawny is a powerful lawn-mower that can be controlled from any smartphone or desktop computer

to be controlled from any phone or from a desktop computer. The Raspberry Pi Camera Module 3 provides an as-it-mows Lawny-eye view of the grass it's poised to cut. A NodeJS server connects Lawny to the smartphone to provide directions.

Get the motor running

The basis of Lawny is the head of a steel razor strimmer to which Eugene added an electric motor to cut grass. He designed the system himself, making the frame from plywood since he wanted to keep it as simple as possible. He shares many of his builds on YouTube, so it made sense to offer a straightforward build option that viewers could potentially replicate.

Quick **FACTS**

- Lawny is operated via a NodeJS server
- This receives commands from a smartphone via a WebSocket
- The open-source lawn-mower cost around $250 to build…
- And took around a month to perfect
- Snowplough or transporter versions could easily be created

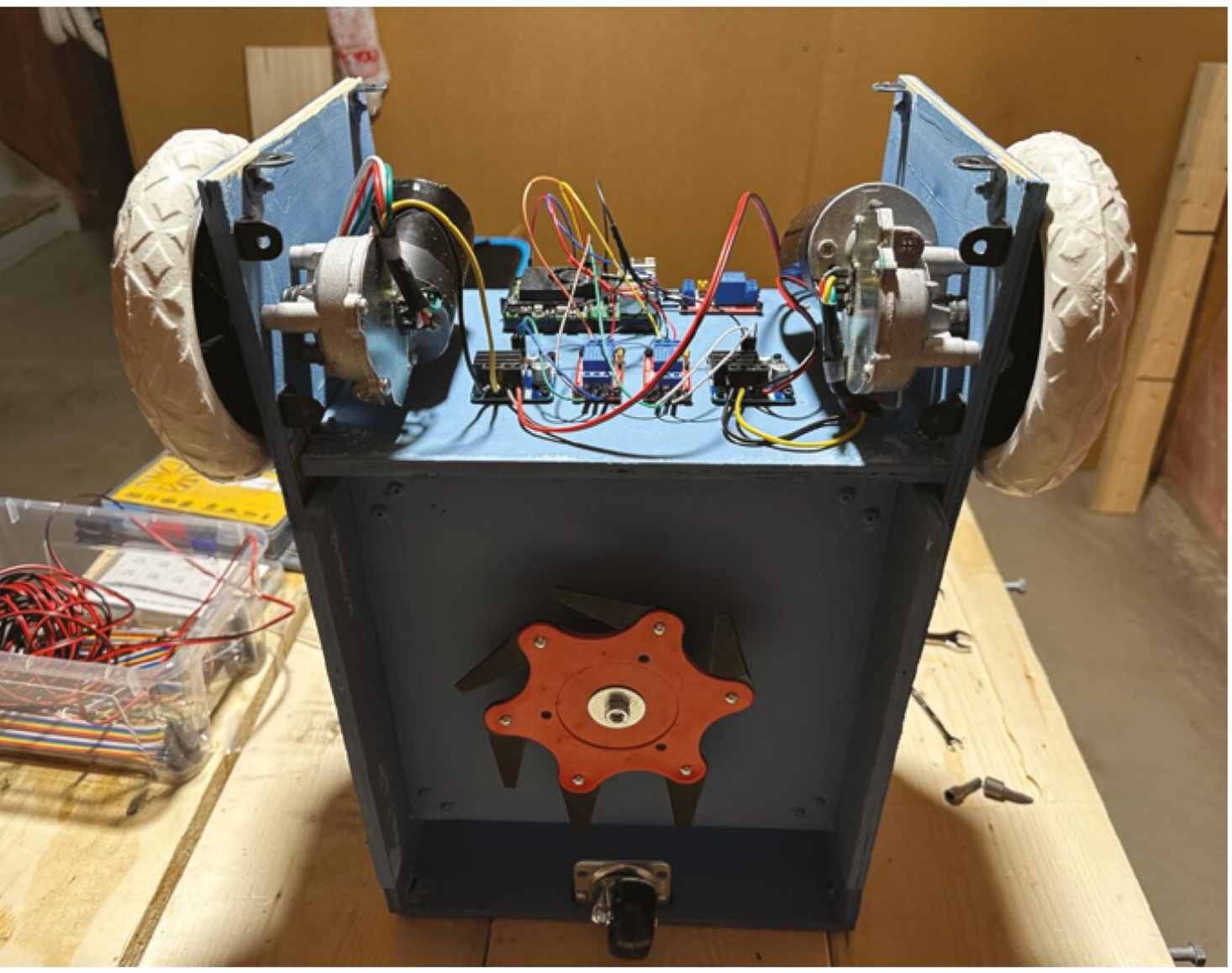


Powerful car windscreen wiper motors drive Lawny's wheels



A smartphone view of the grass Lawny is about to mow

> The Raspberry Pi Camera Module 3 provides an as-it-mows Lawny-eye view of the grass



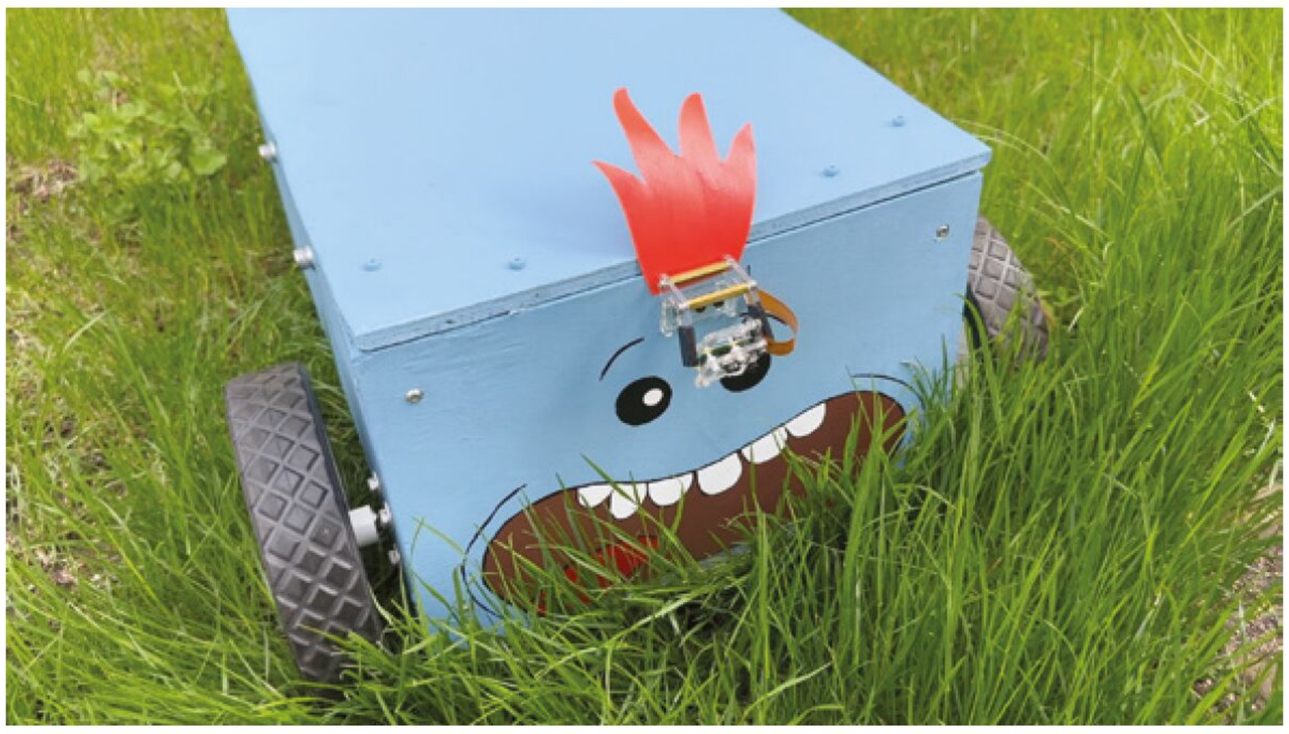
Lawny being built. Blades are attached to the razor motor

Having got the grass-cutting action working, Eugene set about making Lawny mobile, since a static lawnmower would be of limited use! Two additional motors and H-bridges allowed for movement from left to right so Lawny could be manoeuvred. Power rather than speed was required, so he used car windscreen wiper motors for what needed to be a sturdy construction. Similarly, Lawny required plenty of power, with separate battery packs for Raspberry Pi and the electronics and a dedicated power source for the heavy-duty motors that provide movement. A three-wheel setup made sense in terms of manoeuvrability. "Equal power to the two windscreen wiper motors drives Lawny in a straight line. However, if the left wheel has more speed, the lawnmower will move to the right, and the rear wheel will be turned by force of the body," Eugene explains.

Eugene chose Raspberry Pi for its community support, detailed documentation, and because "it's easy to get started and become proficient with such a versatile product". He initially made Lawny using Raspberry Pi 5 (because he had one), but switched it for a Raspberry Pi Zero 2 W since "even a cheaper board can tackle all requirements".

Aside from the Raspberry Pi elements which he bought from an Approved Reseller, most of the components were ordered online. The relays and motors were ideal, but the wheels that arrived lacked grip and would have been nearly useless at tackling the thick grass of Eugene's back garden.

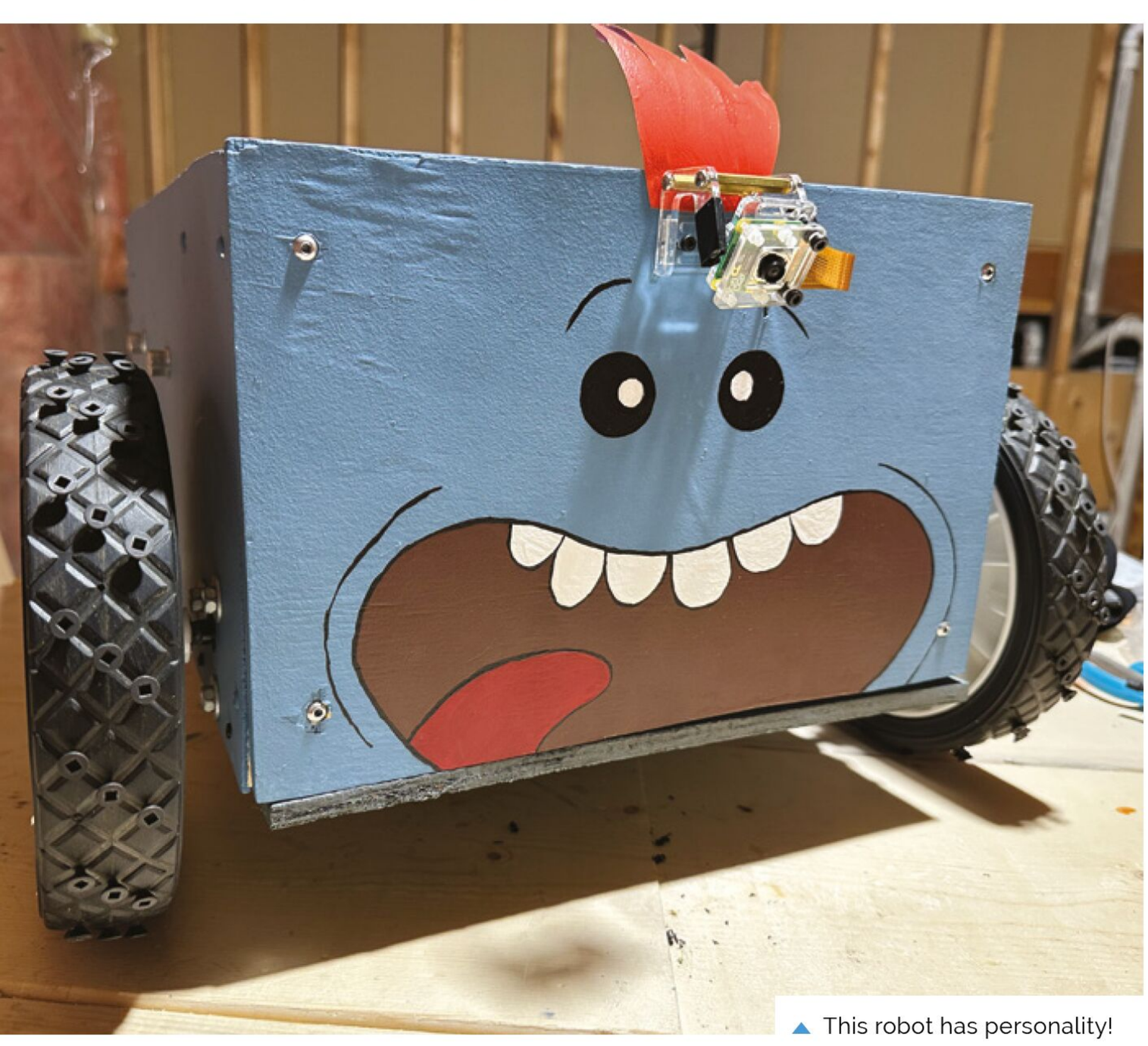




While the project itself required many iterations along the way, the wheels were the main bugbear. "I eventually ended up screwing a bunch of screws into a plastic wheel. Also, I replaced and sharpened the blades because it was hard to go through tall grass," Eugene reveals.

These powerful blades soon made Eugene realise that although the original aim was to create a remote-control lawnmower, doing so was a challenge if he was to rely on a video stream from the camera. From a safety point of view, Lawny should always remain in sight given the power of the blades, he cautions.

▲ With its grippy wheels, Lawny can handle rough terrain

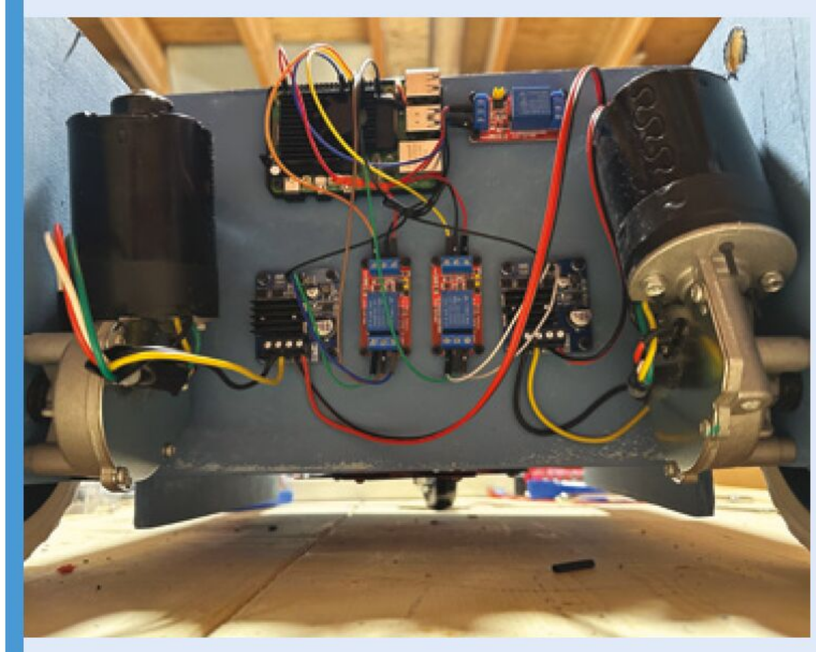


▲ This robot has personality!

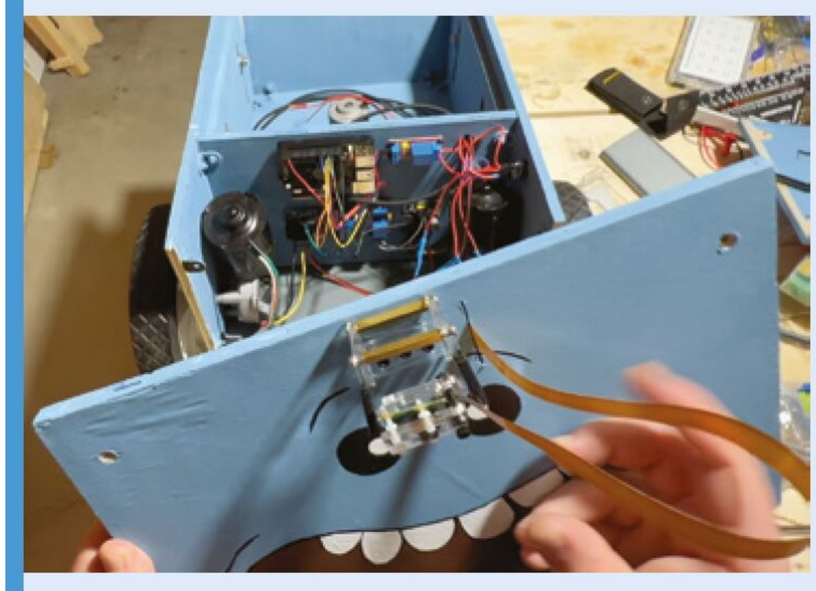
Go on, Mo!



01 Create a plywood box to house Raspberry Pi, camera, motors, and power sources, drilling holes for the wheels to turn and adding internal waterproofing.



02 Set up and connect the motors, H-bridges, and relays and attach to Raspberry Pi and the power supply. Once these have been tested, install them into your Lawny box.



03 Paint and decorate the box and screw everything into place, then position the Raspberry Pi Camera Module so it faces forward and can show the user the state of the grass (and any obstacles) Lawny is approaching.

CanSat

A competition for space-bound students resulted in a tiny, can-sized, Raspberry Pi-powered satellite. **Rob Zwetsloot** boldly takes a look at it



MAKER

LittleBlueDot

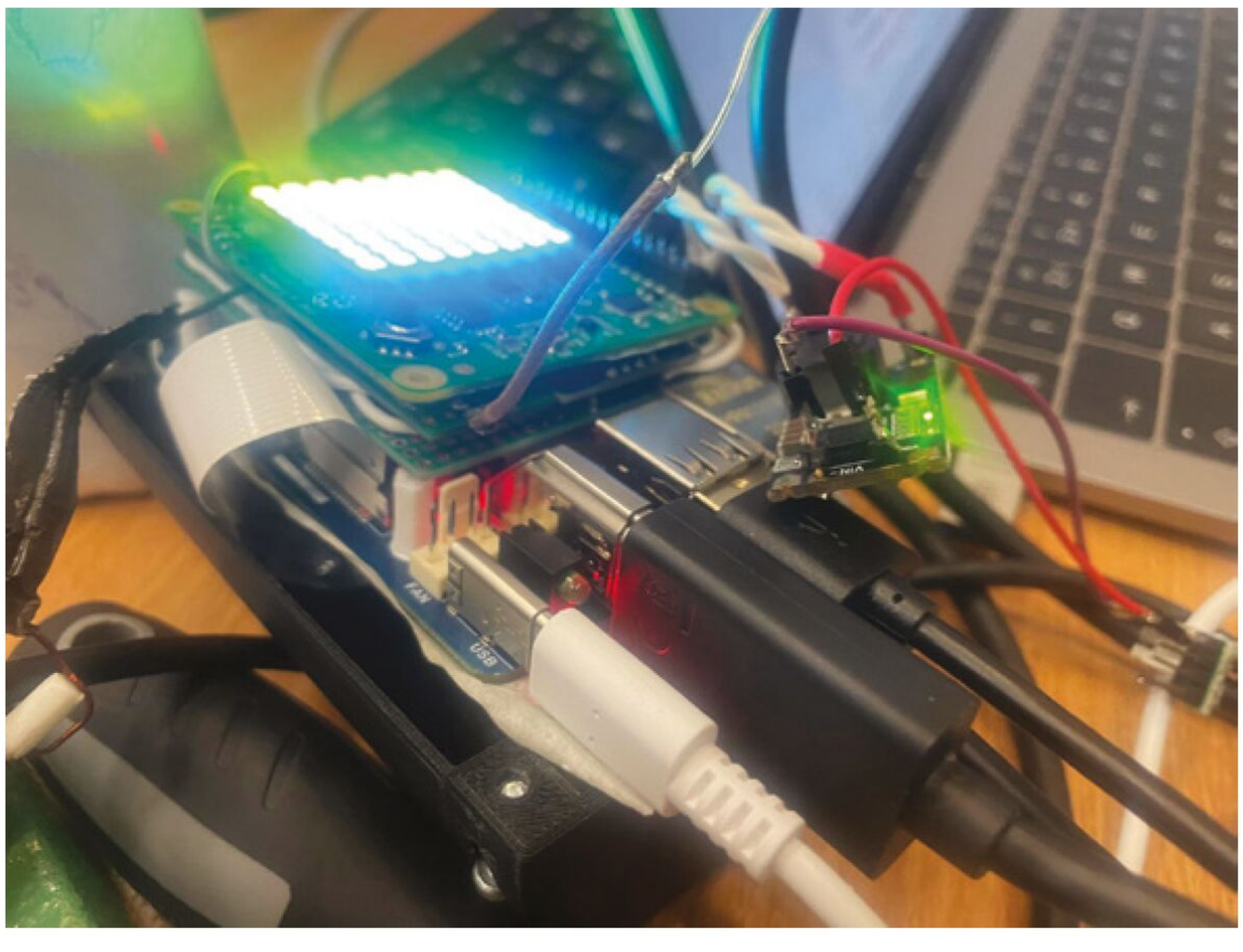
Mia, Rishi, Robin, Roland, and William are a team of Year 10 students from Peterborough who took part in the CanSat UK competition.

magpi.cc/cansat

What would you do if you had to create a satellite the size of a drinks can? The yearly CanSat competition for students in their teens asks this question and many teams have answered – including LittleBlueDot.

"The challenge for students is to fit all the major subsystems found in a satellite, such as power, sensors and a communication system, into this minimal volume," the team tell us. They came third in the country for their final build. As the competition instructions explain, "After building their CanSat, teams will be invited to launch events across the UK to launch their CanSats on small rockets, with their CanSats returning to Earth using a parachute designed by the students. Teams are set a primary mission of measuring air pressure and air temperature during the CanSat's descent, with data being transmitted to the students' ground station."

They also needed to design a secondary mission, which in the case of LittleBlueDot included taking photos of the ground below to map it. "The idea of mapping large areas, including foreign bodies, came up when we were discussing potential asteroid mining in the future," the team say. "And also improving efficiency in agriculture, both fields where large benefits could be seen from mapping land cheaply."



▼ Raspberry Pi was chosen for its small size, but it's still a tight squeeze inside the Can

Trial and error

For the project, Raspberry Pi was an obvious choice for the team – while a microcontroller would be able to handle the environmental recording and transmitting requirements, a Raspberry Pi computer allowed for on-board image processing. The team then got to work building and refining.

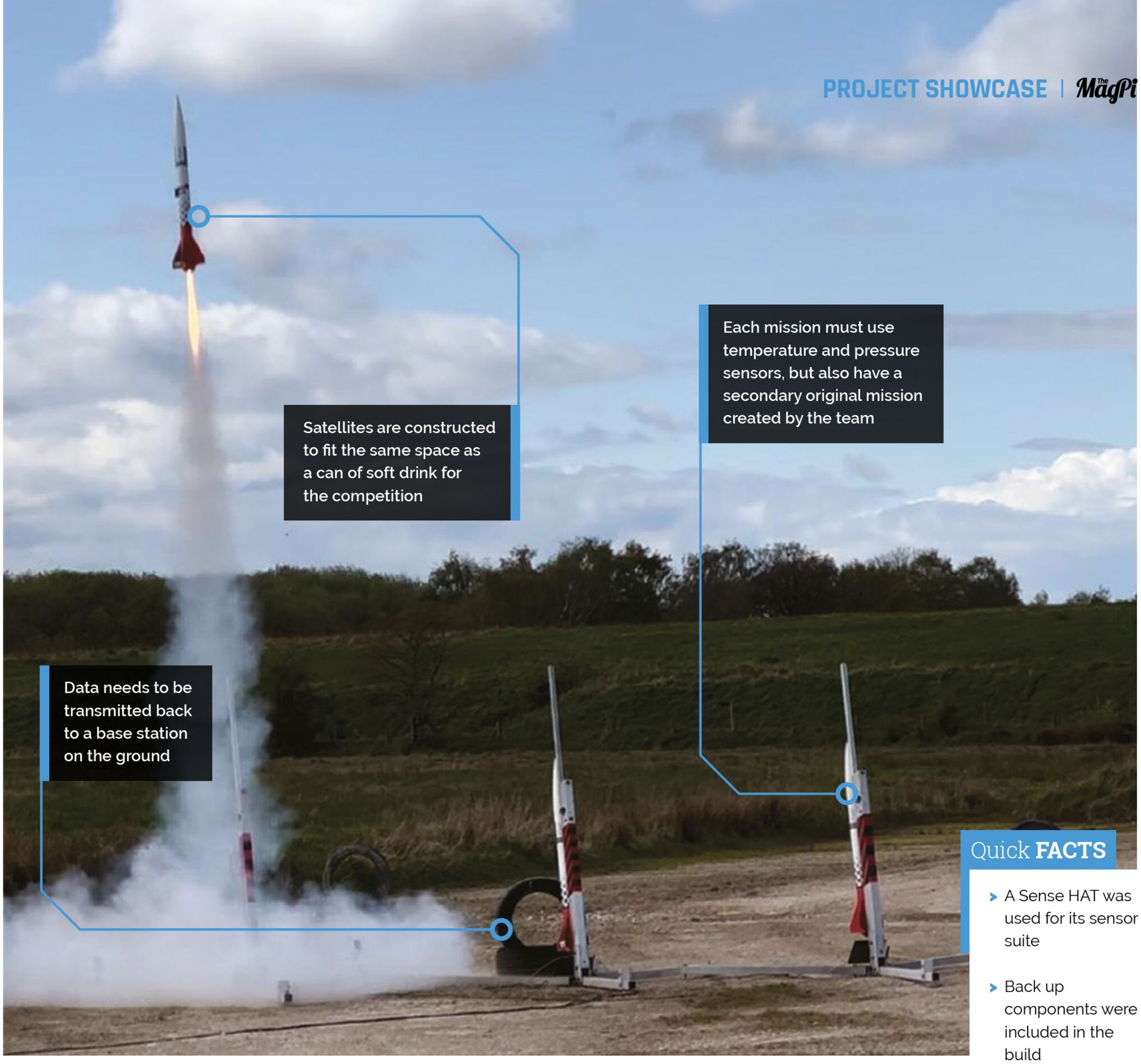
"Initially, a very basic CanSat was made to help visualise the size and space that was available to be worked with," they explain. "Different ways to secure the Can's inner electronics in an accessible way were explored. In V0, there were two bodies: a screw lid with an attached compartment behind, and the main module itself."

The V1 build went from a vertical orientation to horizontal to accommodate a larger gap between the cameras. Across V1 and V2 builds, different ways of wiring up and loading the circuit were explored, and clear acrylic discs were added to protect the cameras from moisture and to reduce their drag.

"In V1, the parachute was attached via four straight vertical holes," the team continue. "V2 featured a more reliable solution using four M5 nuts inset into the walls of the Can to secure the paracord in place and put the strain on the parachute rather than on the Can itself."

After some issues at the regional launch, a V3 was created to better fit all the components they required.

"The Can was simplified by removing the inner module and trays [for the electronics], and a friction fit was used to directly mount components to the inside of the CanSat," the team say. "During testing of the temperature readings, it was found



the heat from the internal components was affecting the readings being taken. To mitigate this, fans were added for cooling, and vents were installed on both sides of the CanSat using a honeycomb grid to allow air flow. The strength of the vents were tested in Fusion 360 and they still passed the stress tests."

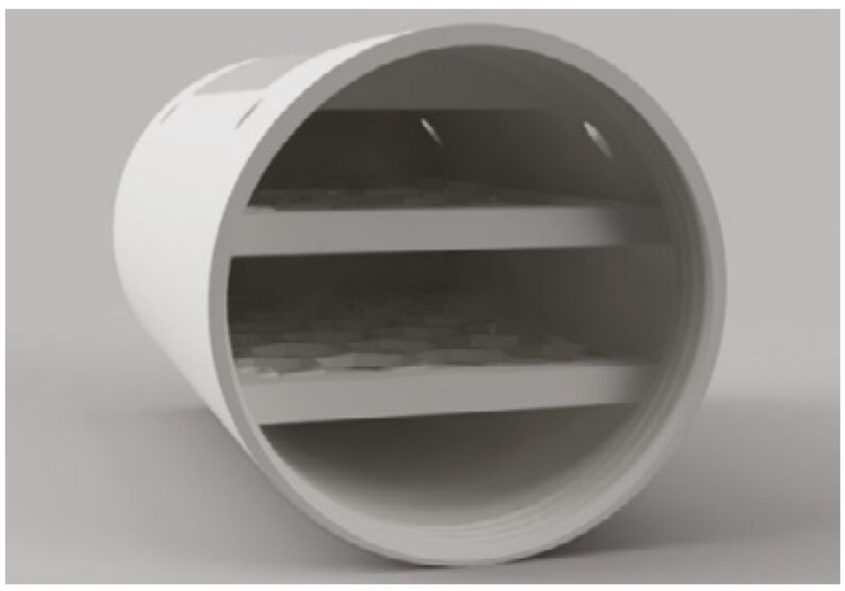
With this they were ready for the national launch, where they were part of the national finals.

Mapping with data

As well as cameras, the CanSat had temperature and pressure sensors, an IMU (inertial measurement unit), a magnetometer, and GPS. These were used to calculate altitude and orientation.

"The two on-board cameras took photos of the ground simultaneously," the team explain. "This meant that an FFT [fast Fourier transform] taken of an image from the first camera would give a wave that was a translation of the wave an FFT would give for the second camera. This translation would vary based on the orientation of the Can, the distance between the two cameras, the altitude of the Can, and finally the actual altitude of points on the ground. Given values for the first three variables, the fourth could be calculated using trigonometry."

The team came third overall in the competition. And the data? Sadly, due to a safety quick-release switch being released during launch, they were only able to get one set of images. Hopefully they can get it all working for another launch.



The design was iterated on several times via 3D prints

Quick FACTS

- A Sense HAT was used for its sensor suite
- Back up components were included in the build
- Fans and vents made sure Raspberry Pi did not affect the sensors
- A Raspberry Pi Compute Module 4 was used
- Rubber grommets were used to keep the antennae safe from moisture

Cave mapping with Raspberry Shake

Accurate maps of intricate cave systems help improve the safety of intrepid divers. **Rosie Hattersley** hears about Raspberry Shake's contribution



MAKER

Richard Wylde

Richard Wylde FREng "runs a couple of scientific instrument businesses that currently mainly build parts for weather satellites".

terahertz.co.uk

Richard Wylde describes himself as "a sort of physicist and engineer living between the business and academic worlds" whose passion for cave diving is "closer to an obsession than a hobby". He is co-founder of Terahertz, an advanced engineering company which, among other impressive achievements, developed remote sensing instruments for the European Space Agency's EarthCARE mission (**magpi.cc/cloudradar**). Richard is also one of several experienced cave explorers involved in mapping the subterranean network of cenotes [sinkholes] in Yucatan, Mexico. "The caves are stunningly beautiful and [mapping them] is technically difficult," he says. "A lot of effort goes into staying alive." Acoustic and magnetic mapping can help plot the location and direction of these unexplored passageways improving safety for all who visit them – an endeavour made more robust using Raspberry Shake, a Raspberry Pi-based device more commonly used to detect earthquakes.

The maps are also useful for dive guides keen to show off the speleotherms (mineral deposits such as stalactites and stalagmites), for developers. Also, to know whether building on a particular area is possible and permissible. Their dives also reveal the effect of developments such as golf courses



▲ Richard Wylde, Fred Devos, and colleagues published a booklet mapping the cave system at Actun Koh

Raspberry Shake acoustic seismographs help confirm the accuracy of caves mapped by the intrepid divers, keeping future explorers safer

The gruelling dives in the Yucatan 'cenotes' underwater caves involve total trust and dependence on colleagues as well as rigorous attention to oxygen supplies

Richard and colleagues painstakingly record details of remote and barely accessible stretches of the cave system beneath the jungle in Quintana Roo, Mexico

which are built by clearing jungles, use nitrates to maintain their greens, and may also be drawing water from the aquifers.

Distinguished company

Richard often dives with renowned cave explorer Fred Devos (**magpi.cc/ancientmining**) in Mexico's Quintano Roo region, which has no overground rivers. Mapping its subterranean cave network is "incredibly dangerous and physically challenging".

Exploring the caves involves following taut lines of string with knots every ten feet to mark the way, just like Theseus in the Greek myth. Richard mentions the trust and focus needed to accurately read a compass and count out distances travelled ten feet at a time based on how many knots you've passed. Visibility and human physical resilience are all factors too – if you're exhausted from a lengthy dive, you probably aren't noticing arrows or counting knots accurately. "It's milk of magnesia down there when the bubbles hit the ceiling."

Richard explains the process: "We mark the depth, the distance and the azimuth, the existence



Richard, Sam, and Chris embark on a cave dive at Actun Koh

Quick FACTS

- Divers' photos reveal the caves' stark beauty…
- And lay bare the effects of nitrate run-off from nearby golf courses
- The pristine cenote waters are home to Remapedia crustaceans…
- And translucent fish that live in the dark
- But now have massive algae blooms from chemical pollution



Golfing greens are treated with nitrates that poison the cenotes with algae

and the angle to the next station" – often simply where the line is wrapped around a rock. Painted arrows help ensure divers don't get lost, but some caves have more than one entrance, or arrows pointing in more than one direction.

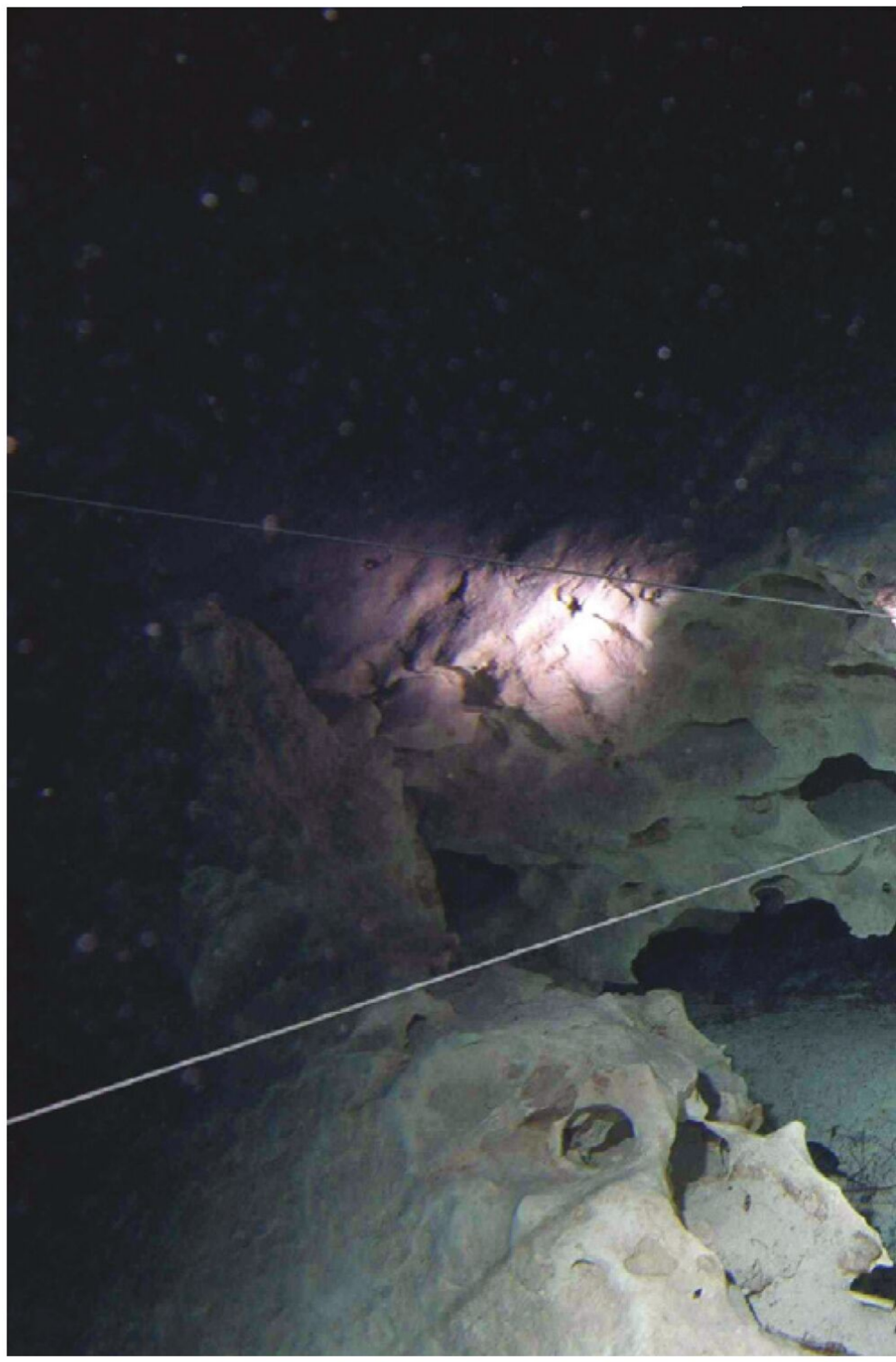
The maps are written on specially printed paper and include geographical features such as cave openings, changes in the cave and water depth, and height. Relating this information to the outside world requires a way of referencing it to the surface and getting a GPS position from it. "The map is linked to an absolute position by taking the line out of the cave entrance and accessing a GPS coordinate in an area with few obstructions to the sky," says Richard. "In caves which have more than one

> Exploring the caves involves following taut lines of string with knots in every 10 feet to mark the way, exactly like Theseus in the Greek myth

entrance, it is possible to ascertain and correct for the build-up of errors by taking GPS measurements at the entrances. Programs such as ARIANE [a widely used mapping tool] can then be used to distribute the correction though the map."

Instrumental improvements

The team previously used a fluxgate magnetometer to match above-ground and subterranean locations



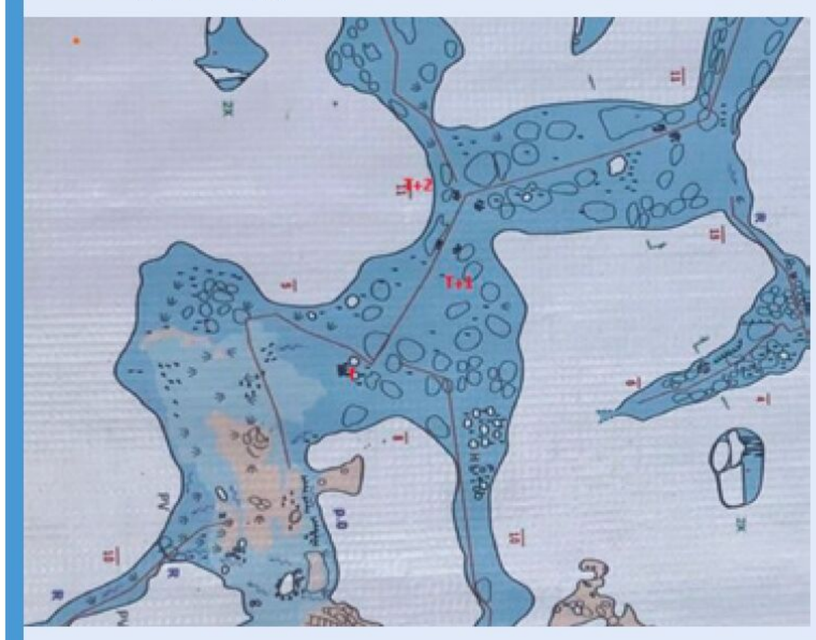
at the Sagitario cenote. In the summer of 2024, Richard and his cave-mapping colleagues trialled new means of confirming their findings, using both the Raspberry Shake 1D vertical motion seismometer and a far more sensitive acoustic magnetometer. Getting to the site after hacking through the jungle, the Raspberry Shake and acoustic magnetoscope were placed directly above where divers believed the cave was located.

"Raspberry Shake helped confirm our findings and add a degree of accuracy that was not previously possible," says Richard. The results were promising enough that the team ordered an RS3D three-axis model for their planned return trip in early 2025. This time the Raspberry Shake will be placed in an IP67 waterproof box and the team hopes the additional measurements will allow direction to be determined from the relative amplitudes of the disturbance in the X, Y, Z frames.



▼ Cave measurements are made manually underwater using a compass and tape measure

Mapping the underworld



01 Comparing the time of a 'stomp' that causes imperceptible vibrations picked up by the Raspberry Shake with the known time above ground helps pinpoint the location of an underwater station to within a 3% accuracy.



02 Maps plotted from underwater dives can be refined and corrected, hugely improving their usefulness to divers who may be some five miles into the cave system and 45 minutes from a possible exit.



Fig 5: Plot of the depth of during the dive: Arrow point to the T+2, T+1 and T as the dives exited the cave

03 A 150×100×50 mm ferrite magnet was placed in the cave and tumbled to create a thump on the ceiling at various locations. Thumps were detected and recorded by the Raspberry Shake, with seismic data analysed using US Geological Survey SWARM frequency/time analysis.

PROJECTS FOR MAKERS & HACKERS

BUILD A FLAT-PACK ROCKET

MAKE ELECTRONIC MUSIC WITH A RASPBERRY PI PICO

BOOK OF MAKING

2025

MAKE A CONNECTED PLANT MONITOR

BUILD SMART HOME LIGHTING

& LOTS MORE

FROM THE MAKERS OF HackSpace MAGAZINE

BOOK OF MAKING

2025

STEP INTO THE WORLD OF MAKING!



- CONTROL THE WORLD AROUND YOU WITH A RASPBERRY PI PICO
- BUILD YOUR OWN CREATIONS USING OUR STEP-BY-STEP GUIDES
- DESIGN FOR 2D AND 3D FABRICATION METHODS AND MAKE THEM A REALITY
- FULL OF PROJECTS PERFECT FOR AN HOUR, AFTERNOON, OR WEEKEND OF MAKING

hsmag.cc/BookOfMaking2025

150 Raspberry Pi People & Projects

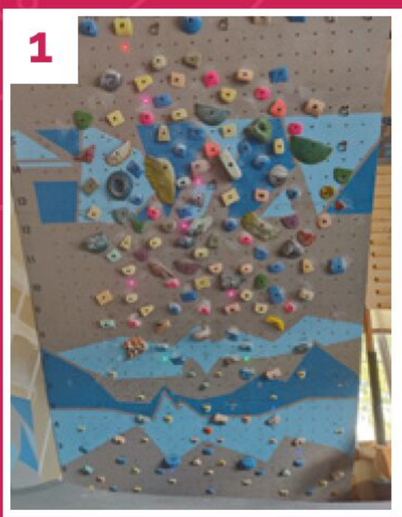
The MagPi team picks the best projects, people, and things that happened over 150 glorious issues…

Can you believe we made it all the way to issue 150? This is an astounding feat and is largely due to the incredible and amazing people and projects in the Raspberry Pi community. To celebrate, the whole team has come together to list 150 projects, people, and the Raspberry Pi products that powered them.

Here they are, as they say on television shows, "in no particular order!" Because we think they are all wonderful.

Big Builds

1



1. PeggyBoard

We like a big, massive build here at *The MagPi* and few come larger than this climbing wall. PeggyBoard is an interactive climbing wall powered by a Raspberry Pi that allows the user to set specified routes using a web app which also allows them to save routes or load old ones.

› magpi.cc/139

2. Olga The Fortune Teller

Olga The Fortune Teller is a shiny build designed by AlterD to sit in a store. It runs MicroPython on a Pico W to communicate with a thermal printer via an RS232 connection and prints out a fortune message (generated by ChatGPT).

› magpi.cc/131

2



3. We Still Fax

People found creative ways to stay entertained in 2020 and We Still Fax is an intriguing theatrical project that interacts with an audience remotely using a fax machine. The core components of the show are the fax machine, Raspberry Pi, and Grandstream adapter which translates a phone signal into an Ethernet signal and vice versa.

› magpi.cc/102

3



4. Package Thief Deterrent

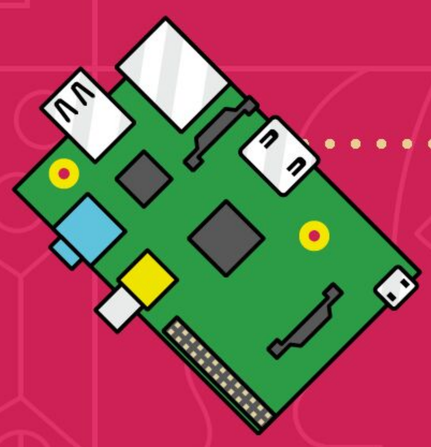
Following the theft of a package from his porch, Ryder decided to take action. Images from a camera are pulled by a Raspberry Pi and processed by a custom machine learning model to detect if there is or isn't a package. If the package is taken away, the Raspberry Pi sends signals to a relay (via its GPIO pins) and activates a variety of alarms including a sprinkler, a loud truck horn, and a flour shower.

The project is great if you're looking to get into machine learning, image recognition, and practical hardware integration. We recommend enrolling some friends for testing – Ryder got his neighbours to try it out and bought them boxes of chocolate to make up for the flouring.

› magpi.cc/110

4





29/02/2012

110 Raspberry Pi released

Raspberry Pi Model B, the first Raspberry Pi, is released to the world

05/05/2012

111 The MagPi #1

The very first issue of *The MagPi*, then a fanzine, is published by the community

5. Machine Learning Prosthetic Arm

We love this impressive build, even if it isn't that practical in real life. James Bruton created a motion capture suit from 3D-printed parts and gathered all the data from his body motions – arms, legs, and head – to control them with a machine learning model. The suit measures joint movements using rotating pieces with magnetic encoders, along with limb and head positions via a special headband.

› magpi.cc/110



6. Tank Driving Simulator



This incredible German tank simulator was developed in the 1970s and used to train prospective tank drivers. A small camera on a trolley rolls around a 12-metre long terrain model and the camera display is fed into a hydraulic recreation of a tank interior. The combination of responsiveness to the driver's steering movements and on-screen display created a realistic driving experience that predated arcade games by several years. This rebuild uses Raspberry Pi 3B+ as a new central control computer to replace the original boards.

› magpi.cc/128

7. DeMoor Orrery

This recreation of the oldest working orrery in the world (created by the Frisian amateur astronomer Eise Eisinga) uses six Raspberry Pi Zero computers to control each of the six planets. Chris de Moor set about building his replica with planets fitted to copper tracks.

› magpi.cc/114



8. Open weed locator

Removing unwanted plants but leaving others behind requires knowledge and precision – exactly what machine learning is adept at. Open Weed Locator uses a Raspberry Pi 4 to manage agricultural sites efficiently. An algorithm running on the Raspberry Pi identifies any weeds. A solenoid is then switched on to deliver herbicide to the detected weeds.

› magpi.cc/117



9. Portsdown 4 Digital TV transmitter



Digital TV broadcasting was thought to be out of the reach of the home enthusiast, but the advent of Raspberry Pi has changed all that. You'll need a licence to operate a Portsdown 4, granted by Ofcom in the UK. You can even add a powerful enough antenna to relay your DTV signal to a satellite.

› magpi.cc/118



10. GroundBIRD telescope

GroundBIRD is a Raspberry Pi-enabled millimetre-wave telescope that observes polarisation patterns of the cosmic microwave background, which in turn reveals information about the very early universe. GroundBIRD's telescope has an amazingly high rotation speed of 120° per second, and is kept cool to near absolute zero temperature. Multiple Raspberry Pi computers control its rotation speed and the temperature, humidity, and pressure.

› magpi.cc/119

18/07/2012

112 Raspbian released

Raspbian would quickly become the official OS of Raspberry Pi



06/09/2012

113 UK production

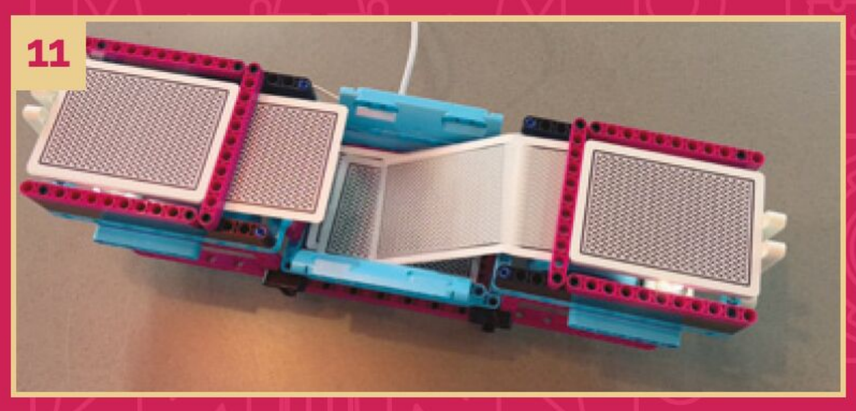
Raspberry Pi is now made in Pencoed, Wales

Cool Robot Builds

11. LEGO Card Shuffler

Maker and Cambridge engineering undergraduate Louis Wood spent time as an intern at Raspberry Pi towers and built this amazing card-shuffling robot. Based around the LEGO Build Hat and a LEGO NXT system, it spins wheels to automate card shuffling.

› magpi.cc/146





13. Herbie_Bot

Keeping weeds at bay is no easy feat – unless you build a robot to help you. Russ Hall built Herbie_Bot with a Raspberry Pi and an OAK camera (with a Movidus chip inside). Russ trained an AI with YOGO-v5 on Google servers to detect the weeds in his garden. The robot trundles around, dropping herbicide in all the right places.

› magpi.cc/128



14. Bluebot Shoal Fish Robot

The Blueswarm team from Harvard University set out to explore how shoals of fish coordinate by building a swarm of underwater fish robots. Raspberry Pi Zero W was used to create multiple Bluebot fish-style robots that can be accessed remotely.

› magpi.cc/107



12. Smart Crust-Cutting Robot

For Andrew DeGonge, bread crusts are something to be banished. He used his loaf and created an automatic guillotine-like device to do the hard work for him. Controlled by Raspberry Pi, it uses a Camera Module and computer vision to chop off the unwanted bread parts.

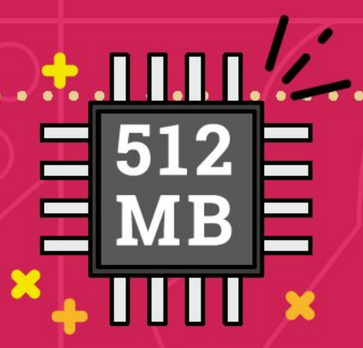
› magpi.cc/104

15. Robot Arm Clock

This deliberately over-engineered timepiece provides a satisfying distraction. When Hendrik Ohrens's clock stopped working, he built a robot arm to manually move the dials around. He used a position-teaching approach to manually pose the robot. This is a cute robot arm build, but well worth learning from.

› magpi.cc/112

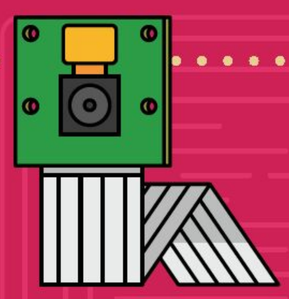




15/10/2012

114 Memory upgrade

Raspberry Pi Model B now comes with 512MB of RAM, double that of the launch model



14/05/2013

115 Camera Module released

The first Raspberry Pi Camera Module is released, making use of the CSI port

16. Droiid

Inspired by the likes of Amazon and Starship, two companies that have both created six-wheeled delivery robots, UK-based Eben Kouao wondered if he could possibly build a similar vehicle with a Raspberry Pi 4. Droiid is a six-wheeled robot that can be controlled from anywhere in the world.

› magpi.cc/112



16

19. K-9

The K-9 project helped Fitz Walker fulfil an ambition to build a full replica of one of his favourite Doctor Who companions. K-9 is a combination of 3D-printed parts and components sourced from online stores, including Adafruit and SparkFun.

› magpi.cc/125



19

" Time and effort went into creating the submarine's beautiful transparent acrylic case "

17. Mini Smart Mirror

Chosen by Wesley Archer

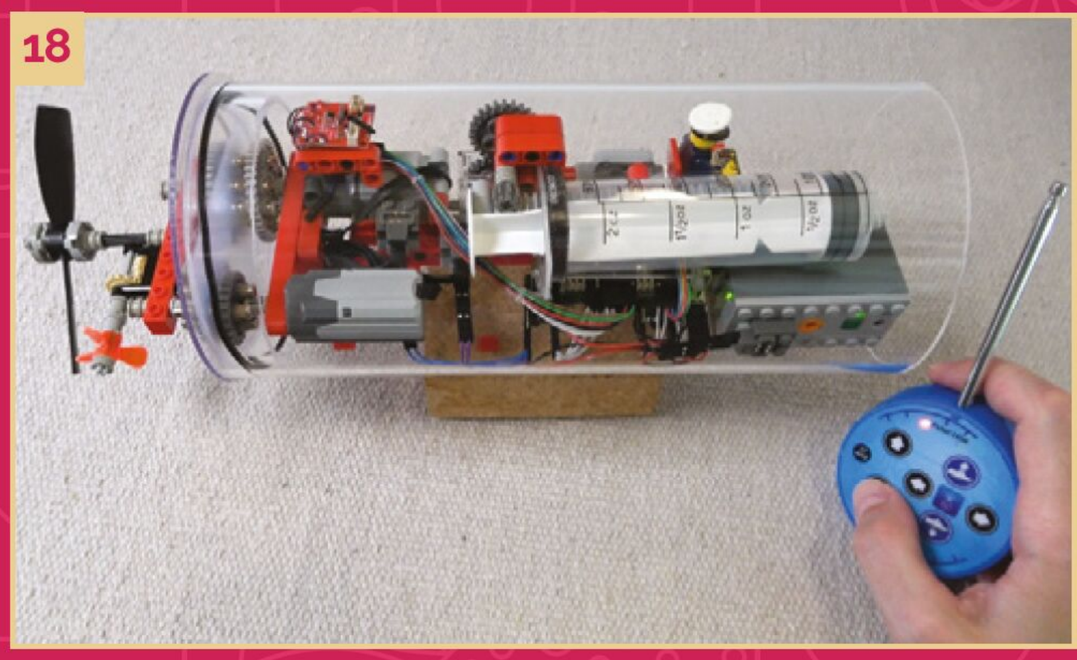
This project showcases how to use Raspberry Pi to interact with the real world using simple and affordable sensors (to measure temperature and humidity) and a dot-matrix style LED to show data in real-time. All of this is embedded in a picture frame.

› magpi.cc/72

› magpi.cc/minimirror



17



18

18. LEGO Submarine 4.0

LEGO Submarine 4.0, runs off a LEGO EV3 motor and Raspberry Pi Zero 2 W. The fourth iteration adds weights and a pressure sensor alongside a SparkFun TFMini-S Micro laser sensor to measure the submarine's depth. A fair amount of time and effort went into creating the submarine's beautiful transparent acrylic case with tightly fitting and invisible end caps.

› magpi.cc/122

20. Desert Eye 2.0

Desert Eye is a sophisticated robot that can traverse difficult terrain. Raspberry Pi controls the two main DC motors, a stepper motor and a rotating camera, GPS and wireless connectivity, and a three-axis sensor and a fan. Infrared LEDs illuminate the camera and it beams video data over an encrypted wireless connection to a distant location.

› magpi.cc/127

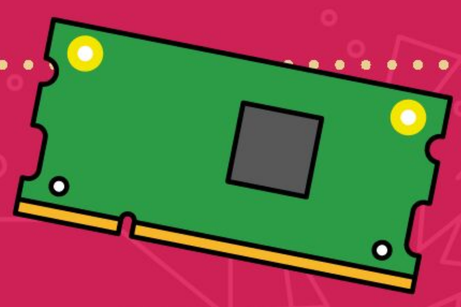


20

06/06/2012

116 NOOBS released

The New Out Of the Box Software, NOOBS, made it easier for new users to set up their Raspberry Pi



07/04/2014

117 Compute Module

The original Compute Module releases as embedded computing demand grows

Home Automation Projects

21. RC Plane OSD

Upgrading your remote-control plane is easy when you can get a Raspberry Pi Pico to give you a heads-up display. A camera attached to the nose of the aircraft allows for a first-person view. Video is played back on a separate screen for the user so they can see where they're flying, along with flight data.

› magpi.cc/142



22. Farm Sensor Dashboard

This handy dashboard helps farmers track the temperature and humidity of greenhouses and fridges. It's a relatively simple build requiring one main sensor, a DHT22, but is an incredibly useful device for anybody working with green fingers.

› magpi.cc/106



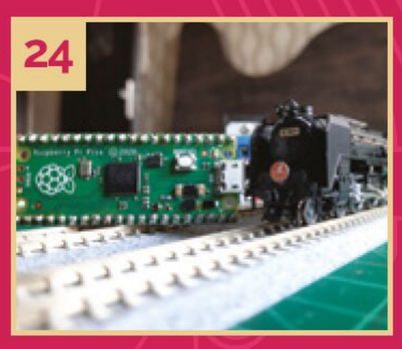


23. Campervan LAN

Enrico Miglino's campervan, Jan The Van, sports a secure mobile LAN powered by three Raspberry Pi computers. It allows Enrico to use a single login to provide internet access to any of the devices on his network.

› magpi.cc/108

24. Model Railroad



Mechatronics student Kushagra Keshari combined his love of locomotion with his interest in electronics with this Pico-controlled model railroad. A 'sensored track' detects a train passing and instructs it to speed up, slow down, or come to a halt.

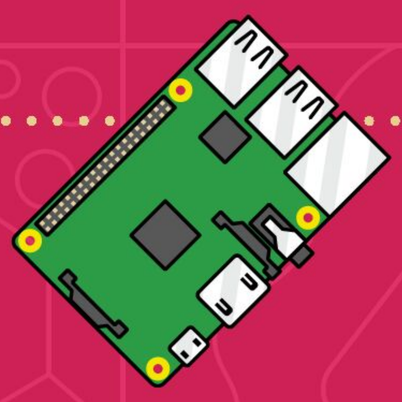
› magpi.cc/109

25. Teasmade 2.0

Martin Spendiff and Vanessa Bradley updated a Goblin Teasmade with a Raspberry Pi Zero WH to produce their hot drink of choice... coffee! It uses a Grove ReSpeaker HAT and a speaker with a relay switch to replace the alarm. A script monitors Google Calendar and if it sees a trigger phrase, it starts the boil cycle.

› magpi.cc/114

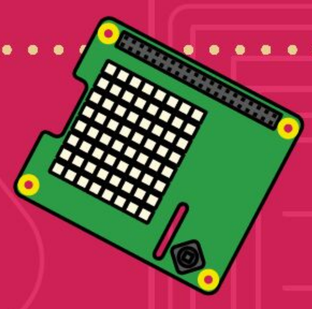




14/07/2014

118 Raspberry Pi Model B+

Raspberry Pi Model B+ refreshes the board design, which is still used to this day



31/07/2014

119 Raspberry Pi HATs

Now with 40 GPIO pins, the HAT specification is released, resulting in a huge number of add-ons over the years



26. Szerafin MM5D mushroom farm

This mushroom monitoring system consists of a Raspberry Pi which measures temperature and humidity. The remotely accessible system shows the status of the lights, fans, humidifier, and watering system – including the pressure, and whether or not the tent door is open. It also accesses data from OpenWeatherMap.org.

› magpi.cc/118



27. OpenMower

OpenMower is a smart robot mower project that can handle different garden areas. It uses a Raspberry Pi 4 as the main processor to run the custom OpenMower software. OpenMower is able to localise itself using very precise real-time kinematic (RTK) positioning, meaning it can mow a patch of grass efficiently. All the real-time tasks are a job for a Raspberry Pi Pico, which hides underneath the RTK GPS board.

› magpi.cc/119



28. The Next Verse

Chosen by Sean McManus

Artist Stewart Easton and musician Gawain Hewitt co-created The Next Verse, a textile artwork that shows the circle of life. Raspberry Pi provides an audio accompaniment for each scene on the journey, from birth to death. From a technical point of view, this project is relatively straightforward, and certainly easier to build than the robots and mechanical projects we feature in the magazine. However, The Next Verse stands out for me because it makes an emotional connection with viewers and listeners, with Raspberry Pi helping to tell a universal story. Raspberry Pi is typically used for science and technology projects, but I love to see artists adopting it to create interactive artworks.

› magpi.cc/67

Retro Projects



29. Pi Switch

Nintendo Switch is an excellent handheld games console. Its detachable dual Joy-Con controllers appealed to wannabe retro gaming fan Christopher Foote. He used the built-in Bluetooth to connect with a Raspberry Pi 3B+, reprogrammed Linux Joystick Mapper so it was compatible with the joypads, and added a speaker, headphone jack, and camera. Chris designed and 3D-printed a case and added a battery to enable portable gaming fun.

› magpi.cc/68 › magpi.cc/piswitch

30. Dicemaster 2000

Playing card games with friends is a great way of bonding. When one member of a group started losing his eyesight, friend Chris Hall set about creating him a Braille dice roller using Raspberry Pi Pico, a custom circuit board, a 3D-printed case (**magpi.cc/dice2000files**), and some CircuitPython code.

› magpi.cc/143

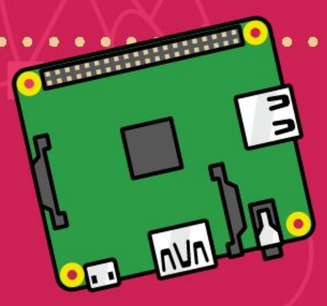


31. Doom on a LEGO Brick

Taking gaming on a tiny screen to its extreme, maker James Brown responded to enquires about whether his LEGO brick-embedded console could play the popular first-person shooter. With a 0.42-inch OLED, 4MB flash chip, and RP2040 microcontroller (as on Pico), it uses the latter's second core to update the screen fast enough to create greyscale images (**magpi.cc/ugreygit**) and play video.

› magpi.cc/129

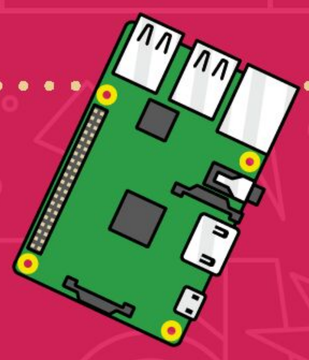




10/11/2014

120 A+ released

This refresh of Raspberry Pi Model A is the first time the form factor has been reduced in size



02/02/2015

121 Raspberry Pi 2

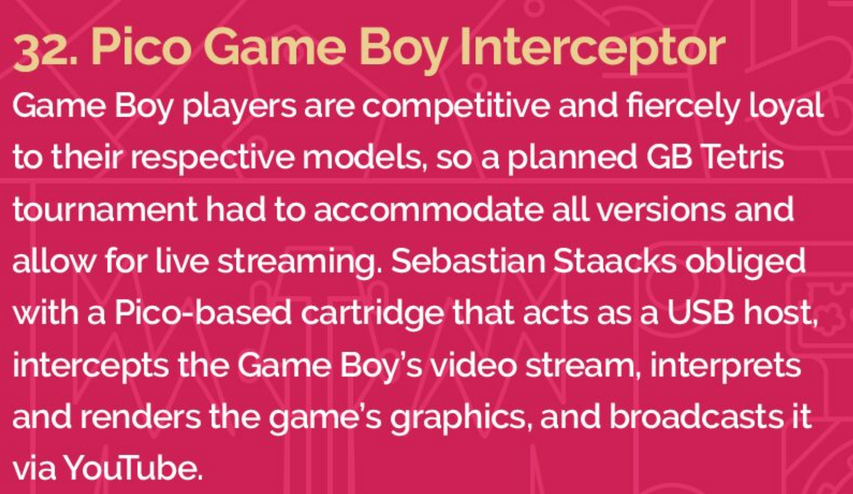
Bringing more memory and a quad-core processor, Raspberry Pi 2 is a huge update over the originals



32. Pico Game Boy Interceptor

Game Boy players are competitive and fiercely loyal to their respective models, so a planned GB Tetris tournament had to accommodate all versions and allow for live streaming. Sebastian Staacks obliged with a Pico-based cartridge that acts as a USB host, intercepts the Game Boy's video stream, interprets and renders the game's graphics, and broadcasts it via YouTube.

› magpi.cc/128



36. Spin AI

Arvind Sanjeev wanted to use AI for his own creativity. The result, Spin AI, is a synth-like 'curiosity tool' with which to explore the boundaries of creating music. Buttons on the Raspberry Pi 4 and Arduino Mega controlled digital vinyl system select options in the MusicGen cloud-based remix tool such as mood (spacey, warm, dark etc.), instrument, and musical genre such as death metal, trance, or jazz.

› magpi.cc/143 › magpi.cc/spin



33. Old School Minitel Laptop

Iconic 1980s French info terminal Minitel got a Raspberry Pi 3B makeover and acquired internet connectivity thanks to Gautier Serodon. He replaced the CRT with a 10.4-inch touchscreen, but kept the clicky keyboard and power buttons.

› magpi.cc/113 › magpi.cc/minitel

37. DEC Flip-Chip Tester



Reviving an ancient PDP valve computer hinges on whether the 600-700 Flip-Chips that comprise the processor are functional. This tester uses a Raspberry 3B+ to check the power output using relay modules and signal clips, giving accurate info on power draw and output.

› magpi.cc/147

› magpi.cc/decflipchip



38. Raspberry Pi Amiga 600

For this retro computer project, Billy Nesteroulis used Raspberry Pi 4 with Dimitris Panokostas's Amiberry emulator. The 3D printed replica Amiga case is paired with an original nine-pin joystick and USB adapter.

› magpi.cc/103



34. mt32 Pi Atari ST

Combining his love of retro computers and classic synths, *The MagPi* publisher Brian Jepson's project bridges the gap between the MIDI ports on a 40-year-old Atari ST and Raspberry Pi to make music.

› magpi.cc/141

› magpi.cc/mt32pi

35. Modern Jukebox

Bob Murphy repurposed an old Wurlitzer jukebox with Raspberry Pi controls and 3D-printed elements (**magpi.cc/classicjukefiles**). An IQaudio DigiAMP+ HAT routes music to two full-range speakers, while a SparkFun Sound Detector adds sound-reactive lighting effects.

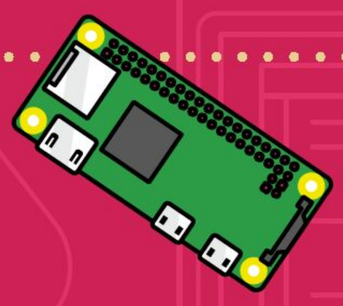
› magpi.cc/modernjukebox



27/02/2015

122 The Official Raspberry Pi Magazine

The MagPi goes official, giving it unprecedented access to Raspberry Pi products



26/11/2015

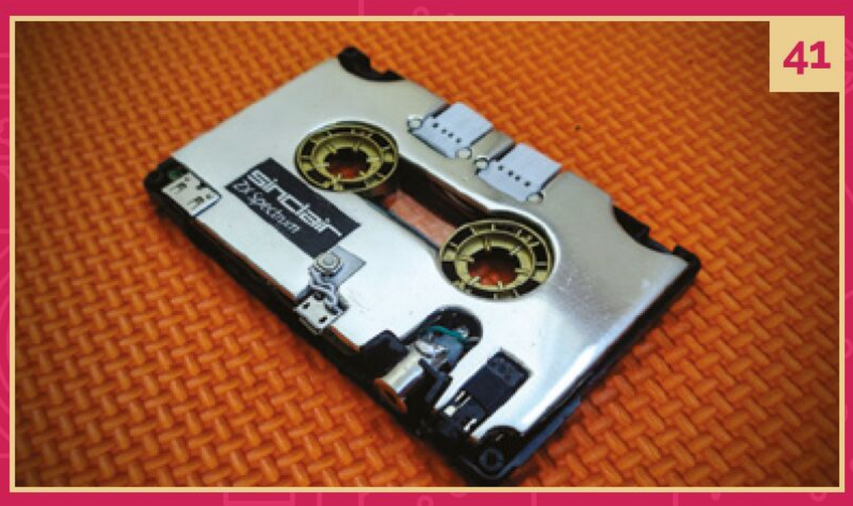
123 Raspberry Pi Zero surprise

Launching on the cover of *The MagPi*, Raspberry Pi Zero revolutionises microcomputers with a $5 price tag

41. ZX Spectrum cassette

Stuart Brand recreated his childhood computer in handheld form as a means of embracing his inner nerd and pushing his Raspberry Pi skills: cramming in all the cables was a big challenge. The Pi Zero W gamer's sheet-metal cassette case and heatsink were finessed using a Dremel and fine sandpaper. Configuring the DietPi and Fuze ZX Spectrum emulator involved lots of tweaks, but it now boots in a creditable 16 seconds.

› magpi.cc/116



41

42. Team Pinball

Wales-based Team Pinball designed their The Mafia game from the ground up. Its custom Raspberry Pi controller board, Rboard, is compatible with direct switches, has a switch matrix with up to 100 switch inputs, can drive more than 200 LEDs and 48 solenoids, yet takes up a tenth the space of other pinball control boards. Dedicated DAC and H.264 video make it a cut above some other pinball boards.

› magpi.cc/teampinball


42


39

39. 3/4 Star Wars Arcade Cabinet

A Raspberry Pi 3B+ fitted with a Picade X HAT runs everything in Retropie, leaving maker James to focus on creating a faithful three-quarter-size replica of the 1980s arcade cabinet, complete with yoke.

› magpi.cc/105

43. Roktrack

Chosen by Nicola King

This ingenious solar-powered robot helps ageing farmers keep their rice terraces weed-free in a very mountainous area of Japan. Roktrack works its way towards pylons, cutting back the grass and weeds as it goes.

› magpi.cc/roktrack


43


40

40. Fancy Octopus Arcades

Modding up a Raspberry Pi 3B+ to control a custom single-player arcade kick-started a new career for Shonee Stother and his son Wolf, creating bespoke games machines. Raspberry Pi's "small profile and extremely robust performance" helps them "pack a lot of oomph into a very small package."

› magpi.cc/115

Popular Projects

44. Cyberdeck

Cyberdeck builds abound in *The MagPi* and HackSpace annals. This example has a scrollable screen thanks to a rotary encoder, while all its screws are neatly hidden away inside so that the Raspberry Pi 4-based portable computer resembles the sort of dependably sturdy machine that used to get rolled into classrooms for weekly IT lessons, albeit one that offers internet access and a chance to play Doom.

› magpi.cc/cyberdeck

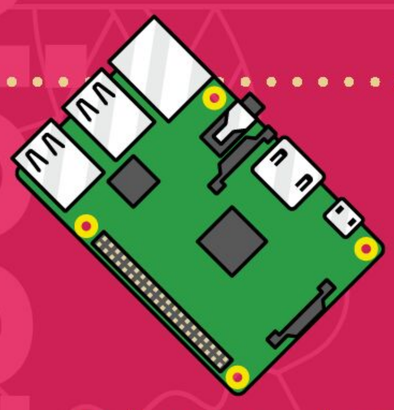

44

45. BrewPi



BrewPi was one of the first initiatives to recognise the power of Raspberry Pi for precision brewing. The BrewPi Spark 3 is a temperature controller that handles beer or wine fermentation with 0.1˚C precision and sends data to an on-board display.

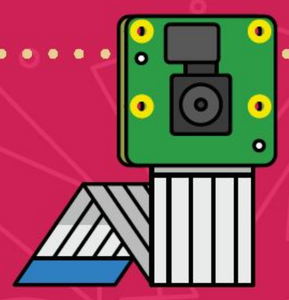
› brewpi.com



29/02/2016

124 Raspberry Pi 3

On Raspberry Pi's birthday, this powerful new model is launched, now with on-board WLAN and Bluetooth



25/04/2016

125 Camera Module V2

A newer, more powerful Camera Module boasts a huge increase in megapixels



46

46. CheerLights

CheerLights brighten up everything from rooms to the front of buildings, all controlled by Raspberry Pi Pico W and MicroPython. The really clever bit is that the wireless chip means it can be part of a globally controlled network. Here is a 12-foot CheerLights display from Chale Bay Farm on the Isle of Wight, making use of a Galactic Unicorn LED matrix.

› magpi.cc/cheerlightspico



48

48. NOUS: undersea vision surveillance system

Greece's NTAU School of Naval Architecture and Marine Engineering knew plenty about Raspberry Pi before selecting it for its underwater archaeology surveillance project in which a self-powered submarine unit detects people or craft coming close to sensitive marine areas and sites of historic wrecks and alerts authorities to potential intruders.

› magpi.cc/117

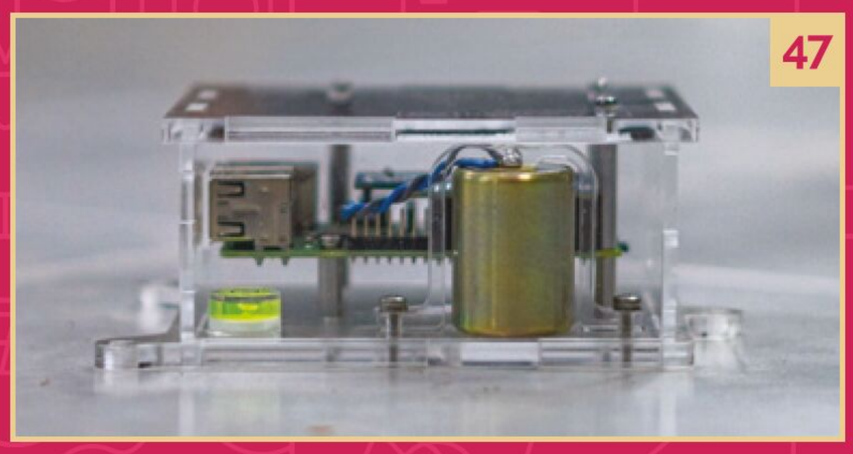


50

50. Naturebytes

Naturebytes' Wildlife Cam Kit enables you to take stealthy photographs and video of wildlife. The triangulated design helps keep water away from the internal component, while hinged clips provide easy access.

› magpi.cc/naturebytes



47

47. Raspberry Shake

Acoustic vibrations from earthquakes, volcanoes, pneumatic drilling, explosions, stampedes, and mass transit are all picked up, recorded, and shared online by the seismograph in the Raspberry Pi-controlled device enthusiastically embraced by both academic geological researchers and citizen scientists around the globe.

› raspberryshake.com



52

52. World o'Techno

Chosen by PJ Evans

Years ago, I encountered Jarkman's World o'Techno at the Electromagnetic Field bi-annual camp for makers. A duct-tape-and-string affair, it sat there beeping to itself through two speakers. Handles invited you to give it a push and, as I did, the music started to change. I later found out that a GPS unit, tied to a Raspberry Pi 2B, was used to make the musical sequence unique based on its physical location. It's a simple build, but one that has brought a lot of smiles over the years.

› magpi.cc/worldotechno



49

49. Pi-hole

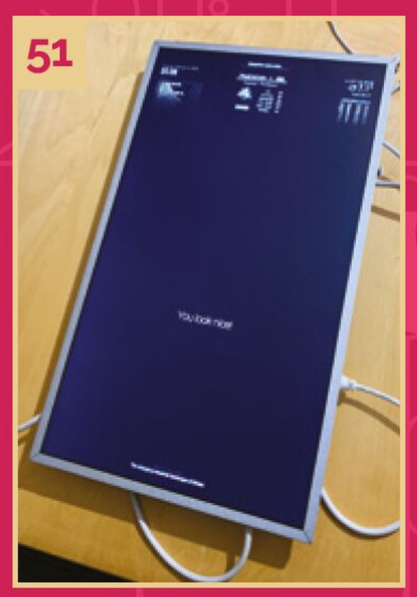
Find adverts annoying? Pi-hole turns a Raspberry Pi into a network-wide ad-blocking service. You connect Raspberry Pi to your router and use it to create a Wi-Fi network that blocks all adverts on any device. Clever!

› magpi.cc/pihole

51. Magic Mirror

Place a Raspberry Pi and display behind mirrored glass and load up the Magic Mirror software to create a smart display. In our 50th issue, this was voted the number one project by the Raspberry Pi community!

› magpi.cc/magicmirror

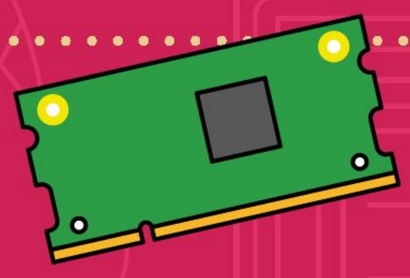


51

29/09/2016

126 **The MagPi #50**

We count down the 50 greatest Raspberry Pi projects, voted for by the community



16/01/2017

127 **Compute Module 3**

Jumping a generation, Compute Module 3 will stay the premier embedded option for nearly four years

Amazing Events

53

Pi WARS
THE RASPBERRY PI ROBOTICS CHALLENGE COMPETITION

53. Pi Wars

Less destructive than its TV counterpart, Pi Wars is nonetheless the premier Raspberry Pi robot competition. Complete with races, obstacle courses, and balloon jousting, it spun off from CamJam years ago and now has various competitions around the world. Many winners have been featured in, and even written for, *The MagPi*.

› piwars.org

COOLEST PROJECTS

54. Coolest Projects

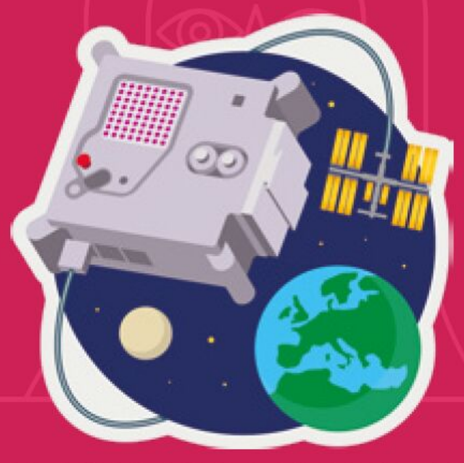
The Raspberry Pi Foundation's regional and online showcases of young people's inventions and creations, a lot of which end up using Raspberry Pi or Pico in them. They're full of all kinds of projects and previous winners have gone on to be big deals in the tech scene.

› coolestprojects.org

56



55. Astro Pi



Did you know there are Raspberry Pi computers up on the International Space Station? Every year, school groups are challenged to create an experiment that ESA astronauts can run on these Sense HAT-fitted space-bound computers, which have cameras and other sensors attached too. There are two tracks to choose from, with Mission Zero being for younger students and Mission Space Lab available for serious science.

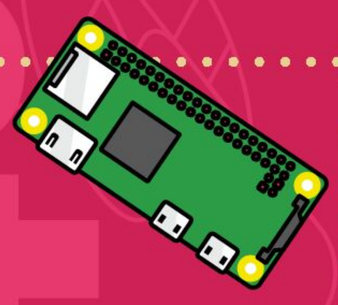
› astro-pi.org

" Did you know there are Raspberry Pi computers up on the International Space Station? "

56. Community Jams

Jamming with friends in the park is great - especially on a nice sunny day in San Francisco. When Covid forced Bob Steele and his group outside, he upgraded the group's setup with a Raspberry Pi so everyone could have synced-up notes, lyrics, and music sheets even where there's no electricity.

› communityjams.org



28/02/2017

128 Raspberry Pi Zero W

This important upgrade for Raspberry Pi Zero adds wireless LAN, just in time for the fifth birthday



16/03/2017

129 Third best-selling computer

Raspberry Pi sales reach 12.5 million, surpassing the C64 to make it the third best-selling computer ever



58. Open Sauce

A new and very successful event focusing on STEM, Open Sauce is a celebration of inventors and engineers held in the Bay Area of California. Interactive exhibitions, showcases, and panels are presented by well-known inventors and engineers, such as Adam Savage of *MythBusters* and YouTuber Colin Furze.

› opensauce.com

60. Raspberry Jams

Community events run by fans of Raspberry Pi and supported by Raspberry Pi itself. These events happen across the globe throughout the year and can have anything from talks by Raspberry Pi users, to project showcases from school clubs of what they've been making. Running one is easy, and you can even get gifts to give attendees as well.

› magpi.cc/events

57. Electromagnetic Field

A camping festival for makers of all kinds is a playground of electronics, chiptunes, blacksmithing, and more! Many Raspberry Pi community members attend and show off the stuff they've made, or pick up scrap to make their own cool projects; like the 1990s RAF flight simulator sticks that were converted to modern PC flight sticks with a Pico in issue 146 (magpi.cc/146).

› emfcamp.org



59. Wuthering Bytes

A technology festival that recently held host to Open Source Hardware Camp, showcasing a ton of projects from British makers and creators, including Raspberry Pi-powered robots and open source rocketry you may remember from previous issues of HackSpace magazine. There's also a lot of vintage computing at the show for folks with a nostalgia bug.

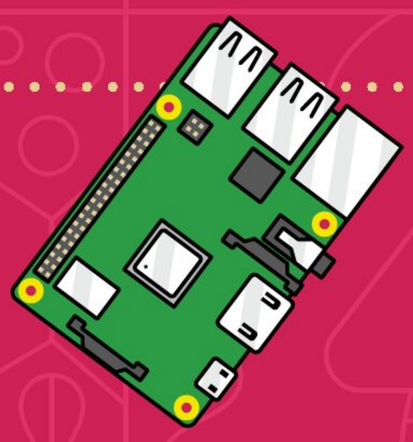
› wutheringbytes.com



61. Open Hardware Summit

Organised by the Open Source Hardware Association, the Open Hardware Summit is a yearly event held in different cities around the world that showcases maker and related projects of any kind. In 2025 you'll find it in Edinburgh, a bit closer to home!

2025.oshwa.org



14/03/2018

130 Raspberry Pi 3B+

The ultimate evolution of the original model is faster still, and offers network speeds three times quicker

25/10/2018

131 The MagPi #75

Another big issue, this time with 75 of the greatest Raspberry Pi projects voted for by the community

Projects For Good



64. Antarctic PiCam

Inspired by a previous project in *The MagPi*, this waterproof Raspberry Pi camera built by a student maker uses a simple plumbing tool to create an air-tight seal. While originally designed to look at fish in a local river, it ended up on its way to the Antarctic to observe algae growing on ice in freezing waters.

› magpi.cc/130 › awi.de



62. Bugg.xyz Acoustic Monitoring

You can analyse the general health of a habitat using the noise the wildlife creates. Using a Raspberry Pi and some smart machine learning algorithms, Bugg.xyz analyses sounds from the quietest to the loudest and reports on any changes for conservationists to follow up on.

› magpi.cc/129

› bugg.xyz



63. Arribada Penguin Monitoring

Recording penguin habits over long time periods in -30˚C temperatures is a job for Raspberry Pi – luckily, it performed better than expected as Covid caused a three-year gap between setup and retrieval. 32,000 photos were taken for one of the cutest (and most scientifically important) time-lapses imaginable.

› magpi.cc/123 › arribada.org

65. Exoskeleton



Powered exoskeletons are being studied as mobility aids. Usually, they end up tethered to a power system, but this one using Raspberry Pi is fully mobile and makes use of machine learning models to adjust to the user's specific way of moving.

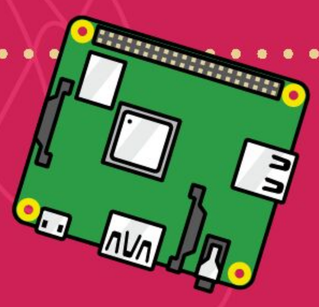
› magpi.cc/126 › magpi.cc/biomechstan

66. Air Raid Siren Monitor



To try and stay safe from air raids, Ukrainian maker Dmytro Panin used a Raspberry Pi Zero with an e-ink screen to parse information from various sources to show where air raids are happening in the country – the idea of which is to then inform you if you need to get to safety.

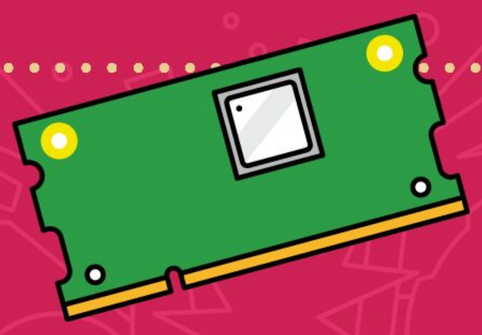
› magpi.cc/118 › magpi.cc/airraidmonitorgit



15/11/2018

132 Raspberry Pi 3A+

The first new Model A in five years brings the power of Raspberry Pi 3B+ to a much smaller form factor



28/01/2019

133 Compute Module 3+

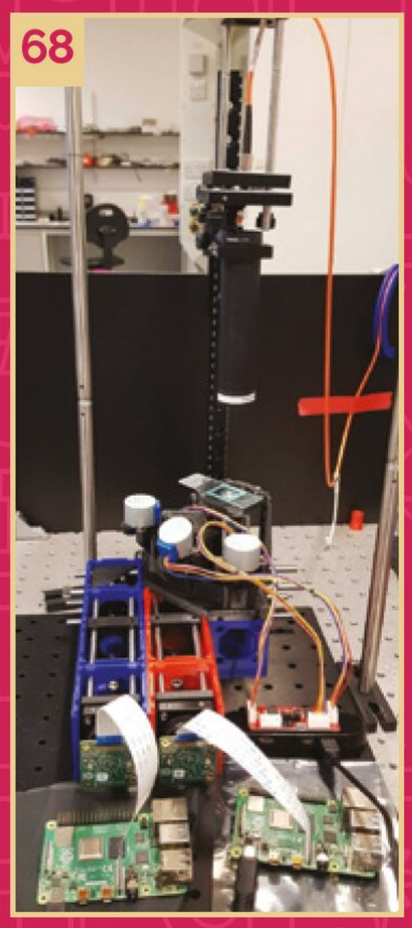
The board for deeply embedded systems gets the 3+ treatment



67. VespAI

Studying the spread of Asian hornets requires some smart computer vision to distinguish them from bees, wasps, and other hornets. Using a specially designed bait trap to attract wasps, VespAI then looks at through a camera before determining which species is which.

› magpi.cc/146 › magpi.cc/vespaigit



68. M4All

This special modular microscope setup is open source (the software and STLs are available from GitHub) and uses Raspberry Pi Camera Modules as the image-capturing equipment. It's an incredible system for scientists who would otherwise need to spend thousands on equipment.

› magpi.cc/116
› magpi.cc/m4all



70. Big Boxes

The internet has become so ingrained in day-to-day life, it seems like it would be impossible to live without it. When the unfortunate happens and natural disasters knock out public infrastructure, Big Boxes allow for people to get back online. They even help remote or displaced communities and peoples access the internet.

› magpi.cc/113 › janga.la



69. Maka Niu

The ocean is one of the least explored areas on the planet, and this special Raspberry Pi rig is used for deep sea imaging – potentially for up to 99.9 percent of the ocean with the right sapphire glass attached. It's also modular and open source so other scientists can make use of it.

› magpi.cc/125 › magpi.cc/makaniu



71. Smart Buoy

A solar-powered sensor buoy that is 'cheap to build, easy to run' and provides continuous and reliable data. It helps study rising sea levels and was deployed in Grenada in the Caribbean for this job. It communicates via radio signals to a Raspberry Pi base station. Something Raspberry Pi is very well suited to.

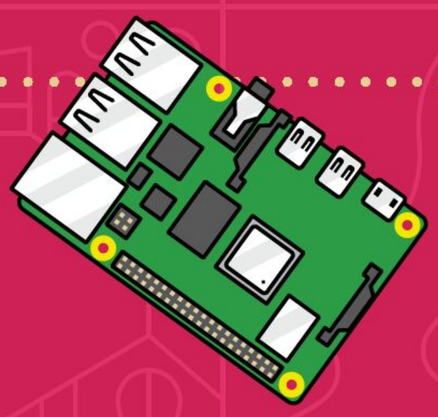
› magpi.cc/106 › t3chflicks.org



72. Remote agricultural monitoring

Invasive species are a problem around the world, and one government agency in Japan is employing Raspberry Pi fly traps with Camera Modules in a special case to monitor for specific kinds of fruit flies – although a human eye does the analysis once an email of the fly is sent to them.

› magpi.cc/109 › mechatrax.com



24/06/2019

134 Raspberry Pi 4

With up to 4GB of RAM, USB 3.0, Gigabit Ethernet, and support for dual monitors, this is a huge launch



30/04/2020

135 High Quality Camera

The latest version of the Raspberry Pi camera allows for interchangeable lenses and incredible photography

Raspberry Pi In Pop Culture

73. Mr Robot

Raspberry Pi shows up throughout hacker series *Mr Robot*, which has been praised for how accurate it is. It's still a TV show though, so a small computer PCB looks very technical and hacky to viewers.

› Various episodes



74. Black Mirror

Charlie Booker's speculative horror anthology tends to focus a lot on technology and in one monochrome episode, a van is hot-wired using a Raspberry Pi via a USB interface. Plausible enough for viewers, although these days you could probably do it remotely.

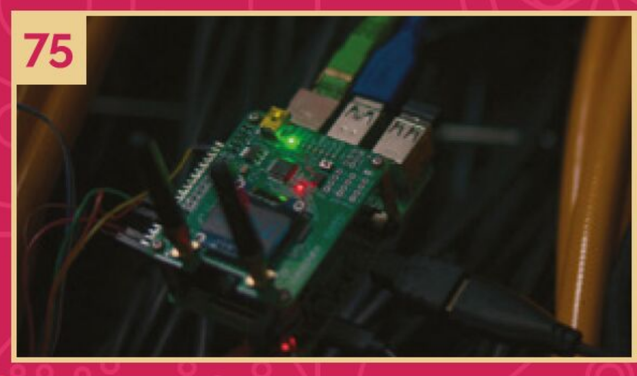
› **Episode: Metalhead**



75. Nightsleeper

A Raspberry Pi is used to hack a train so that over the course of six episodes, two unlikely heroes must save the sleeper train. This one is interesting as it has a specific modem HAT attached to it – usually we just see Raspberry Pi on its own.

› Episode: Episode One



76. Point Break

Not the iconic Keanu Reeves version but the remake. These Raspberry Pi boards with clear enclosures and a little display look technical enough to be used to detonate some bombs. Raspberry Pi is honestly a little bit overkill for this job.

› Year: 2015



77. CSI Cyber

CSI Cyber was a cheesy but fun show about cyber crimes that tried to be realistic but is still a procedural drama at heart. Case in point, this stripped-down Raspberry Pi 1 Model B is used as an example of a device that can take over a whole building! Imagine that without an Ethernet port.

› Episode: CMND:/Crash

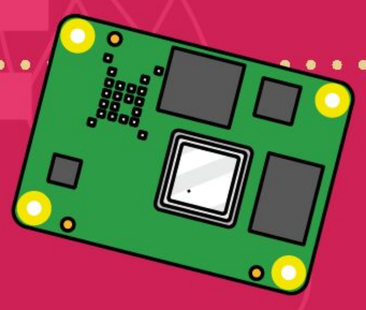


78. Hard Drive

This one gets regularly sent to us by folks and we have to begrudgingly admit it's very funny. We do disagree and say you should use a Raspberry Pi as an emulation machine, although of course we only condone grabbing legal ROMs once you've built it, resources for which you can find at **magpi.cc/legalroms**.

› magpi.cc/harddrive





19/10/2020

136 Compute Module 4

With a complete redesign, the latest and greatest Compute Module has all the power of Raspberry Pi 4



02/11/2020

137 Raspberry Pi 400

A throwback to computers of yore, Raspberry Pi 400 is a 4GB Raspberry Pi 4 fitted neatly into an official keyboard

Famous Makers



79. Allie Katz

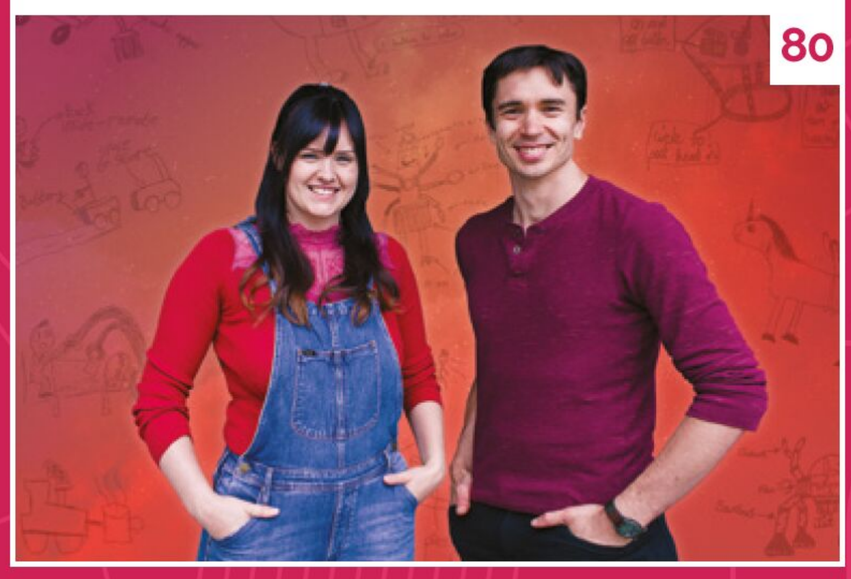
Allie Katz is a self-taught creative technologist who brings technological inventiveness into everything they do. This cosplay prop is a perfect example: it's a self-playing bass guitar, which uses a Raspberry Pi 5, internal speakers, and an amplifier board to play tracks from Spotify and YouTube.

› magpi.cc/149

80. Kids Invent Stuff

Who among us hasn't yearned to make real-life flying carpet, a piano that shoots fire, or a unicorn that defecates sugary treats? No-one we know. Yet only Shawn Brown and Ruth Amos – the brains behind the YouTube channel Kids Invent Stuff – have actually done it, and used Raspberry Pi while they're at it.

› magpi.cc/kidsinvent



81. Tanya Fish



An early adopter of Raspberry Pi as a tool for learning about computing, Tanya is a self-taught polymath and educator. One of her first Raspberry Pi builds was the Eurovision Crown, a wearable project that used a Raspberry Pi Zero W and a load of LEDs to display tweets about Europe's favourite song contest.

› magpi.cc/103

82. Liz Clarke



Raspberry Pi, Arduino, 3D printing, Python, LEDs – these are some of the areas that Liz Clarke, AKA Blitz City DIY, keeps coming back to. She's always making something cool, and she's always making sure that the projects are documented well enough so that anyone with a soldering iron can follow them at home.

› magpi.cc/lizclarke

83. GurgleApps

Meet the siblings behind GurgleApps: Amélie, Caleb, and Ziva. They got into computing for fun and stayed in computing to make educational videos to fill the gap left in school lessons created by the Covid pandemic. Making gadgets and videos on YouTube as GurgleApps, they're big fans of the Raspberry Pi Pico in particular.

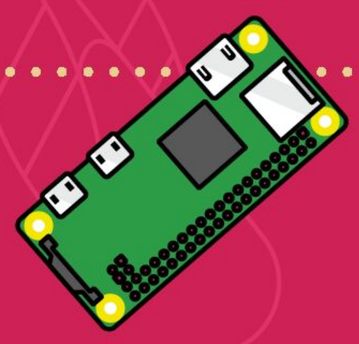
› magpi.cc/gurgleapps



21/01/2021

138 Pico & RP2040

Raspberry Pi introduces its microcontroller board and reveals Raspberry Pi silicon



28/10/2021

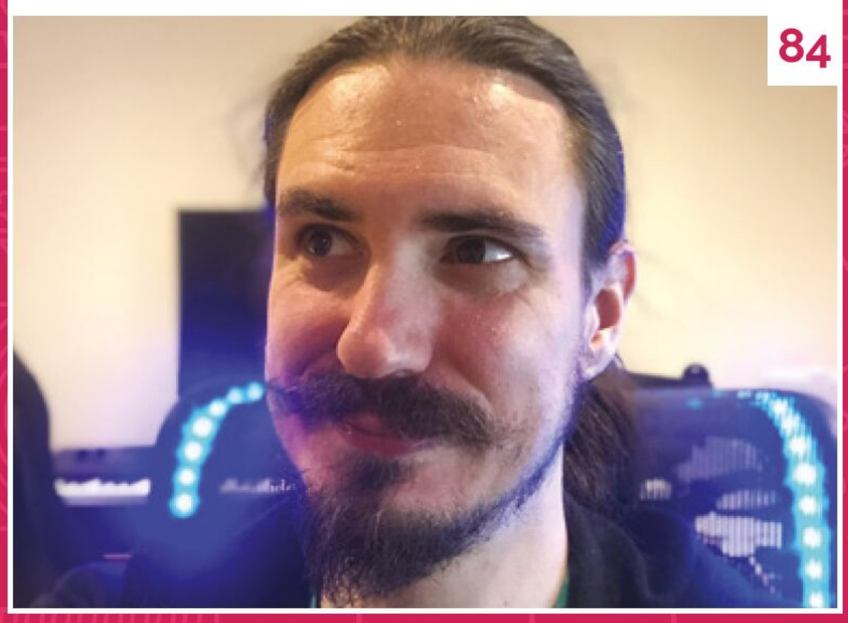
139 Pi Zero 2

Raspberry Pi's small and ultra-low-cost computer gets a speed and RAM upgrade, making it incredible value for money

84. Phil Howard

Hardware and software engineer at Pimoroni, maker of Raspberry Pi-based boards, displays, sensors and more. If you've ever had the pleasure of buying a new add-on for your Raspberry Pi and finding out that it's fun to play with and works perfectly first-time, there's a good chance that Phil made it so.

› magpi.cc/gadgetoid



86. Estefannie

In her own words, Estefannie makes "feminine rage tech." She started with a 3D printed Daft Punk helmet complete with LEDs, graduated to getting aggro from blokes on the internet, and has somehow retained enough sanity to make clever projects that blend feminism, social awareness and yet more LEDs.

› magpi.cc/estefannie





85. Jeff Geerling

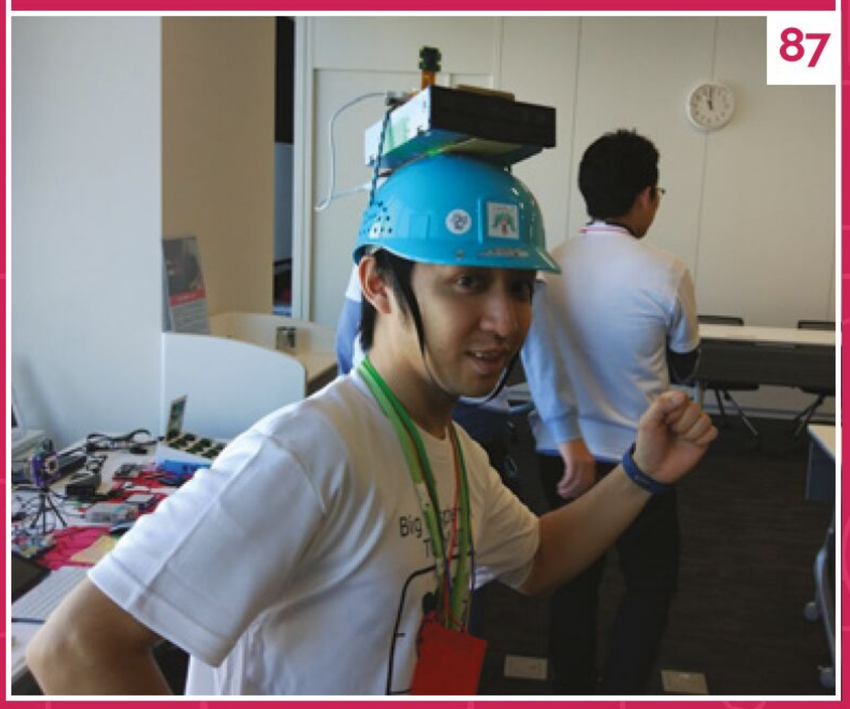
If you can do it with a Raspberry Pi, Jeff's done it. Heck, even if you can't do it with a Raspberry Pi, Jeff's probably done it. From home automation to clusters, to supercomputers, Jeff's YouTube channel is bursting with ideas for anyone wanting to squeeze the last drop of juice from their Raspberry Pi.

› magpi.cc/jeffeerling

87. Akkie

Akira Ouchi, or Akkie as he's best known, is a long-time member of Japan's maker community. He's an early Raspberry Pi adopter, having bought his first one in March 2012 – just days after they went on sale. Since then, he's found loads of playful uses for Raspberry Pi, including computer-controlling a toy monorail.

› magpi.cc/111



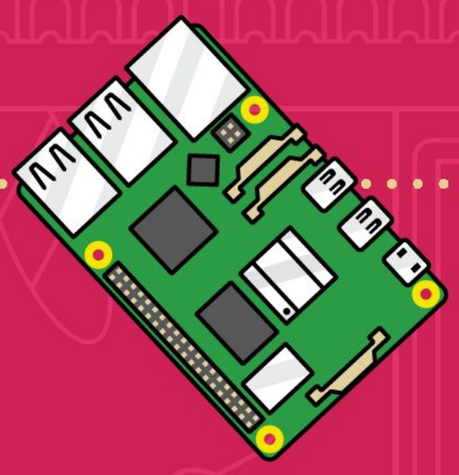
88. Dr Footleg

Raspberry Pi would be nowhere without the small army of volunteers who use it to teach kids how to program and build. One of these is Dr Footleg, who runs after-school robotics clubs, and takes his robots to Raspberry Jams in the mysterious East of England, to encourage children's interest in STEM subjects.

› magpi.cc/drfootleg



> " Raspberry Pi would be nowhere without the small army of volunteers who use it to teach kids "



28/09/2023

140 Raspberry Pi 5

Packing the power of a 2.4GHz quad-core 64-bit Arm Cortex-A76 CPU, up to 8GB of RAM, and new RP1 controller

14/5/2024

141 M.2 HAT+

To connect M.2 M-key peripherals such as NVMe drives and AI accelerators to Pi 5



89. Stewart Watkiss

Stewart first got his hands on a Raspberry Pi in 2012, and since then has written for *The MagPi*, run code clubs, delivered workshops at Raspberry Pi events, and built countless electronics projects for Raspberry Pi. He's even written two books: *Learn Electronics with Raspberry Pi* and *Beginning Game Programming with Pygame Zero*.

› magpi.cc/stewartwatkiss



90. Kevin McAleer

If you want to learn how to build a robot, start with **KevsRobots.com**, the website of Kevin McAleer. He'll take you from the basics of electronics through to advanced concepts such as artificial intelligence, and he does it all in a way that you can understand even without a degree in electronic engineering.

› magpi.cc/kevinmcaleer

91. Alex Glow

Alex is the lead Hardware Nerd at Hackster.io – the community for hardware developers. She's always creating projects, tutorials and videos to help people learn about electronics (including, of course, Raspberry Pi), including her own Raspberry Pi Zero W-powered robot owl, Archimedes.

› magpi.cc/alexglow



92. Odd Jayy

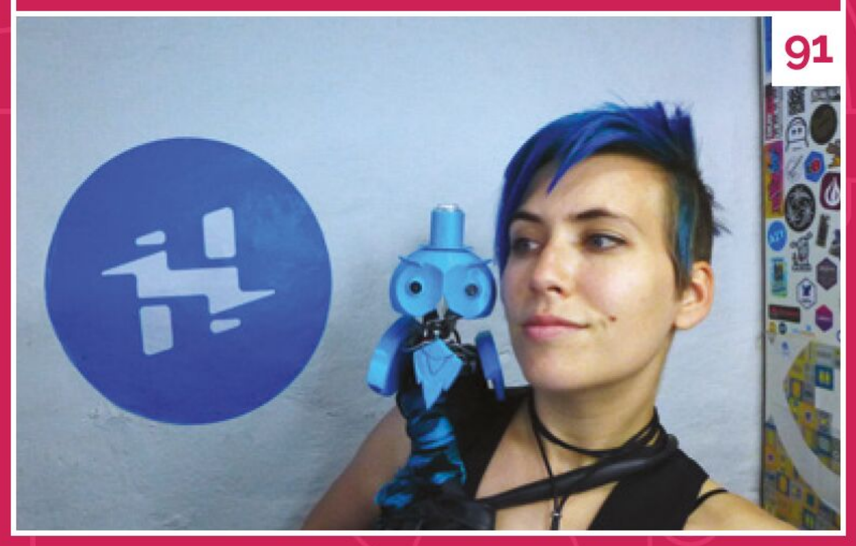
Jorvon Moss, aka Odd Jayy, is our favourite kind of maker. He's self taught, with a background in art and design – so of course, his robotic creations are all utterly gorgeous. If you're not from an electronics background yourself, but would like to give it a go, he's a great person to learn from.

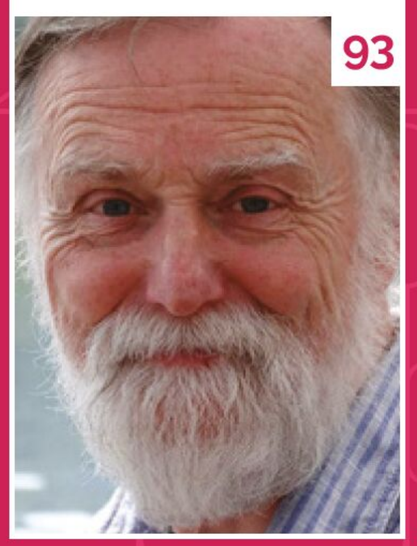
› magpi.cc/jorvonmoss

93. Mike Cook

The word 'veteran' is overused, but it's perfect to describe Mike Cook. "There was no 'online' when I started," he told us in *The MagPi* issue 116, "and so I had to work it all out myself. It is good to give people a helping hand." Mike's first project with Raspberry Pi was a robot Glockenspiel – back in 2012!

› magpi.cc/116

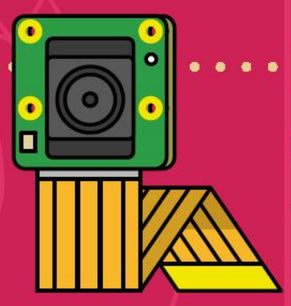




4/6/2024

142 AI Kit

Combining an M.2 HAT+ with a HAILO accelerator to kick-start a new era of AI projects powered by Raspberry Pi



30/9/2024

143 AI Camera

With an integrated AI accelerator to enable a wider range of Raspberry Pi boards to perform sophisticated image processing

94. Selin Alara Ornek

Selin first got into robotics because she wanted to bring back her recently deceased childhood pet, a dog called Korsan. She learned to program with Scratch, then moved on to Arduino, then to Raspberry Pi and Python; now she's building robots, winning awards, and inspiring a new wave of young makers.

› magpi.cc/selinoid





95. Sophy Wong

The undisputed Queen of Wearables, Sophy is a graphic designer, fashion designer, and all-round maker of cool things. You'll find her work all over the internet, but what caught our eye was the SelfieBot, a fun machine that used a Raspberry Pi, a camera, and a thermal printer to generate instant photos.

› magpi.cc/sophywong

97. Veeb Projects

Nostalgia; a reluctance to throw perfectly good things away just because they're old; ultra-clean Swiss aesthetics: these are a few of the ideas that inspire Veeb Projects, aka Martin Spendiff and Vanessa Bradley, two former IT workers who fancied a change one day and now find themselves making beautiful things with Raspberry Pi.

› magpi.cc/veeb



96. Alex Martinez

Alex Martinez is a former geologist turned teacher who is bringing robotics and computer education to kids in the Caribbean island of Puerto Rico. He's founded a maker space, he teaches computing to kids of ages 6 to 14, and he's a mentor to college students building underwater robots.

› magpi.cc/126

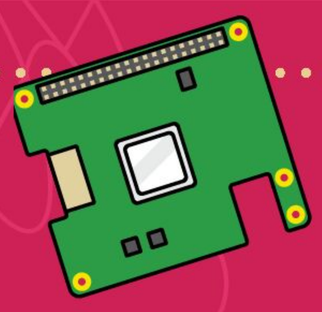




98. Lorraine Underwood

Lorraine Underwood didn't invent the Blackpool Illuminations (they've been a fixture in the English seaside town since 1879), but she certainly took them to new heights in 2022, when she was part of team that created Odyssey – a light installation inspired by the Greek myths and controlled by Raspberry Pi.

› magpi.cc/126



26/10/204

144 AI HAT+

Combining the power of an M.2 HAT+ and HAILO accelerator for an incredible 26 TOPS



4/11/204

145 Touch Display 2

Bringing the touchscreen up-to-date with a higher 720×1280-pixel resolution and slimmer form factor

Best Of The Rest



101. Fireballs Aotearoa

Meteors are constantly flying over us, burning up in the Earth's atmosphere or passing harmlessly overhead. For the scientists whose job it is to monitor these fireballs, Raspberry Pi provides an affordable, capable platform that enables detection and analysis to be run on the same device.

› magpi.cc/121



99. iPod Classic Spotify Player

The original iPod was an instant design classic, but its maximum storage capacity was only 160GB – so why not upgrade one to give it access to Spotify, with its millions of songs? That's what Guy Dupont did, replacing the iPod's original electronics with a Raspberry Pi Zero W.

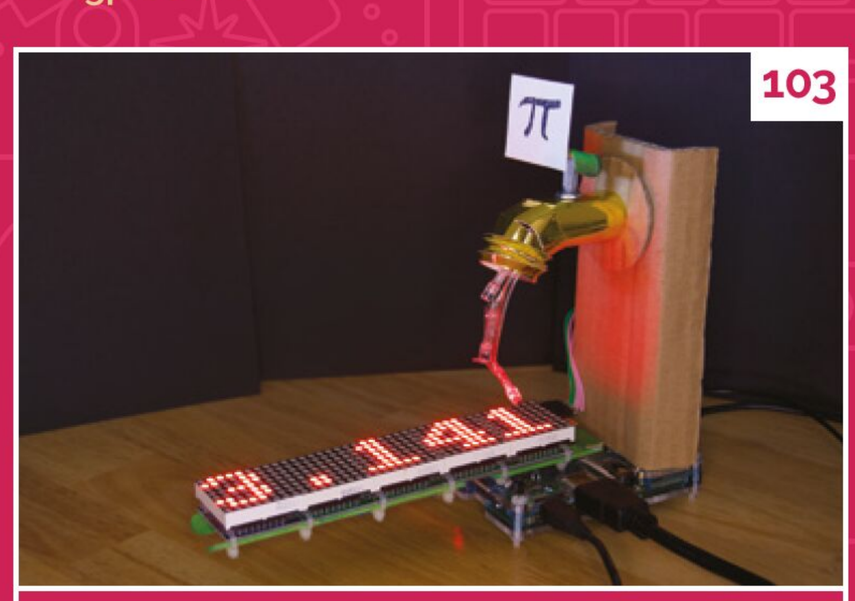
› magpi.cc/104



100. Multi Effects Guitar Pedal

A modular synth in a box, that you can plug a guitar into – that's what Raphaël Isvalin created for his first Raspberry Pi project. This build is based around a Raspberry Pi 3 and, as audio effects need low latency, uses software written in C rather than the more commonly used Python programming language. The results are unique, and jolly impressive.

› magpi.cc/101



103. Raspberry Pi Spigot

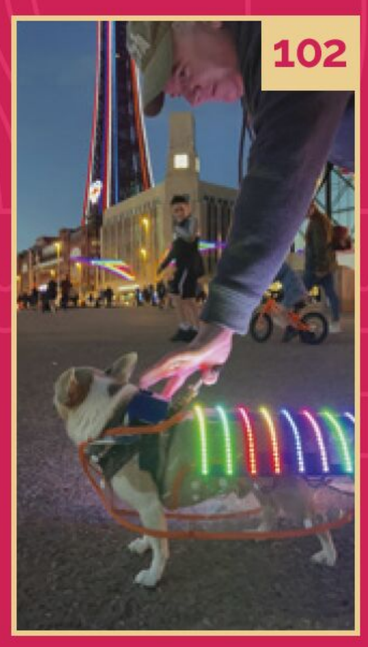
We have Adrian Chung to thank for this silly creation. He "thought it would be neat to use a Raspberry Pi to compute pi [the number] to arbitrarily high precision." And he's right: it is neat! An LED matrix displays the scrolling digits of pi, while a potentiometer detects when the tap has been turned.

› magpi.cc/106

102. Cyberdog Smart Saddle

This smart LED saddle by Kevin McAleer uses strips of addressable RGB LEDs controlled by a Pimoroni Plasma 2040 board, with a Raspberry Pi Zero W to give access to the internet for control via a smartphone app. Brilliant and bonkers!

› magpi.cc/123



25/11/2024

146 Pico 2 W

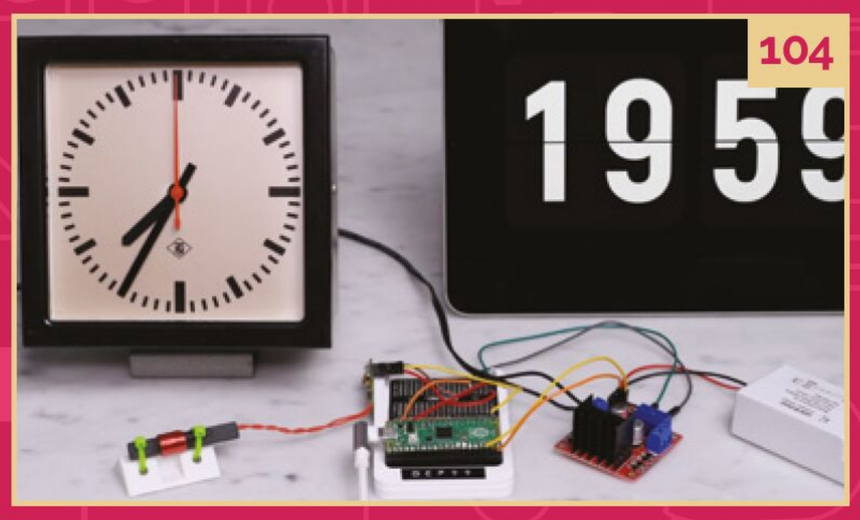
Built around the new RP2350 chip, with both ARM and RISC-V cores, plus wireless networking



9/12/2024

147 Raspberry Pi 500

Putting the power of Raspberry Pi 5 into a small-form keyboard, it's a modern imagining of the classic computer



104. Pico Railway Clock

Here's a second-hand railway station clock, which once used a signal from a master clock (that way all the clocks in the railway station would keep the same time). It now uses an antenna that picks up a signal from an atomic clock broadcast, and a Raspberry Pi Pico to convert that signal into a pulse that drives the clock.

› magpi.cc/120



106. SoFi

Chosen by Phil King

I was amazed by this soft robotic fish built by MIT CSAIL back in 2018 and I still think it's one of the coolest projects I've seen. The way it glides through the water, propelled by its flexible tail, is a sight to behold and enables it to swim quietly alongside deep-sea marine wildlife to observe them with a fish-eye-lens camera. Its pump-based buoyancy system is clever, too.

› magpi.cc/69



105. miniLIGO Gravitational Wave Detector

When six PhD students at Carnegie Mellon University in Pittsburgh decided to build their own LIGO (Laser Interferometer Gravitational-wave Observatory – a way of detecting gravitation waves caused by massive collisions in space), they naturally used a Raspberry Pi, plus an Adafruit Big Dynamic Range Sensor, a laser, a beam splitter, and a Bluetooth speaker.

› magpi.cc/110



107. CinePi XL

Cinephile Csaba Nagy's open-source CinePi project is a direct result of the intersections between his passions for programming and filmmaking. CinePi 2, a Raspberry Pi 4 12.3MP HQ Camera that records 4K video at 50 frames per second, was followed up by the CinePi XL cinematic camera.

› magpi.cc/137

109. Mona Lisa Fluid Painting

Micro-fluidic biosensors are used in microscopic research, and this project showcases 'local and highly parallel dissolution of biochemical reagents in volumes as low as two nanolitres per spot' to paint the iconic Mona Lisa – all photographed by a Raspberry Pi High Quality Camera.

› magpi.cc/132 › magpi.cc/monalisa

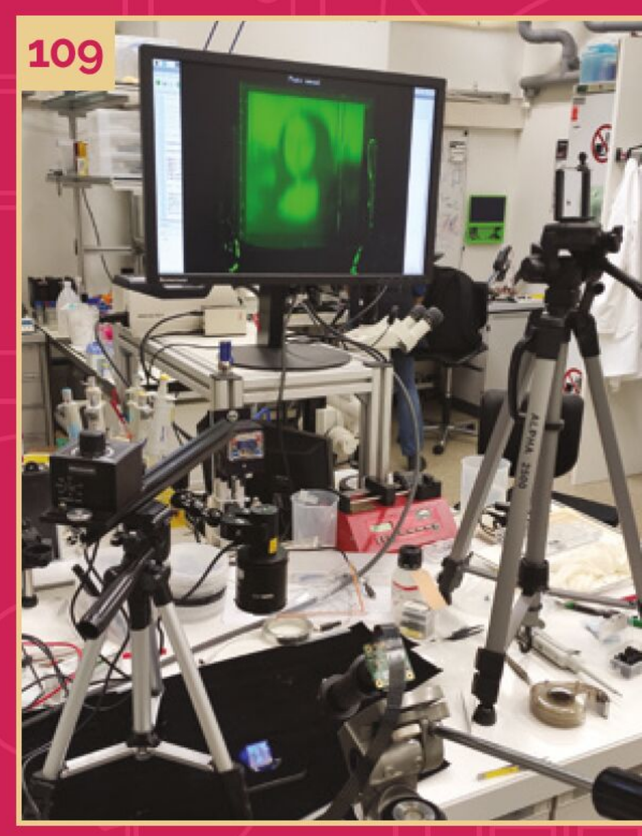


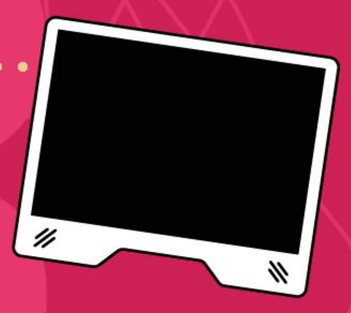
108. Screen Dress

Art and technology can go hand-in-hand, especially with this Raspberry Pi Zero W-powered dress that shows how the wearer is feeling via a special EEG headband they wear and images displayed on the various (eye-catching) screens attached to the outfit.

› magpi.cc/135

› anoukwipprecht.nl





9/12/2024

148 Monitor

An official Raspberry Pi 15.6-inch 1920×1080p IPS LCD display

9/1/2025

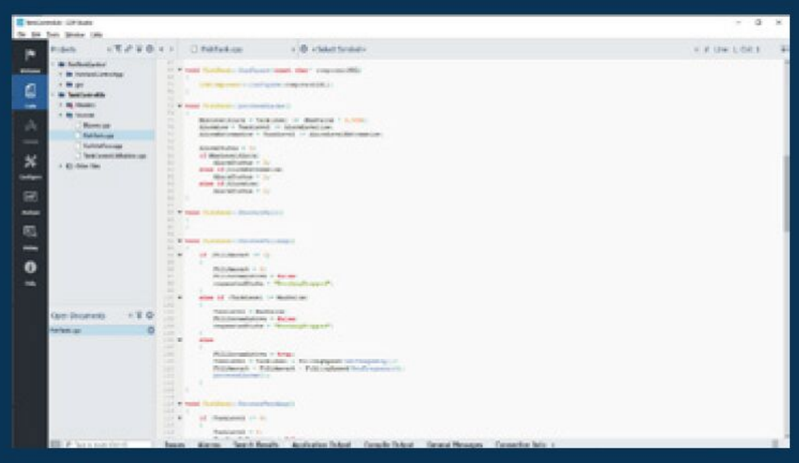
149 16GB Raspberry Pi 5

With 16GB RAM, it's perfect for running machine learning projects and heavier operating systems

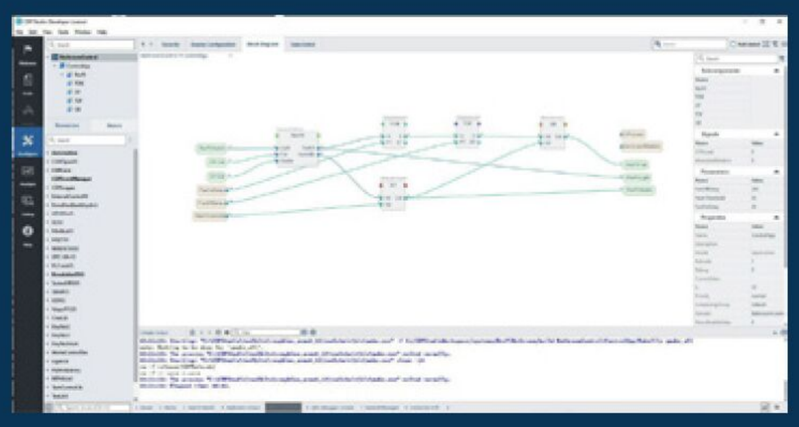
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150 Issue 150

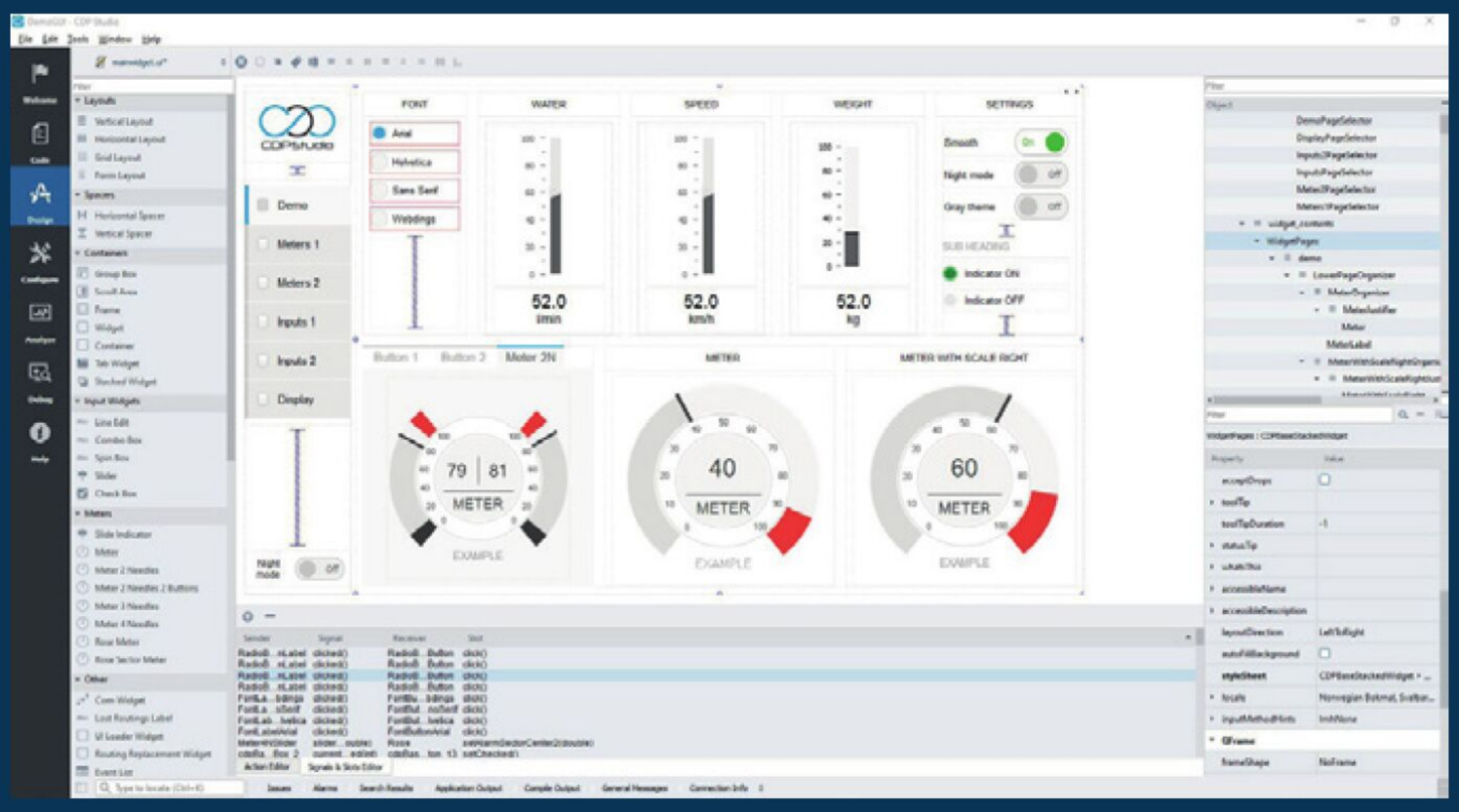
A remarkable feat for a computer magazine – thank you all for reading!



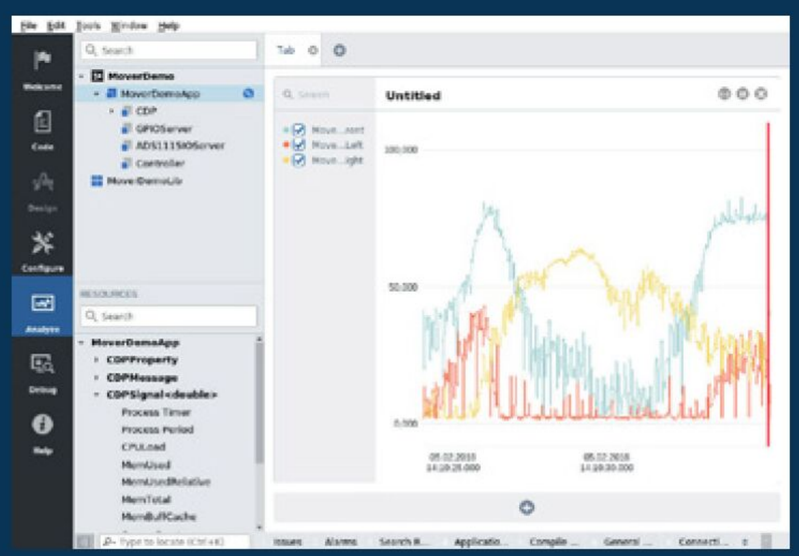
Full-Code



No-Code



Design



Analyze

No-Code UI Designer

for WEB and Native GUI

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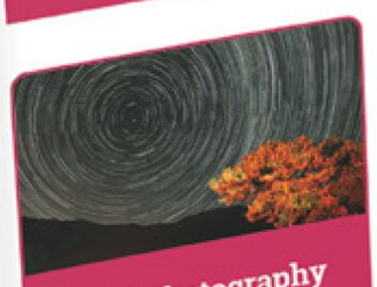
THE *Official*

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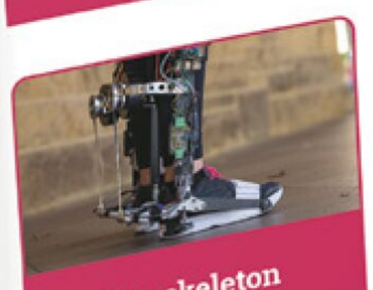
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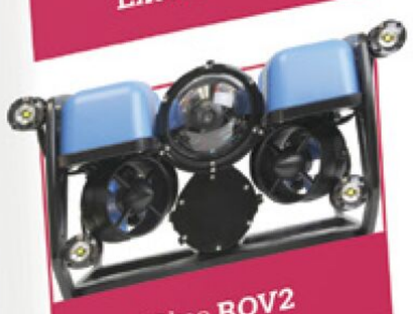
Olga **Fortune Teller**



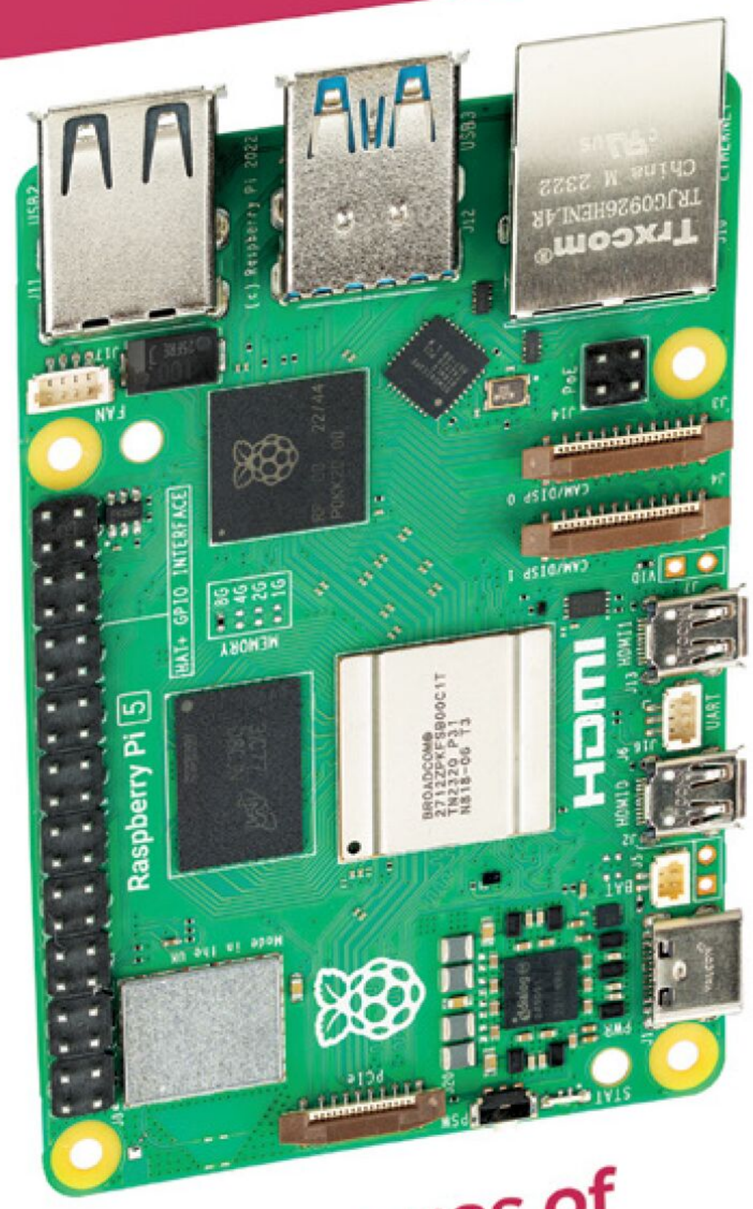
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TOP PROJECTS

PG 68

E-INK CLOCK

An off-the-shelf hardware build courtesy of your favourite Swedish furniture shop



PG 70

PHOTON 2 LANDER

A load of sensors wrapped up in a perfectly soldered circuit sculpture

PG 72

3D-PRINTED 7-SEGMENT DISPLAY



An incredible deep dive into an old technology

PG 74

SOCIAL BATTERY

Simple surface-mount technology with an important message

FORGE

PG 80

DRINKS MANAGER

Keep tabs on the free beverages with a Raspberry Pi Pico and RFID

PG 84

CUSTOM CNC MACHINE

Build a device for wrapping carbon filament

PG 90

SOLAR POWER

Can the UK's dim winter sun power anything useful? We find out

PG 94

PAPER MAKING

The cutting edge of 4000-year-old technology

OBJET 3D'ART

PG 76



SCOTTO44

Type better, faster and more stylishly with this split-panel mechanical keyboard

PG 98

STORAGE

The best non-cloud ways to keep hold of things that matter

Best of Breed













E-ink clock

By **AKZ Dev**

magpi.cc/E-ink-Clock

This project features a 7.3-inch 7-colour Inky Impression by Pimoroni, plugged into a Raspberry Pi Zero 2 W. It's customisable via a range of plug-ins, and there's a local web server hosted on the Raspberry Pi that allows you to update the display from your browser.

Rather than make a frame out of wood, or 3D-print one, this project uses an off-the-shelf frame from IKEA, with a section cut out of the back to leave room for the Raspberry Pi Zero W. It's a simple, smart build, but if it works, it works!



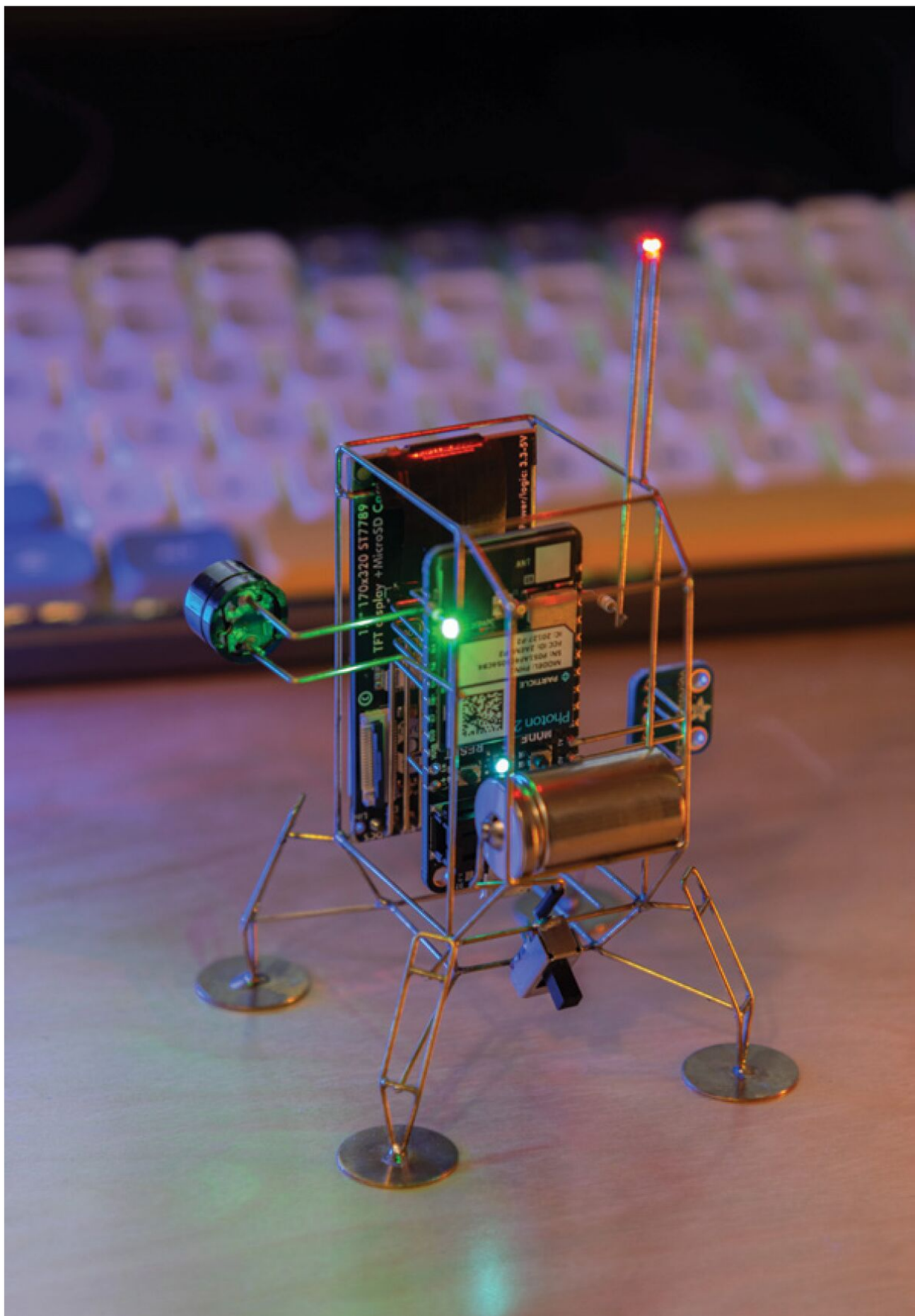
Right
The image refreshes around every 30 seconds, so this is useless for timing Formula 1 races, but pretty cool for telling the time at home

Photon 2 Lander

By **Mohit Bhoite** magpi.cc/mohitbhoite

This is the latest circuit sculpture in a series inspired by planetary landing craft, made by the artist/engineer Mohit Bhoite. It uses the Photon 2 board, which itself is based on the Adafruit Feather form factor. The circuit includes a battery, a 170×320 IPS TFT display and a few sensors, data from which are displayed on the screen. If you were to do this yourself on a breadboard you'd be pretty pleased, but the difference here is of course the sculptural element: the whole thing is a big circuit.

We've seen a few circuit sculptures in these pages before now, and we're always blown away by how good they look. We even had a go at it ourselves once, and it's a lot harder than it looks. Because the brass wire is much thicker than the copper traces on a PCB, you have to put a lot more heat into the joint than you're probably used to when soldering through-hole components. The 20AWG wire that Mohit has used in this sculpture, for instance, is 0.8 mm thick, so any joint that's soldered to it will be surrounded by a lot of metal wicking heat away. Mohit's work is always so clean, so perfect, and so creative that we're in awe, as makers and designers.



Right
According the Mohit, the 14250 Li-ion cell doesn't last long, so he tends to keep this lander plugged in to a USB-C dock


THU
3.8V
26 DEC
2024
10:12
PM
TAM VALLEY
56
07:25
16:58
MUMBAI
11:42
AM
72%
HUMIDITY
12
WIND
3V
SCK
MOSI
RST
SDCS
MISO
TCS
DC

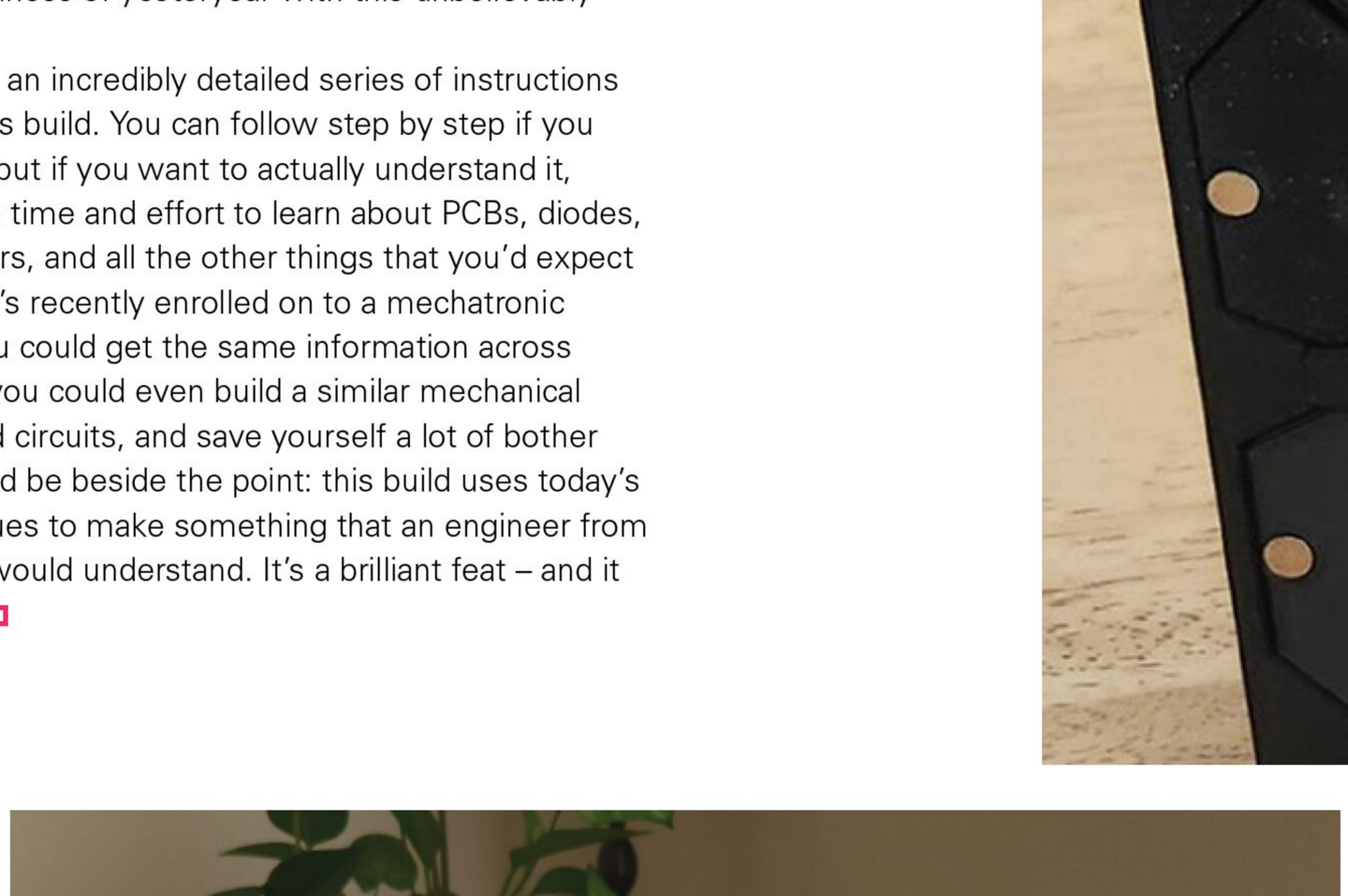
3D-printed 7-segment display

By **Tin Foil Hat**

magpi.cc/3DPrint7Segment

Ah, the reassuring clickety-clack of the railway station mechanical 7-segment display, updating to send commuters scurrying to their platform. Australian self-taught engineer Tin Foil Hat reckons there's something missing in our digital world, and has endeavoured to recreate some of the comforting electromechanical clickiness of yesteryear with this unbelievably complex display.

The maker has given an incredibly detailed series of instructions for anyone to follow this build. You can follow step by step if you just want to build one, but if you want to actually understand it, you'll have to put in the time and effort to learn about PCBs, diodes, capacitors, shift registers, and all the other things that you'd expect someone to know who's recently enrolled on to a mechatronic engineering course. You could get the same information across using a digital display; you could even build a similar mechanical display using integrated circuits, and save yourself a lot of bother that way. But that would be beside the point: this build uses today's manufacturing techniques to make something that an engineer from the pre-computer age would understand. It's a brilliant feat – and it sounds gorgeous too.



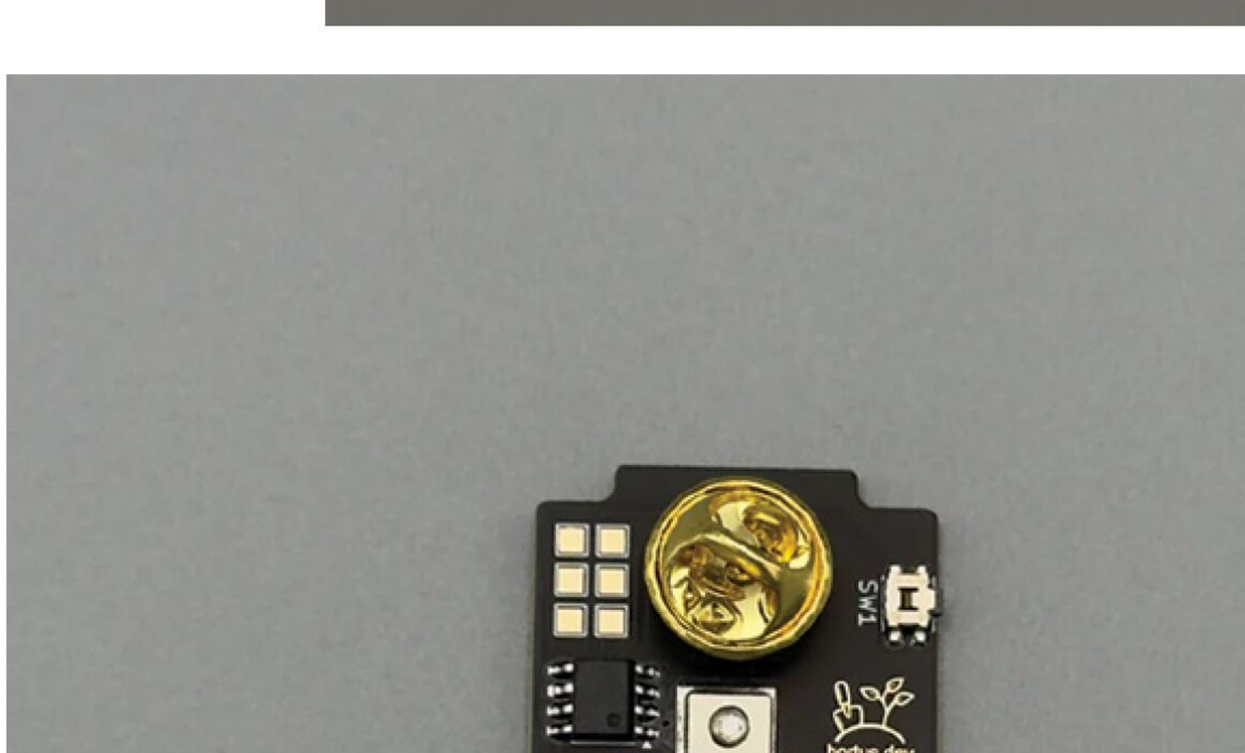
Right
If our local station used these, we wouldn't mind so much when our train gets cancelled

Social battery

By **David Capper** hortus.dev

Introverts aren't shy, quiet creatures that need to stay at home all day – it's more complicated than that. Where extroverts thrive on social interaction, introverts find it takes a bit of energy to be around other people. When they're feeling full of social energy it's fun to socialise; when that social battery is drained, they need to read a book, go for a walk, or conduct some other solitary activity in order to recharge. That's something that a lot of people don't understand, but the next time you're at a conference and you need a break from people, you can spell it out with the aid of this Social Battery by David Capper.

This is David's first attempt at designing for production and sale. As anyone knows who's tried it, making something as a one-off if very different to doing it at scale, and David has explored this in a series of blogs in which he explains the process of going from idea to sales platform. It's powered by an ATtiny13A and a CR2032 coin cell battery, and the user controls the LEDs via a small button on the side of the badge. And it you want to know more about introversion and why it's not what you might think it is, try reading *Quiet: The Power of Introverts In A World That Can't Stop Talking*, by Susan Cain.



Right
The Social Battery was designed in free PCB software KiCad, just like the CM5 IO board. Install it and have a go yourself!


Social Battery
100%
75%
50%
25%
0%

Objet 3d'art

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



Split keyboards are a godsend to anyone who works at a computer and is having carpal tunnel, wrist, hand, shoulder, neck or back problems – we suspect this may be a large number of people. They're great because you can move your hand position to an angle that makes sense for you, rather than have an unnatural posture forced on you by your hardware.

Here's a great example: the Scotto44. It's a split-design, column-staggered mechanical keyboard that uses clicky Kailh Speed Bronze and Pale Blue switches. The two halves of the board are each wired to a Raspberry Pi Pico, and the halves are connected via USB-C. The keycaps are printed in PLA with a layer height of 0.12 mm; because of this, the maker says they don't need sanding. We just know that we like the look of it.

hsmag.cc/Scotto44


BOOTSEL
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Raspberry Pi Pico
DEBUG




FROM THE MAKERS OF The MagPi THE OFFICIAL RASPBERRY PI MAGAZINE
START
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PLAY & CODE GAMES!
File manager
Change color
Change icon
Extra blocks
Save dump
Load dump
Hexeditor
Defragment
Reformat
/ : Select
: OK
: Cancel
Display the list of the files found in the selected VMU.

RETRO GAMING WITH RASPBERRY PI

3RD EDITION

Retro Gaming with Raspberry Pi shows you how to set up Raspberry Pi 5 to play a new generation of classic games. Build your gaming console and full-size arcade cabinet, install emulation software and download original games with our step-by-step guides. You'll discover a vibrant homebrew scene packed with new games for original consoles and legal access to all those retro games you remember!

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A Pico-powered RFID free drinks manager

Keep your generosity in check with a Pico-based free drinks RFID card reader



Rob Miles

@robmiles

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

This project was created for an event celebrating 50 years of Computer Science at Hull University (hullcs50.com). A local company formed by Hull graduates was offering to buy all the attendees a drink, but how would this be managed? The obvious solution was to give out paper drink tokens, but this was thought technically boring. Instead, the delegates were given RFID cards and a reader at the bar ensured that the holder of a card was entitled to one drink. Then, if funds permitted, the system would be reset, allowing another round.

Figure 1 shows the author being denied a drink by his own creation. The first time a card is scanned, the device displays green lights, telling the bar staff to serve a drink. If the same card is scanned again, the lights turn red. A special 'reset' card makes all the cards work for another free drink.

The drinks manager is powered by a Raspberry Pi Pico which is connected to an RFID tag reader and a ring of LEDs that show the status. It runs on the Connected Little Boxes platform, which was written in C++. You can find all the software and full construction details on GitHub: **hsmag.cc/PicoRFIDGitHub**.



Figure 1 The author was sorely tempted to make his card allow infinite drinks

CHEAP CARDS

The system uses 13.56 MHz RFID cards based on the ISO 14443A standard. These are available very cheaply. Fifty can be bought for less than £10. RFID readers based on the RC522 device are available for a similar price and can be connected to a Raspberry Pi or Raspberry Pi Pico. The author was very impressed with the low price of the cards that he got. He was less impressed when quite a few of his cards didn't work. If your reader doesn't seem to work properly, you should try it with a different card and not spend an afternoon trying to fix it like the author did. Investigation using isopropyl alcohol to dissolve the plastic card (do not try this at home) revealed that the antenna was not connected to the circuit board.

ANY CARD WILL DO

Many cards in your wallet use the same RFID (radio frequency identification) standard as the drinks manager. Therefore you might well find that waving a bank or hotel key card over the drinks manager will entitle you to a free drink. Quite a few of the delegates to the anniversary celebration were very pleased to discover that their student ID cards worked in this way! A more advanced version of the project would allow the user to train the system with a set of known RFID cards and then reject any unrecognised ones.

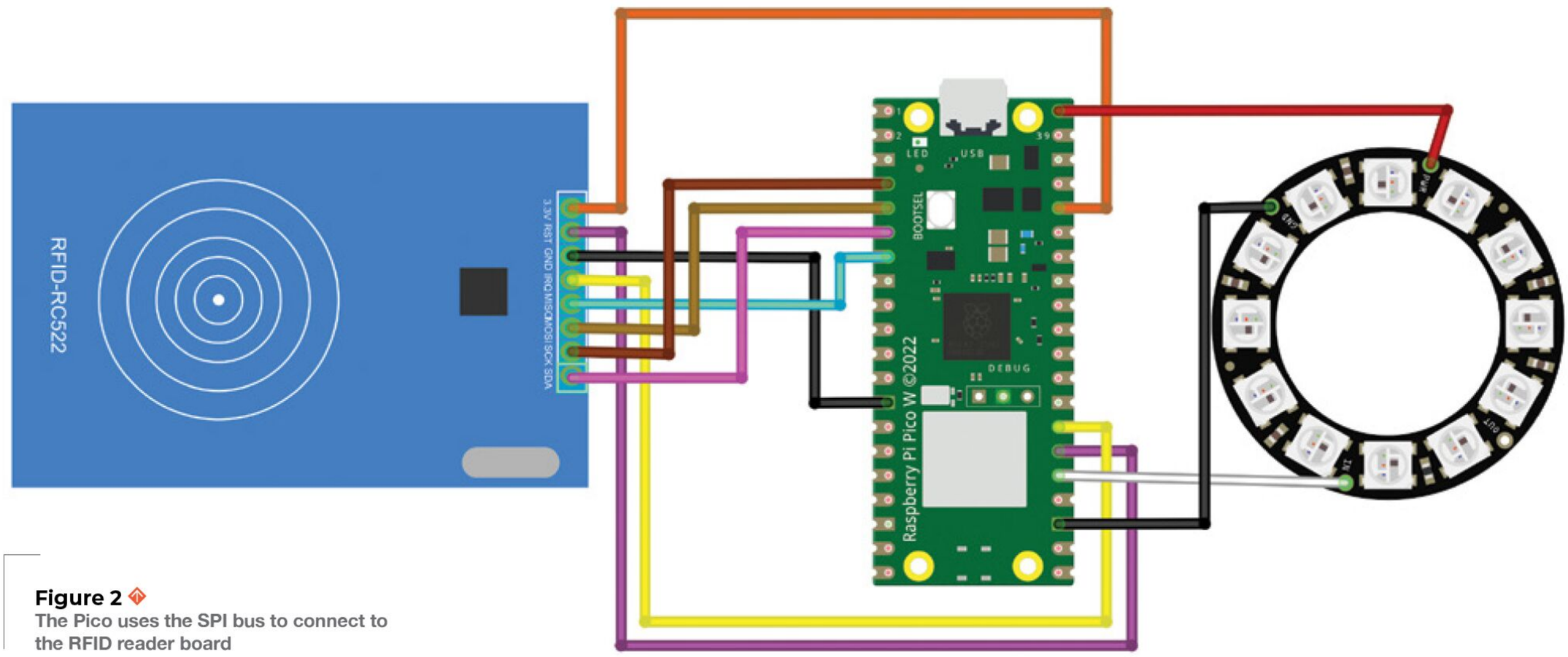


Figure 2
The Pico uses the SPI bus to connect to the RFID reader board

However, the broken cards found a use making kids' card games, so all was not lost.

WIRING UP

Figure 2 shows how the RFID reader board is connected to Raspberry Pi Pico. The connections include an interrupt signal which the card reader uses to tell the Pico when a card has been detected. This allows the Pico to do other things (in this case animate the pixel display) while waiting for the user to present a card for checking. The detailed wiring connections used are as follows:

RFID	Pico
3.3V	Pin 36 – 3.3V
RST	Pin 26 – GPIO 20
GND	Pin 13 – GND
IRQ	Pin 27 – GPIO 21
MISO	Pin 7 – GPIO 5
MOSI	Pin 5 – GPIO 3
SCK	Pin 4 – GPIO 2
SDA	Pin 6 – GPIO 4

Pixel Ring	Pico
Power	Pin 4 – VSYS
GND	Pin 23 – GND
DI	Pin 25 – GPIO 19

MAKING THE MANAGER

Figure 3 shows the inside of the drinks manager. The connections were made using wire-wrap cable on solder pins. This works well and allows multiple connections to a single pin. You can use DuPont (jumper) cable connections, but they might not fit in the box and you must be careful connecting them to the solder pads on the LED ring, as it is easy to pull the solder pads off the ring circuit board. A 3D printable case design is available in the repository for this project. Now that we know how to make the hardware, it is time to consider how the software will work.

DRINK TRACKING

You might think that the manager works by setting a value inside an RFID card to indicate that it has been used to order a drink, but the software is much simpler than that. Each of the RFID cards used for this project does contain a small amount of storage. However, this solution does not store any data in the card; instead, it identifies cards by the unique ID stored on each card and then tracks the cards that have been used.

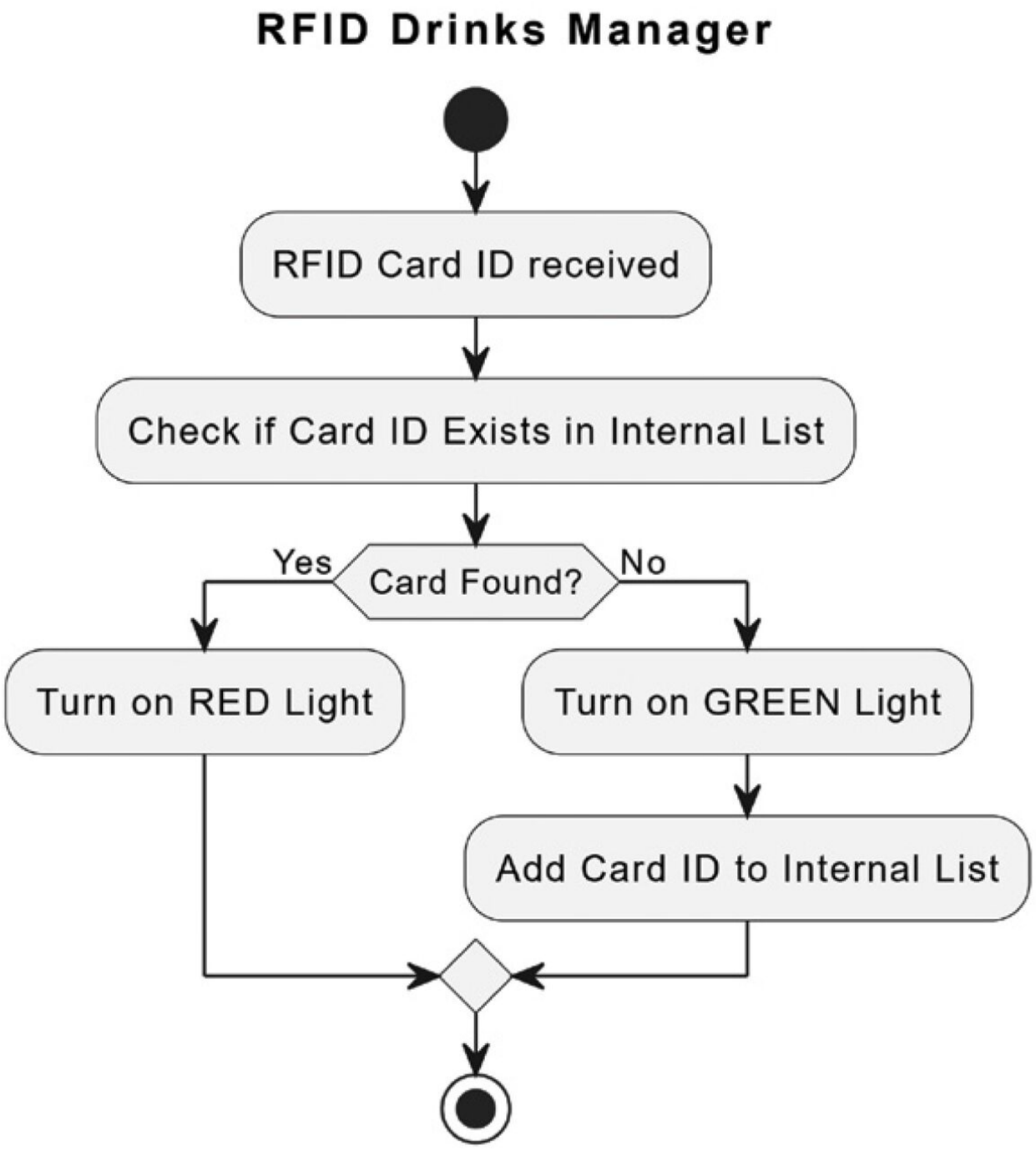
Figure 4 shows how it works. The program in the drinks manager keeps a list of all the cards that it has already seen. When a card is detected, the program searches the list of cards and if the card is found, the light is turned red. If the card is not found, the light is turned green and the card ID is stored in the list. There is an extra behaviour which checks for a

YOU'LL NEED

- A Raspberry Pi Pico
- An MFRC522 reader for tags and RFID cards
- A 12 pixel ring

DISTRIBUTED DRINKS MANAGEMENT

MQTT (Message Queue Telemetry Transport) is a way of connecting devices together. The drinks manager can be made to send an MQTT message when an RFID card is scanned. The message contains the ID of the scanned card. A server responding to this message would check in a database to see if a free drink is allowed for that card and send a command back to the box to display the appropriate colour on the pixels. This would allow the drinks management system to have multiple terminals. You can find the documentation for all the box commands here: **hsmag.cc/CLBdoc**.



'magic' card number that triggers a reset of the list. This drink management behaviour has been added to a 'Connected Little Box'.

BOXING CLEVER

Connected Little Boxes is a platform created by the author which can be used to create embedded devices. Boxes can be connected to input such as environmental sensors, buttons, rotary encoders, and passive infra-red (PIR) sensors. Boxes can control output signals, text displays, printers, pixels, and servos. You can find out more about the platform and what it can do in HackSpace magazine issue 41 (**hsmag.cc/Issue41**). The Connected Little Boxes platform runs on ESP8266, ESP32, and Raspberry Pi Pico devices and there is now a server back-end that can be used to manage boxes and send commands to them via Quick Response (QR) codes. You can get started here: **connectedlittleboxes.com**.

A Connected Little Box runs multiple processes and can interact with multiple sensors and outputs simultaneously. It can connect to Wi-Fi and be controlled by simple commands sent over Message Queue Telemetry Transport (MQTT). Internally the box is organised into processor and sensor software

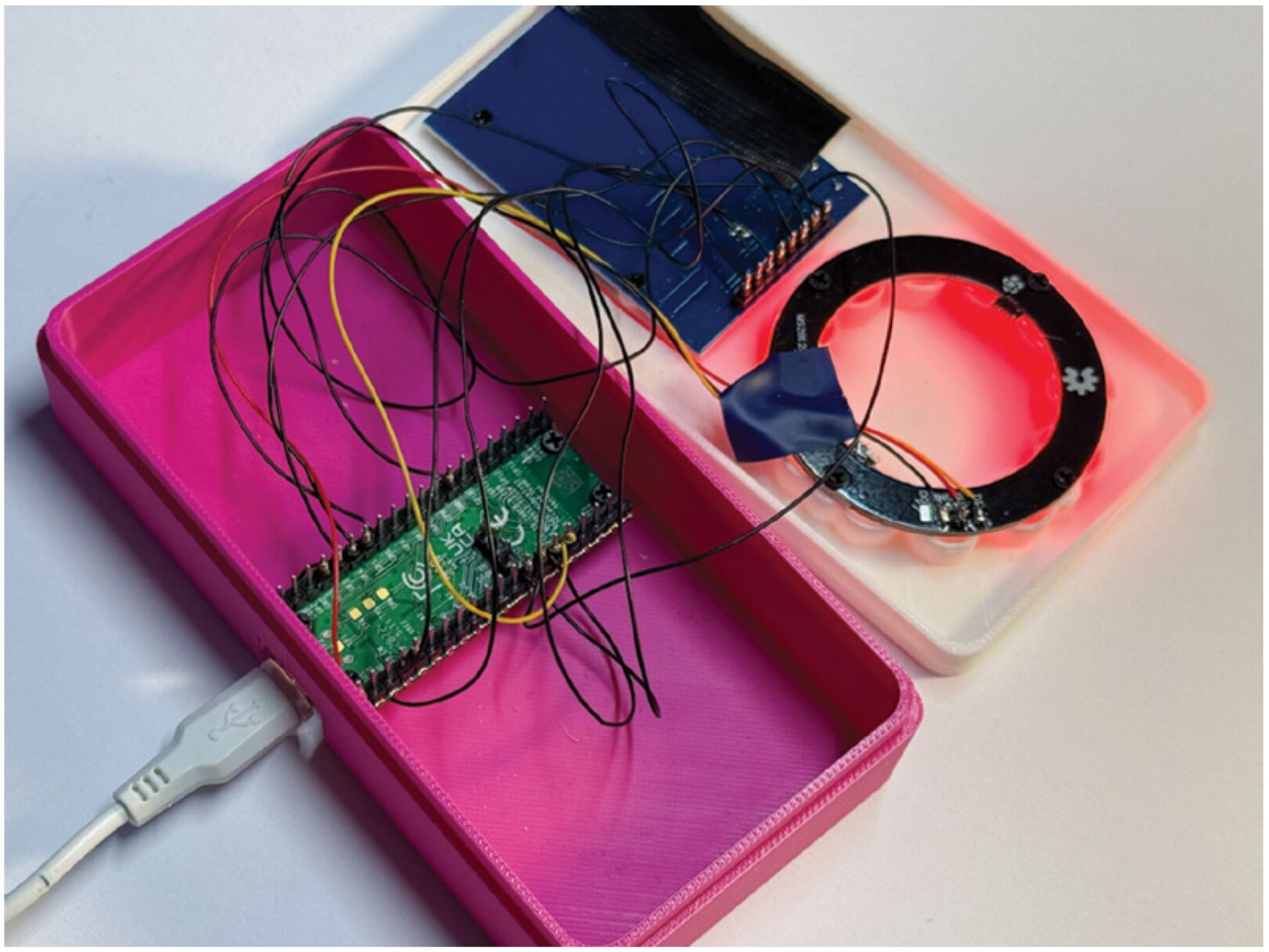


Figure 4
This process runs each time a card is detected

Figure 3
Tape is used to hold the RFID reader in place because the author put the pillars in the wrong place on the initial design. This has been fixed now

objects. For the drinks manager project, the author created an RFID sensor object and then added the drinks manager behaviour to the box. You can turn a box into a drinks manager with a few simple commands that are sent via a serial connection.

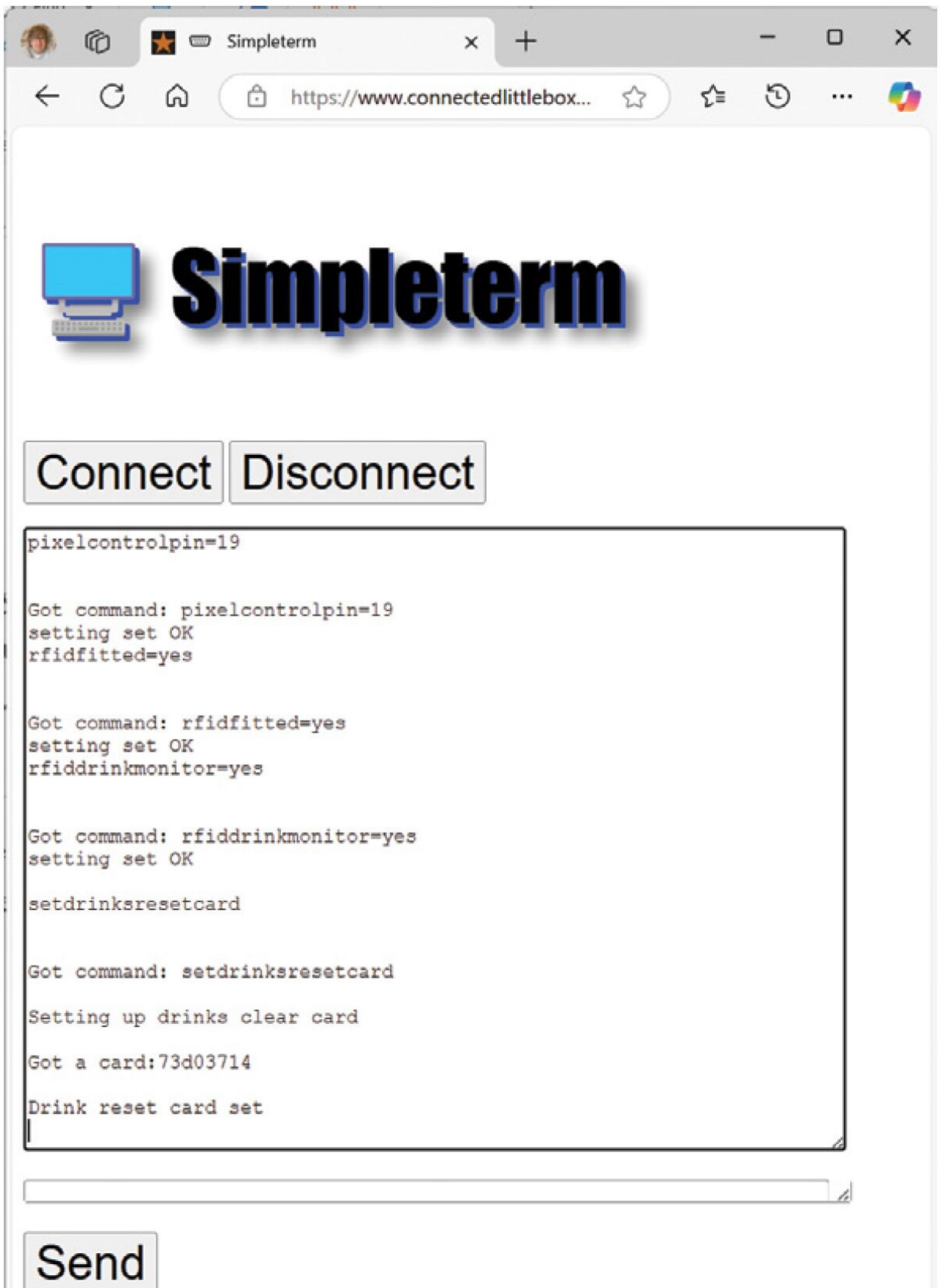
Figure 5 shows a web-based terminal program that you can find at **hsmag.cc/CLBSimpleTerm**. To configure a Connected Little Box, you plug it into your computer, browse to the terminal above, and click Connect. Select your Raspberry Pi Pico device in the dialog that appears and then enter the following commands:

```
pixelcontrolpin=19
rfidfitted=yes
rfiddrinkmonitor=yes
setdrinksresetcard
```

Type each command into the box above the Send button and then click Send. The **setdrinksreset** command sets the card which will reset the drinks. After you have entered this command, the pixel display will turn white. Touch the reader with a card and the display will turn blue. This card can now be used to reset the drinks cards and allow another round of drinks. The card ID is stored inside the drinks manager and will be retained if the power is turned off. If you don't want to use the Simple Terminal website, you can use any serial terminal program to connect to a box. The baud rate is 115200 baud.

CHEERS

The drinks manager worked very well, although a slightly more secure version would be used next time. The hardware also opens the door to more advanced uses of RFID cards such as interactive games and treasure hunts.



BEWARE OF FLIPPER AND FRIENDS

One issue with the drinks manager system is that it is easy to copy and spoof RFID tags using devices like the Flipper Zero (**flipperzero.one**). This popular device contains card reading and writing hardware. It can read the ID of the 'reset drinks' card and then pretend to be that card. A more secure version of the drinks manager would store encrypted data on the card which the flipper would not be able to spoof. However, the security offered by the RFID libraries used by this project is not sufficient for properly secure applications.



Figure 5
The web page works on Chrome and Edge browsers

Left
The Flipper Zero can also generate infra-red signals

PART 01

Custom CNC machine: A carbon filament winder

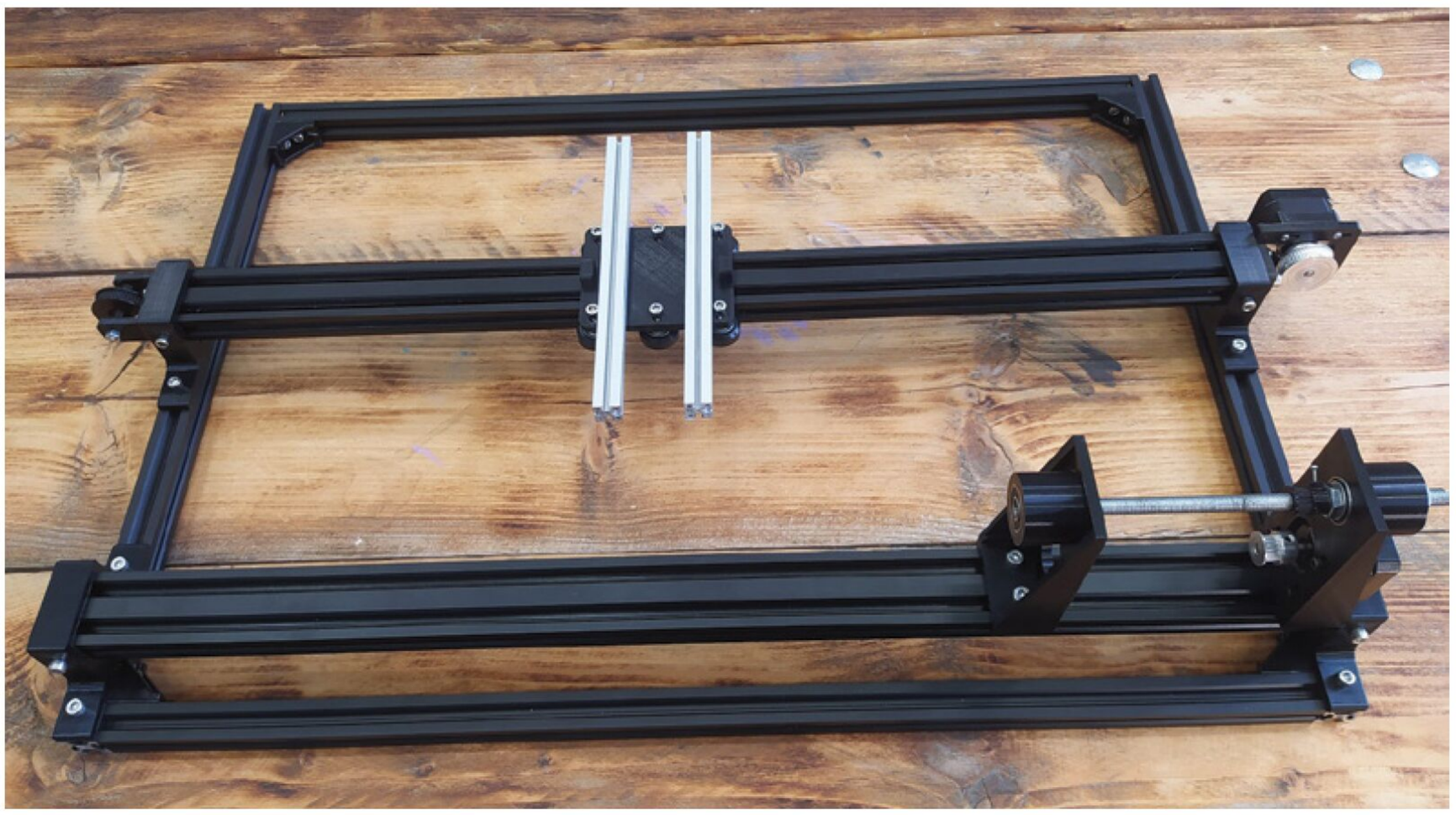
There comes a time in every maker's life where the urge to build a completely custom CNC machine kicks in! Let's explore this increasingly approachable project area, making a prototype carbon fibre filament winding machine



Jo Hinchliffe

@Concretedog

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



Above
The majority of the structural and mechanical parts of our filament winder frame assembled

A **while ago, we published an article about a simple CNC conversion of a small lathe.** In that project, I made some 3D printed adapters and mounted stepper motors to drive the previously manually operated moving sections and looked at creating custom G-codes to drive the machine and create simple parts. Whilst the small CNC lathe had some limitations, it was a simple enough project that developed confidence in custom CNC approaches.

Building on some of the skills developed on that project, I wanted to look at making a completely custom CNC machine. Researching online yields lots of custom CNC projects already undertaken, with a lot of 3D printer and CNC router designs that could make excellent projects. However, I had something different in mind. With my interest in rocketry, I am constantly interested in methods of producing lightweight yet rugged tubes. An increasingly popular choice for higher-end rocket builds is carbon fibre. Carbon-fibre tubes are available to buy, but you are often limited to certain dimensions, and many carbon-fibre tubes are a little overbuilt in terms of rocketry as they are often made for more load-bearing activities.

I'd noticed a few designs for carbon filament winders which utilise CNC approaches to wrap a carbon 'tow' (a collection of carbon fibres fashioned into what appears as a tape) around a rotating cylindrical form referred to as a 'mandrel'. As the tow is wrapped around the mandrel, it is soaked in epoxy resin – the more refined machines pull the tow through a resin bath en route

to the mandrel, while on simpler devices the resin is applied by hand as the wind progresses. The tow is delivered via some kind of head unit that travels along the rotating cylinder under CNC control, with movements co-ordinated to create a crossing pattern building up layers of tow into a solid covered tube.

A LESS RIGID DESIGN

Our CNC lathe conversion was, obviously, built onto a small lathe (**Figure 1**). Lathes are subtractive machines, taking a piece of stock and applying cutting tools to remove material to form your part. This means that they are subject to quite intense forces; so, even when quite small, they need to be rigid, often using large cast metal sections to add weight and rigidity. For more additive machines, we don't need to be quite so rigid, so we can consider lighter materials to form the main sections of our custom machine. Looking to 3D printers for inspiration, you can see lots of examples built up from aluminium extrusions. Aluminium extrusion is an excellent choice for a couple of reasons. One is it's very common and, when you pick a type of extrusion, it is very uniform, which means it's simple to create structures where the individual extrusion sections can be joined easily.

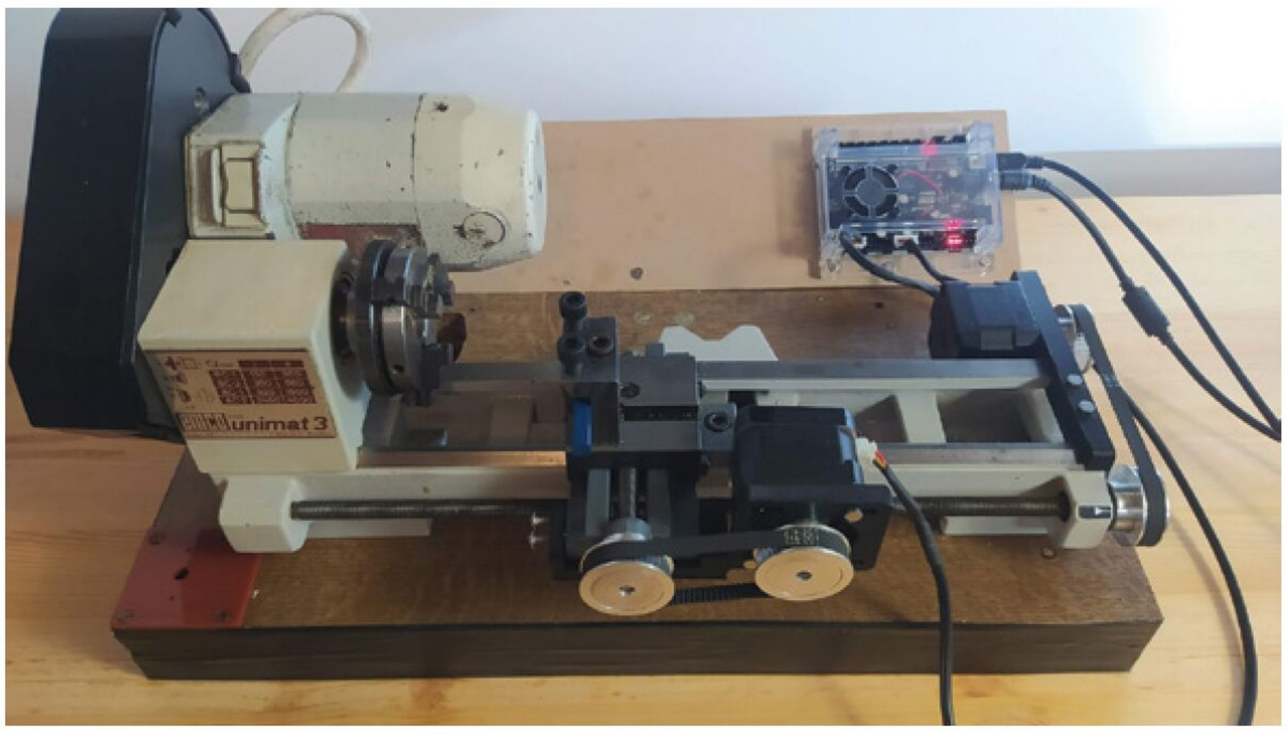


Figure 1
The recent CNC lathe conversion project; the lathe is pretty rigid and heavy, needing to resist cutting forces

> We don't need to be quite so rigid, so we can consider **lighter materials to form the main sections**

Again looking back to our custom CNC lathe conversion, the lathe used lead screws – long lengths of trapezoidal threaded round bars – to create the motion of the various axes. Trapezoidal lead screws are excellent, and are pretty widely available in smaller sections as many 3D printers use them. Another option for motion could be ballscrews, which are again metal screws but which have carriage nuts that contain a clever reciprocating ball bearing system inside that creates incredibly accurate and smooth travel motion. Ballscrews are available, but are a little more costly than trapezoidal lead screws. Both of the above options are great for high accuracy and for reasonably high forces and loading, the latter of which we don't really need for a carbon filament winder.

A third option is to use the aluminium extrusions as part of the motion system as well as the structure. We will need a couple of turning motions in our machine, a

Warning!
Moving parts

Be careful when handling this project because it has moving parts. Children should be supervised.



Figure 2
A basic rectangle made from 2020 aluminium extrusion will serve as the base of our machine

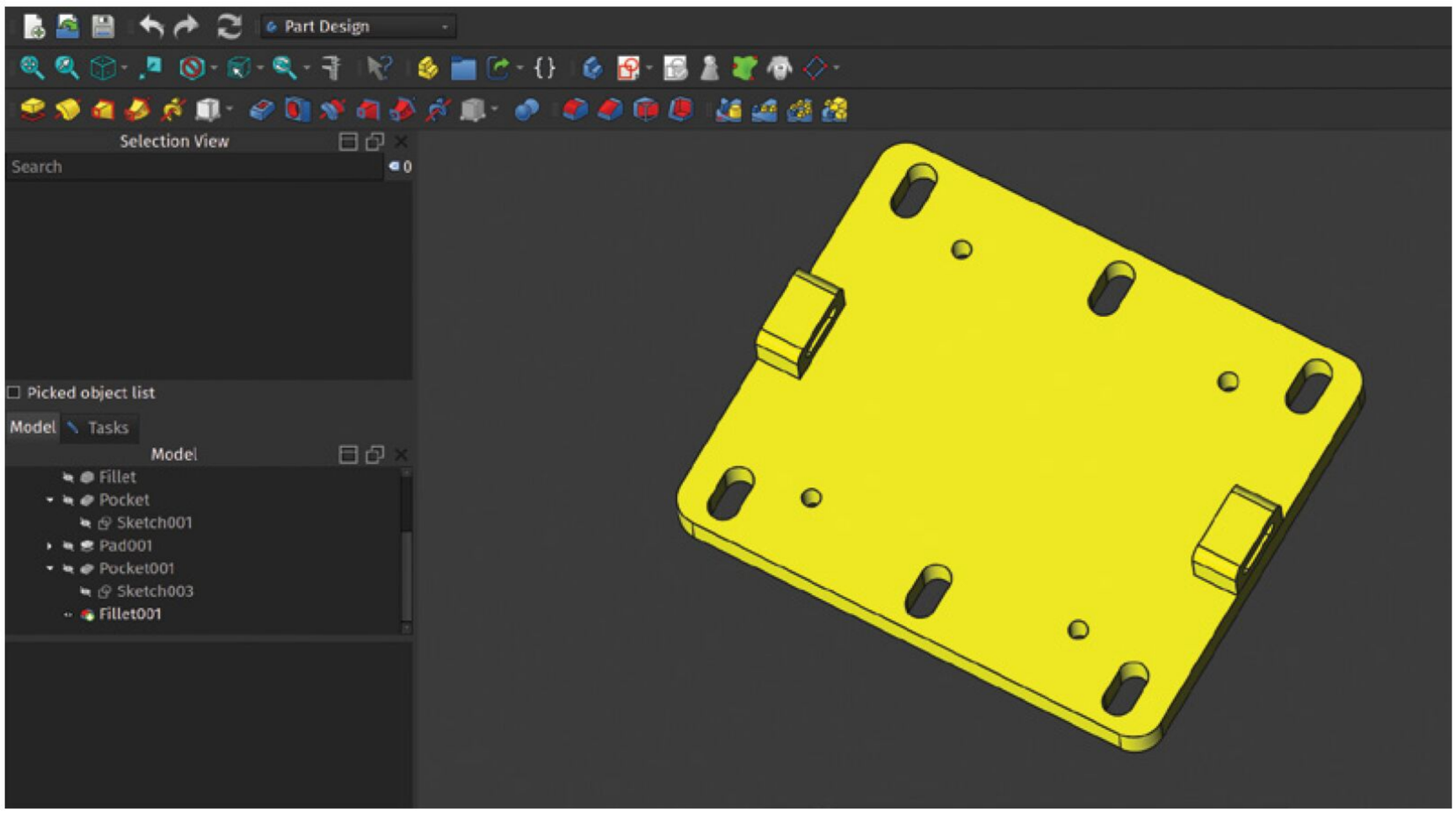


Figure 3
The base of the sliding tool head is a reasonably straightforward job for modelling in FreeCAD

Below
Once mounted, the complete sliding base runs really smoothly along the 4020 extrusion

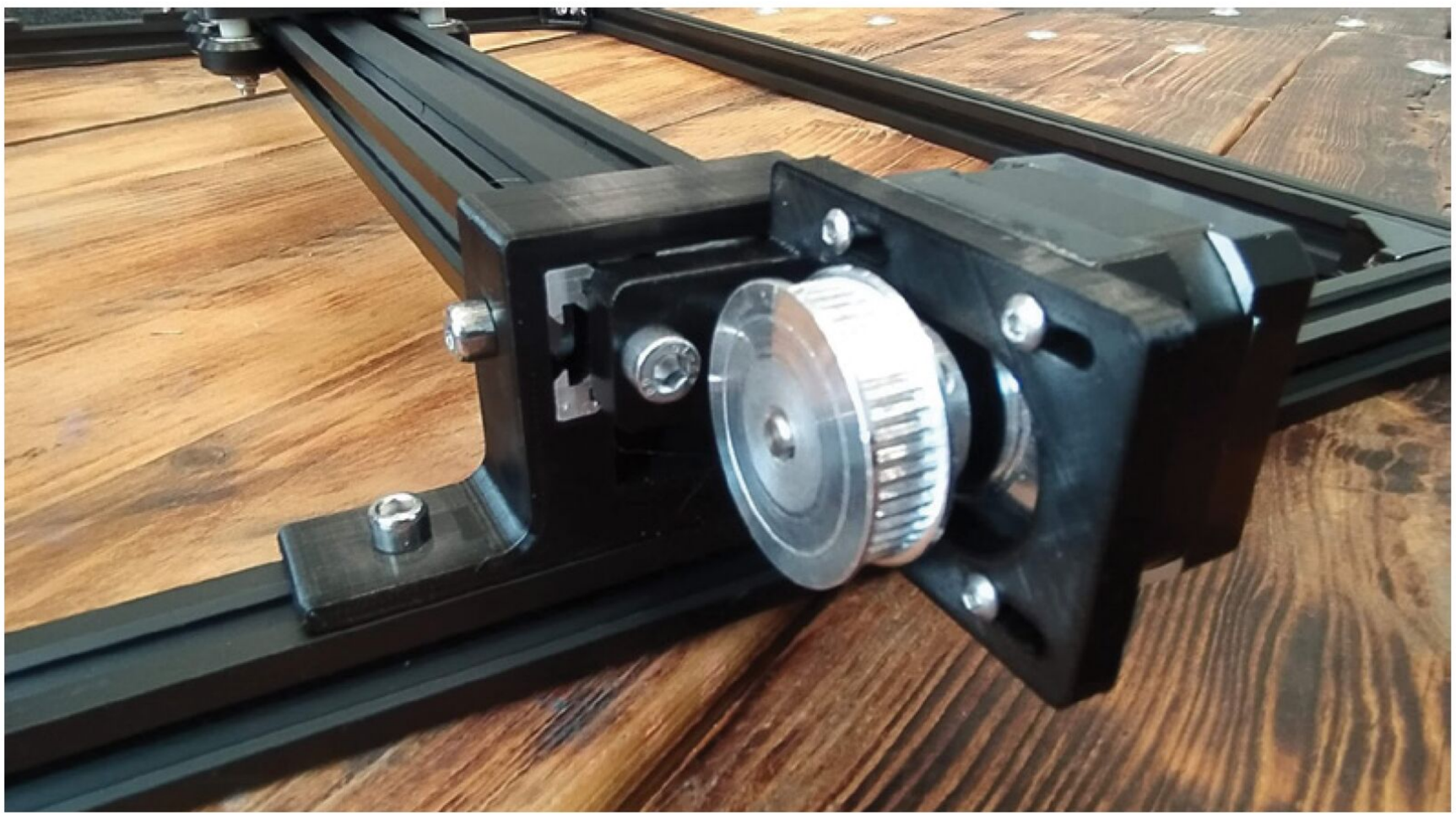
spindle which moves a mandrel, a rotation of the tow feed head, with the largest motion needed being the movement of the sliding tool head along the length of a given project feeding out the tow. The use of aluminium extrusion and V wheels has become pretty common in some 3D printers and in CNC routers; as such, the components to build these type of systems are available for purchase. Finally, to drive the system, connecting the moving parts to Nema 17 stepper motors, we can use belt drives. GT2-type belt systems are again common in 3D printing, so lengths of belts as well as pulleys and gears are readily available.

> To drive the system, connecting the moving parts to **Nema 17 stepper motors, we can use belt drives**



With the decision to use aluminium extrusions, I found I had the makings of a basic frame in 2020 extrusion left over from another project and some 90-degree corner brackets (**Figure 2**). I realised I could make a large rectangular base onto which I could attach the moving sections of the machine. I decided for the long travel axis, a V wheeled sled plate could be 3D printed, but I wanted it to be wider than the 20 mm × 20 mm extrusions I used in the base. There are lots of online suppliers for extrusions and a great option in the UK is Ooznest – which, as well as a range of complete CNC machines, sells a range of extrusions and will accurately cut extrusions to length. After a quick measure-up of my rectangular base, I bought two pieces of 40 mm × 20 mm extrusion cut to the length matching the base pieces I already had.

The plan for the 4020 sections is that they will both mount across the rectangular base. One section will have a headstock and tailstock arrangement with a spindle in between which eventually will hold the mandrel/tube pattern and will rotate it. This means that the headstock and tailstock need some kind of bearing and one of them, the headstock, will need a stepper motor mount to drive the spindle. The other 4020 section will have a sliding block that will be pulled and pushed by a belt drive, allowing it to be moved back and forth along its length. This sliding tool head will eventually have a collection of parts that hold and deploy the carbon fibre tow from a reel and may need to vary the angle at which the tow is delivered to the spindle/mandrel arrangement. For this part one section of the project, I made the sliding base of the tool head and added mounts for some smaller aluminium extrusions to which, in later development, I can mount the carbon tow delivery system.



Left
A simple L bracket with mount slots for the Nema 17 motor will provide the drive system to move the sliding tool head

Starting with a simple job, I fired up FreeCAD and sketched a basic pad with some slotted holes through which I could mount some longer M5 bolts to which I could mount V wheels that can slide along the sides of the 4020 extrusion. Whilst it's totally possible to 3D-print your own V wheels, hard-wearing and accurate V wheels are used a lot in 3D printers and CNC machines, so finding them cheaply available online makes it an easier choice to purchase a bunch. Notice in **Figure 3** that I used slots for the M5 bolts that would eventually hold the V wheels. This means that I can assemble and adjust the tension of each V wheel on the sliding pad and get rid of any play in the system. When it came to mounting the 3D printed sled, I found I would set one side of the V wheels against the side of a slot so they were all aligned and then adjust the other side inwards to create a smooth, play-free, sliding system. Rounding out the sled design, I added some small M3-size holes which I would later use to mount the 15mm by 15mm aluminium extrusions and some small loops on the sides of the pad with an 8mm by 3mm slot which would serve as attachment points for the 6mm-wide GT2 belt which will connect the stepper motor to drive the sliding tool head system back and forth along the 4020 extrusion.

Alongside designing the sliding tool head, I made a quick design for a mounting bracket to mount the 4020 extrusions to the 2020 base extrusions. This is a pretty simple design that works for all four of the mounts. At one point, I considered that I could design mounts for the sliding tool head extrusion which could have the stepper motor mount and the opposite end's idler wheel mount in single designs. However, this means that you end up designing more complex parts and I often find it's easier to design a single part for a single task. The four printed mounts have holes through which I can use short M5 bolts which firmly attach the extrusions by mating with M5 T/V nuts which slide into the slots in the extrusions. It's a very simple and rugged fixing approach that works incredibly well.

Adding to the sliding tool head system, I designed an L bracket in FreeCAD which uses the tapped M5 mount holes in the ends of the 4020 extrusion to clamp on with a section to mount a Nema 17 stepper motor too. On the previous CNC lathe conversion,

TAPPING HOLES

I had to break out some hand tools to tap a thread into the holes in the 4020 extrusions. At the time I ordered the extrusions from Ooznest, I hadn't quite thought out how I was going to mount the stepper motor to the sliding section of the machine. In hindsight, I could have clicked the option to get Ooznest to tap the holes for me. However, using an M5 hand tap and a little oil, it's straightforward to tap the holes. 2020 and 4020 and other members of the 20mm extrusion family all tend to have 4.2mm diameter holes, precisely the size needed to tap to M5 thread.



QUICK TIP

CNC stands for 'computer numerical control'. As such, it can apply to any machine that a computer controls, from CNC milling machines and laser cutters to digital embroidery machines.

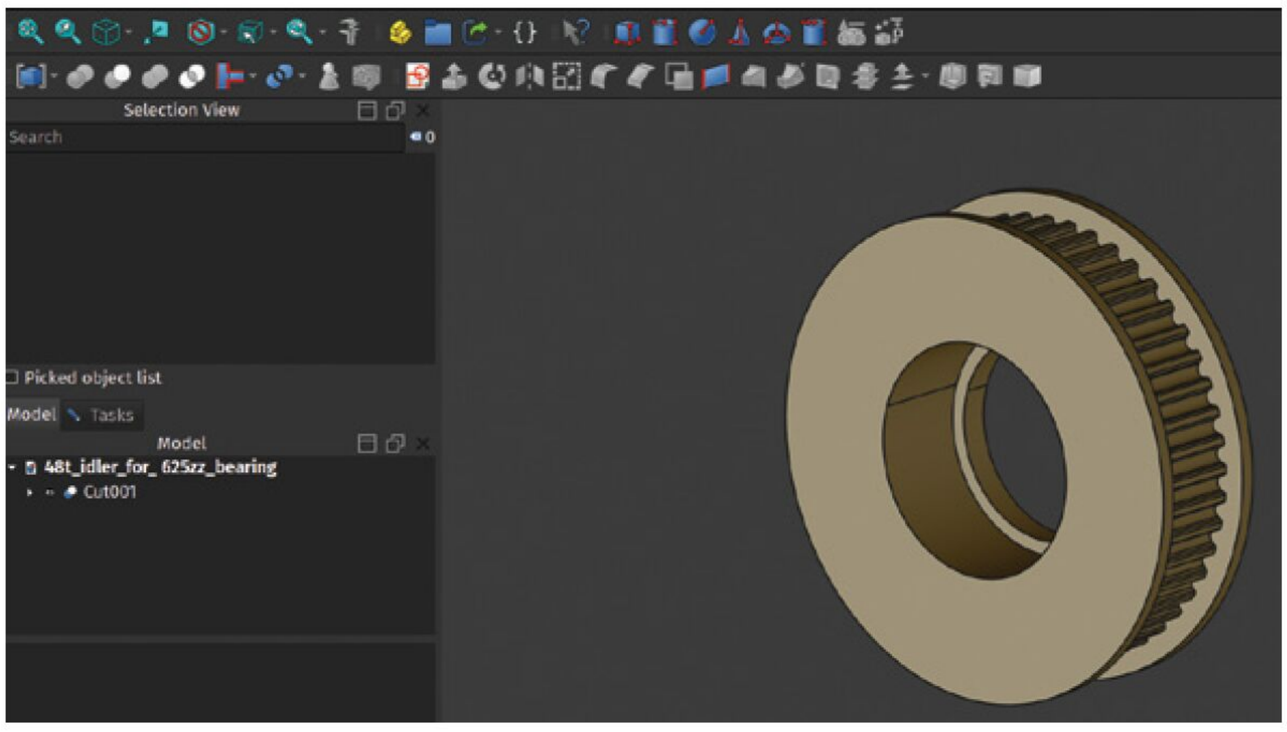


Figure 4
Using the FreeCAD Gear workbench addon makes creating custom GT2 pulleys and gear wheels a breeze

I'd laid out a FreeCAD sketch where I had diligently followed a Nema 17 dimensional drawing to create the slotted mount geometry I wanted. Having done this groundwork, it made lots of sense to go and find that FreeCAD project and copy that part of the sketch into my new part designs in this project. Note that again, like the V wheel mounts on the sliding tool head platform, I used slots to allow the mounted Nema 17 to be adjusted back and forth in the mount. This means that you can adjust the tension and the overall length of the GT2 belt system a little; this pays dividends later in terms of, in the case of the headstock drive, finding a small closed belt option that fits – and for the sliding head extrusion, getting the open belt to a decent tension.

SPECIAL CAPTIVE NUTS

Almost all of this build uses M5 fixings to attach the 3D printed parts to the extrusions and the extrusions to each other. This involves the use of special captive nuts that slide into the slots in the extrusions. There are a couple of things to keep in mind when using this approach. It's important to think about and check the length of any bolts you are using, to avoid the bolt going all the way through the captive nut and then pressing into the back of the extrusion channel. You want the bolt to be long enough to fit through your part and pull the captive nut up into the underside of the slot, but not long enough that the leftover section of bolt pushes into the back of the slot. Also, an amusing one that catches me out more times than I care to admit is that sometimes you arrange extrusions so that when they are assembled, you can't slide in any captive nuts! In the image here, you can see that whilst I can slide nuts into one of the extrusions, the end of the connected extrusion is blocked. Sometimes you need to think ahead, or indeed, undo work to insert them when you realise your mistake.



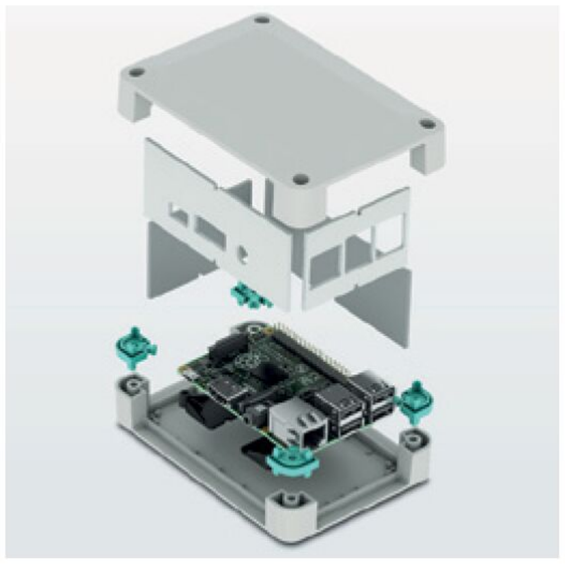
MAKING GEAR WHEELS

Whilst designing the L bracket for the stepper mount, I had identified a 48-tooth wheel (a spare from the CNC lathe project) that I wanted to use as a drive wheel attached to the Nema 17. At the far end of the sliding rail extrusion, I needed some kind of idler wheel for the belt to run around. I could have bought another aluminium GT2 wheel, but it's actually really easy to create GT2 gear wheels in FreeCAD. Using the Addon manager under the Tools menu in FreeCAD, you can install the Gears workbench. In **Figure 4**, I've generated a 48-tooth GT2 timing gear as simply as clicking the timing gear tool icon and then adding the number of teeth I required. I then used the Part workbench to round out the design, adding some guide walls at the edge of the pulley to keep the belt inline and adding an accurately sized hole so I could fit a bearing with a 5 mm internal diameter. This meant that, once printed, I could use a U-shaped mount, an M5 bolt, and a couple of 3D printed spacers to mount the free rotating idler wheel to the opposite end of the slider tool head 4020 extrusion.

Finally for this first part of the build, I designed a part that could act as the headstock and tailstock for holding a spindle and mandrel. The part slots over the 4020 extrusion with a tab on either side, meaning that the part is always parallel on the extrusion. The upper section of the part has a cylinder designed to receive a pair of skateboard wheel bearings which have an 8 mm internal diameter. This can then receive a section of M8 threaded rod to make some form of spindle. I haven't quite fully decided if I want to drive a complete spindle spanning the entire machine, or to have some kind of chuck or work holding system on the driven end and then a small mount in the tailstock to support the other end of the mandrel. The current design of the head/tailstock gives me both options to explore. The piece can be bolted in place using two M5 bolts and this means I could adjust the position of both these pieces. The head/tailstock design has a Nema 17 mount in place and I plan to run a small closed belt up to a GT2 pulley mounted on the spindle to create the rotation.

In the second section of this project, I'll look at designing the tool head system for deploying the carbon tow, finish out the spindle design, and get the machine functional. Then the testing and tinkering with G-code will commence, hopefully leading to some nice winding patterns on a mandrel. As a final thought, it's fantastic that we have the tools to approach projects like these and I urge you, if you have some fabulous machine idea, to get stuck in. Better yet, build it and show us what you've made!





Raspberry Pi finds a new home

Versatile enclosure for Raspberry Pi B+

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

For additional information call 01952 681700 or visit

https://phoe.co/ucs-series

PHOENIX CONTACT
INSPIRING INNOVATIONS

Solar power

Using a solar panel to power a simple Raspberry Pi Pico project



Phil King

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

Warning!
Batteries

Take extra care when using rechargeable lithium batteries. Ensure their polarity is correct when inserting/connecting and always use a suitable power management board to charge them.

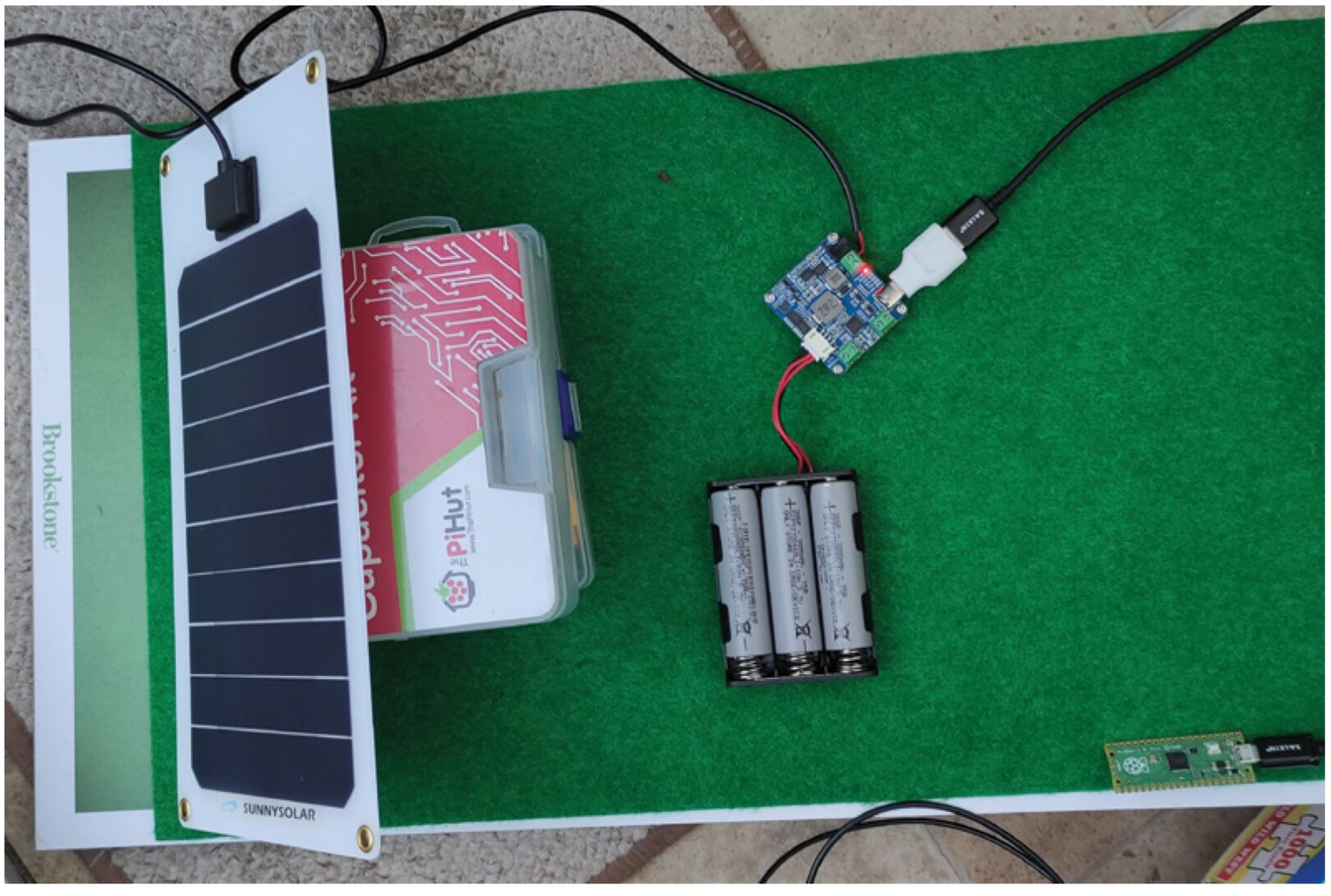
magpi.cc/batterysafety

For an outdoor or remotely located Raspberry Pi single-board computer or Pico project with no mains power available, the obvious solution is to use some sort of rechargeable battery pack, but having to remove the latter periodically for recharging isn't ideal. So why not use the power of the sun to keep the batteries charged and power your project? As well as being convenient, it's free power.

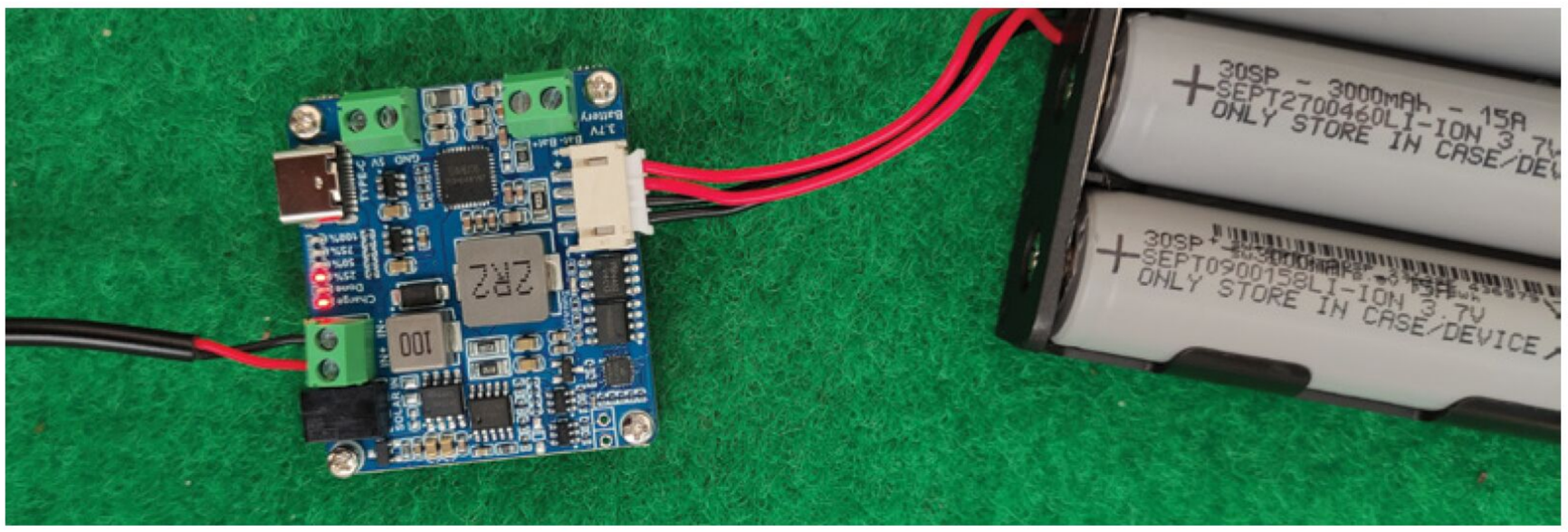
First things first, you can't just point a solar panel at the sun and connect it directly to your project and/or battery pack. For a start it's dangerous: as well as potentially causing the battery to overcharge, which can damage it and reduce its life span, there's the chance it could even cause the battery to explode. So don't do it! Instead, you should always use an appropriately rated power management board to take the output from the panel and regulate/convert it for a connected battery pack and any devices connected to the outputs.

A WINTER'S TALE

With this in mind, we thought we'd try powering a Raspberry Pi Pico with a small solar panel, battery pack, and power management board. Considering we were starting this (not very scientific) experiment in the bleak mid-winter in the UK, it would really be a test of whether we could supply enough power to keep it running. Not only would the panel receive a mere eight hours or so of daylight per day, but the light is weaker in winter, with the sun arcing very low in the sky, which may also result in shadows from trees and other objects.



Right
Our solar setup. The solar panel is connected to a power management board that charges a battery pack and supplies power to a connected Pico



Left
We used a Waveshare Solar Power Manager Module, but other power management boards are available

We sourced a small DFRobot Semi-Flexible Monocrystalline Solar Panel with an operating voltage of 5V and maximum current output 1A (i.e. 5W maximum power). You could opt for a larger panel for increased output for your project, if needed, or use more than one small panel arranged in series. For the all-important power management, we opted for a Waveshare Solar Power Manager Module with a wide voltage input range of 6V to 24V. In hindsight, this was slightly above our panel's 5V actual output (though matching its 6V open-circuit voltage, a different spec), but it seemed to work fine in practice. The board is supplied with a plug-in 3× 18650 Li-ion battery holder, though you need to source the batteries for it – each of ours had a 3000mAh capacity, so 9000mAh in total.

Before connecting everything up, we thought we'd check the output from the panel. With it facing roughly south toward the sun, we connected the two (positive and ground) wires of its output to a red LED (with resistor) and the latter lit up. Note that the optimum panel orientation and tilt angle depends on your location and the season – see the 'Optimum angle' boxout for details. You could mount your panel on some sort of easily tiltable surface; we just propped ours up with a couple of components boxes.

We then hooked the wired up to the battery terminal inputs on the Solar Power Manager Module, inserted the three 18650 batteries into the holder, and connected the latter's plug to the relevant output on the board. We could then see that the panel was charging the batteries, as indicated by the 'Charging' LED on the board and another one flashing for '25%' – showing that the battery level was somewhere between 0 and 25%.

With protection circuitry to prevent overcharging, overheating etc., and a couple of ICs to manage input and outputs and automatically convert voltage, the board handles such charging safely and efficiently. In addition, it can simultaneously power a device from its 5V 3A screw terminal output. It also has another screw terminal output for a 3.7V Li-Po battery if you prefer a more slimline battery pack.

For an approximation of the time to fully charge your batteries, you can use the following formula:

Charge time (hours) = Battery capacity (mAh) ÷ Charge current (mA)

QUICK TIP

To connect two solar panels in series, connect the positive wire from the first to the power management board, then its ground wire to the positive wire of the second panel, whose ground wire is connected to the board.

ON REFLECTION

If you are using a solar panel indoors, place it close to a window to get as much light as possible. Even then, some efficiency will be lost due to some of the light being reflected by the glass.

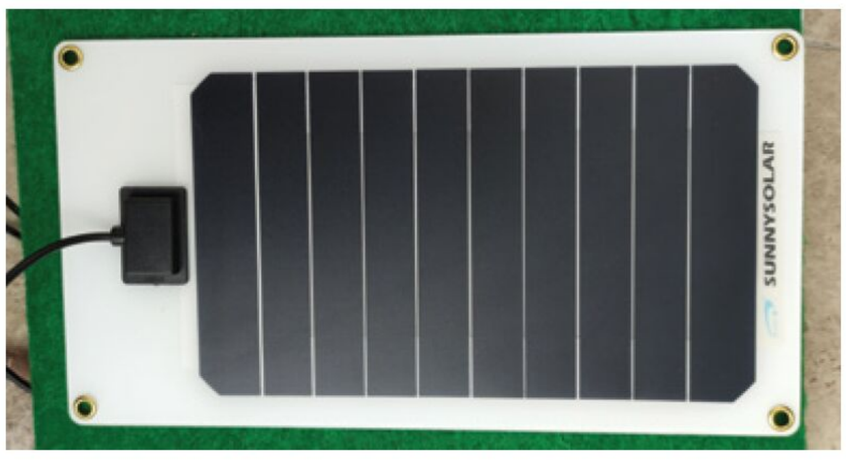
Ideally, you should place your panel outdoors to get maximum performance. Note that it doesn't need to be direct sunlight to work, but on a cloudy day it won't produce so much power. While the panel itself should be waterproof, any electronics – including the power management board and Raspberry Pi Pico or other device you're powering – need to be placed in a weather-proof enclosure.



YOU'LL NEED

- **Solar panel, e.g. Semi-Flexible Monocrystalline Solar Panel (6V 1A),** hsmag.cc/DFRSolarPanel
- **Power management board, e.g. Waveshare Solar Power Manager Module (D),** hsmag.cc/WSSolarManager
- **Rechargeable 18650 batteries and holder, or 3.7V Li-Po battery**
- **Jumper wires**
- **Raspberry Pi Pico or Zero (to power)**

Below
This DFRobot solar panel has a semi-flexible design and can produce up to 1W of power





Right
On a winter's day in the UK, the sun travels a low arc in the sky. Obstructions such as trees don't help

Note that the actual time required may be a little longer, however, due to the charger module and batteries not being 100% efficient.

POWERING PICO

We thought we'd let our 18650 batteries charge up a bit before attempting to power a Raspberry Pi Pico, so we left the system running for a day. As expected, when the light level fell towards dusk, the charging LEDs on the board turned off. The following day, we added a Raspberry Pi Pico (original non-wireless model) by connecting positive and ground wires from the 5V output screw terminal to Pico's VSYS and GND pins respectively. To check it was powering up, we first saved a simply blinking LED MicroPython program on it as **main.py** (to autorun):

```
from machine import Pin, Timer
led = Pin(25, Pin.OUT)
timer = Timer()

def blink(timer):
    led.toggle()

timer.init(freq=2.5, mode=Timer.PERIODIC,
callback=blink)
```

To see how long it would continue running, we created another MicroPython program to take readings from Pico's built-in temperature sensor at regular intervals of 30 minutes and log them in a text file, complete with a timestamp from Pico's real-time clock:

```
import machine
from time import sleep

sensor_temp = machine.ADC(machine.ADC.CORE_TEMP)
conversion_factor = 3.3 / (65535)
rtc = machine.RTC()
#Set RTC to start time
rtc.datetime((2025, 1, 2, 4, 14, 0, 0, 0))
file = open("temps.txt", "a")

while True:
    timestamp=rtc.datetime()
    timestring="%04d-%02d-%02d
%02d:%02d:%02d"%(timestamp[0:3] + timestamp[4:7])
    reading = sensor_temp.read_u16() * conversion_
factor
    temperature = 27 - (reading - 0.706)/0.001721
    file.write(str(timestring) + " " +
str(temperature)  + "\n")
    #Sleep for 30 mins
    sleep(1800)
```

For the delay between readings, we ended up using the standard **sleep** function from the **time** module. We did try using MicroPython's **machine.lightsleep** function to try to save extra power, but found that we then couldn't get the Pico to connect to the Thonny

OPTIMUM ANGLE

The optimum tilt angle (from horizontal) for your solar panel will depend on two things: your location's distance from the equator and the current season. Whether in the Northern or Southern Hemisphere – with the panel oriented due south or north, respectively – the ideal angle be larger in the winter than in summer. As a rough guide, the angle should equal your location's latitude in spring and autumn. In summer, you should subtract 15 degrees from that number; in winter, add 15 degrees to it. For instance, at the author's latitude of 35.8° on the south coast of the UK, the angle would be 35.8° in spring and autumn, 20.8° in summer, and 50.8° in winter. At the equator, the ideal tilt will be around 0°.

You can fine-tune it further for each month if you want. To calculate the exact angles, enter your location or postcode in the Footprint Hero tilt angle calculator: **hsmag.cc/PanelTiltCalculator**. While you're at it, check out the azimuth angle calculator link there to get the precise compass angle to point your panel true north or south – ours was 0.3° east of magnetic south.



IDE on our computer later, to check the readings in the file, and ended up having to flash a 'nuke' UF2 file to get it working again. You may be able to find a way round this, or use CircuitPython or C/C++ for a similar test program. In C/C++, you could even make use of Pico's dormant mode between readings, using an external trigger to wake the board.

IN CONCLUSION

We saved our MicroPython program on the Pico as **main.py** so it would run automatically on power-up when connected to the Solar Power Manager Module. After a day, our Raspberry Pi Pico was still running, and had been doing so continuously (as confirmed by checking the temperature reading log file on a computer). The battery charge level shown on the Solar Power Manager Module was still 0–25%, so it was impossible to see whether it was increasing or decreasing slightly. Given that this was in the depths of winter, however, the result was promising. In addition, we had our solar panel positioned indoors, which isn't ideal for efficiency – see 'On reflection' boxout.

Of course, the original Pico model has a relatively low power drain, typically around 20 mA. Ours was also operating as a bare board, with nothing else connected. If you were to add an external sensor or other components, that would require a little more juice. Assuming a power drain of 20 mA, the Pico would require a total of 480 mAh per day; so, with eight hours of daylight, the solar panel's output current would need to average 60 mA to keep Pico running continuously. Note that this doesn't take into account the power required by the power management board, although it's likely to be low (ours was less than 30 mA).

As for other models, a Raspberry Pico W with Wi-Fi working typically uses 45 mA. A Raspberry Pi Zero W uses considerably more power, typically 150 mA (while a Pi Zero 2 W uses 350 mA), so you might well need a larger solar panel, or regular battery recharging top-ups from another source, to keep it going through winter. If you are lucky enough to live in the tropics, the difference between summer and winter will obviously be a lot less, so you'll have far more reliable daylight levels throughout the year, although very high temperatures can reduce efficiency of solar panels – which is why some solar farms have cooling systems.

Wherever you are, if you plan on powering your Raspberry Pi project with a solar panel, may the sun shine on your endeavours.

HOW SOLAR POWER WORKS

A solar panel contains special photovoltaic cells, featuring two types of semiconductor (usually silicon) that can convert light into electrical energy. Each time a photon of light hits the cell, it causes an electron to be released. Multiple released electrons result in an electrical current that is captured by circuitry in the panel. That's it in a nutshell; for a detailed scientific explainer, see **hsmag.cc/HowSolarWorks**.

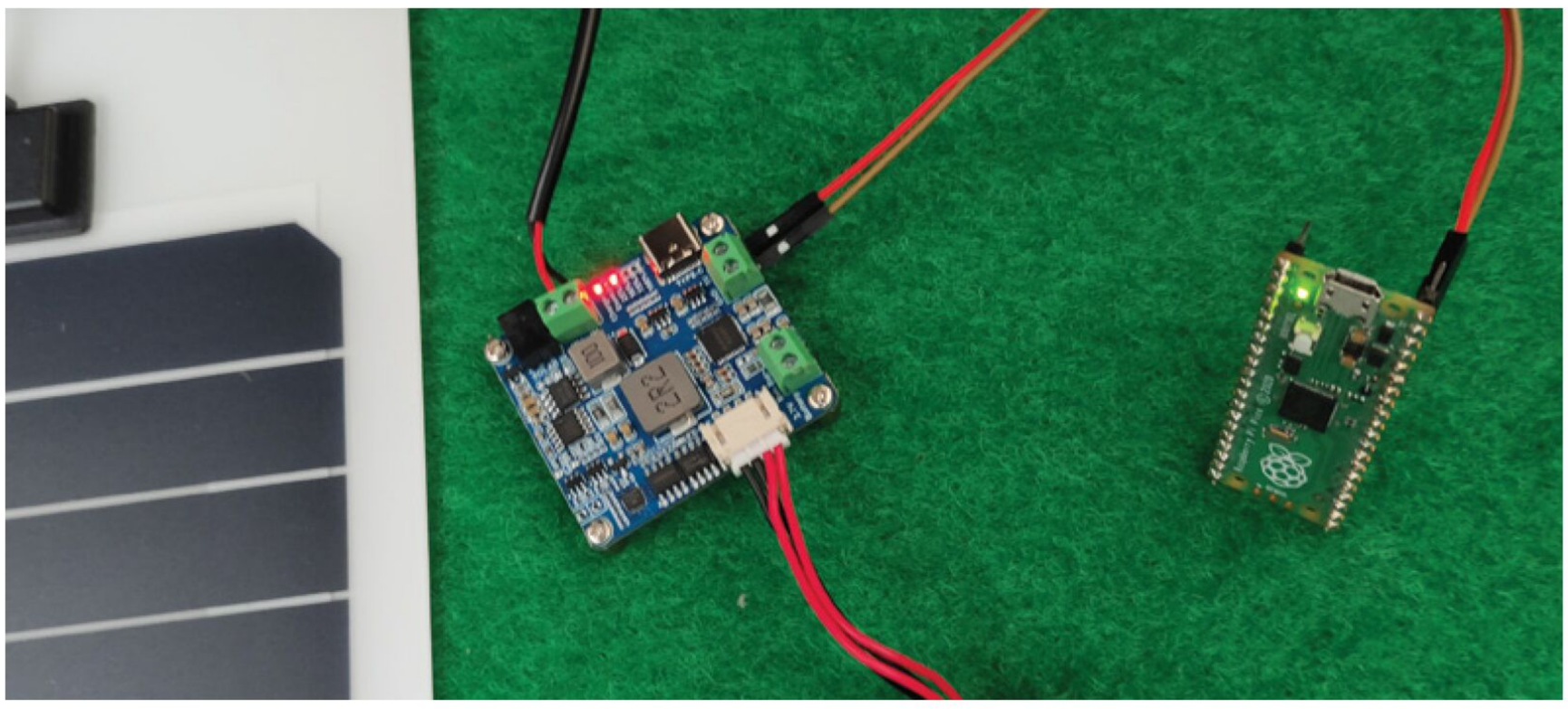
QUICK TIP

Some microcontroller boards, such as the RP2350-based Perpetuo LoRa (**hsmag.cc/PerpetuoLoRa**), have a handy built-in solar battery charging capability.

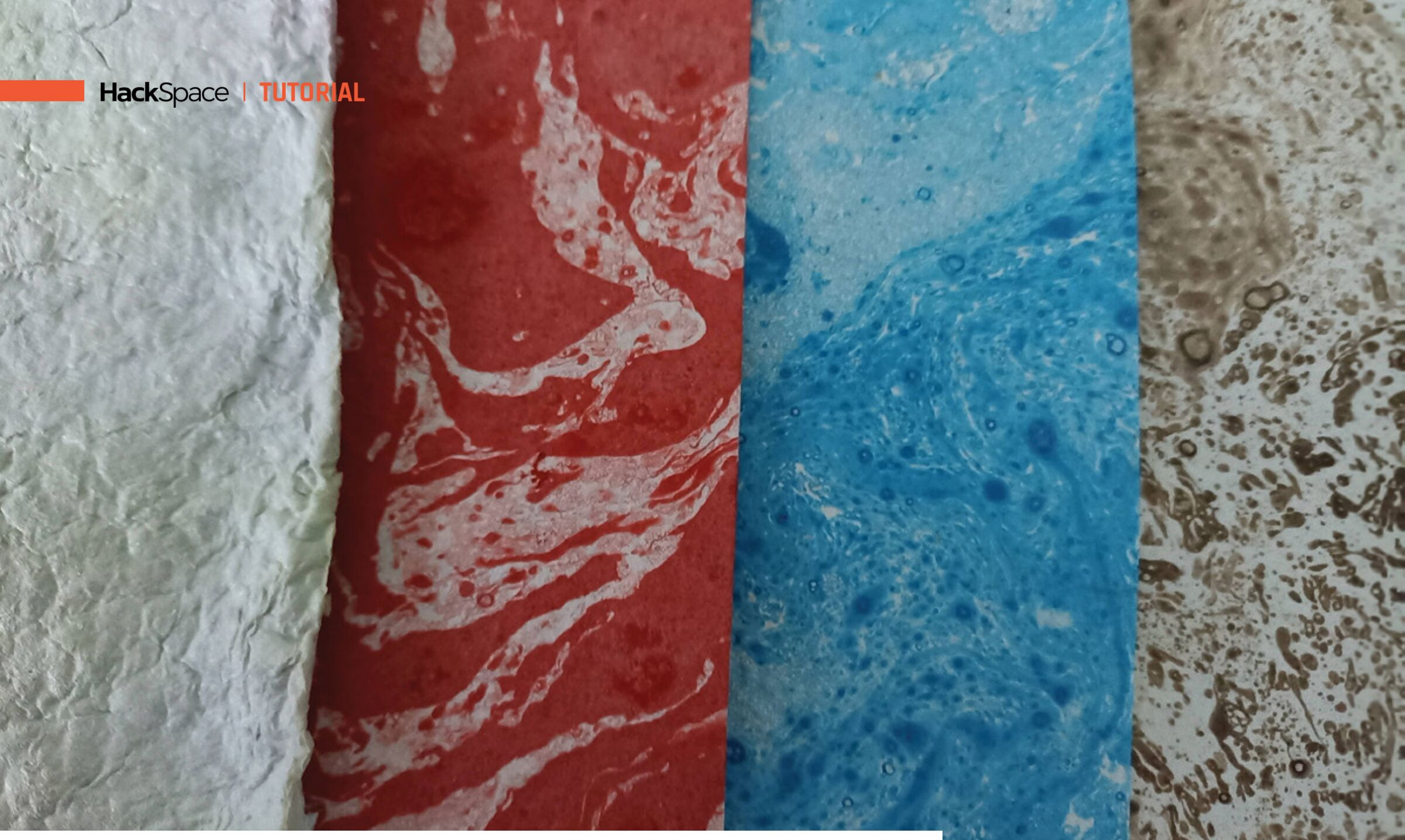
SOLAR PROJECTS

Solar power can be used to supply all sorts of projects. Some interesting ones we've seen include:

- Solar Water Bottle – **hsmag.cc/Issue81**
- PikoQube – **hsmag.cc/Issue71**
- Power Tool Charger – **hsmag.cc/Issue68**
- Solar-powered Robot – **hsmag.cc/Issue57**
- Solar-powered Camera – **magpi.cc/92**
- Aquatic Mini Observation System – **magpi.cc/89**
- Ecosystem Monitor – **magpi.cc/76**
- Nemo-Pi – **magpi.cc/72**



Left
A simple blinking LED program confirms that our Raspberry Pi Pico is powering up



Handmade paper

A worthy hobby for those who never, truly, want to go paperless



Nicola King

@holtonhandmade

Nicola King is a freelance writer and sub-editor. Before she put pen to paper this month… she made some!

Paper is one of those things that we often take for granted, without really thinking too much about how it's made, its lengthy history, the fabulous varieties available, not to mention the plethora of things that can be made from this wonderfully versatile product.

While our everyday paper needs are usually catered for by the large paper companies, don't underestimate how important handmade papers still are to artists and craftspeople around the world. There is always, arguably, a place for traditional craftsmanship and you can put your own handmade papers to good use in a multitude of ways, including making homemade cards or journals, covering boxes or lap trays, making lampshades, picture frames, and other ornamental items, or even doing some simple bookbinding to make your very own paper books. So, we gathered together some basic 'ingredients' to see what we could create using some seasoned and popular paper-forming techniques.

PULP PRODUCTION

As we're new to this craft, we thought it best to start our papermaking journey by making paper with paper, i.e. using old/recycled papers in order to make something completely new. The bonus of this method is, of course, that we are recycling and not just tossing away our paper detritus, and that's always something we like to encourage. We used a mixture of old printer paper, some old envelopes, junk mail, and some old newspaper for our first mix – basically, whatever paper you are going to throw in the recycling bin would be suitable for this paper making process. A couple of caveats, though: do make sure there are no pieces of fabric, strings, or plastic in the mix, and be certain that any staples or sticky tape pieces are removed.

We utilised an old washing-up bowl for the process which was just the right size, but you could use a large cooking pot or even an old large foil roasting tin. The first thing you need to do is break up papers you're using, by hand, into roughly pieces around 3 cm by 3 cm. Then, cover the paper scraps with



Left
Here is the liquidised pulp ready for the mould and deckle. A large rectangular bowl or roasting tray will work really well for this – just make sure your mould and deckle fits easily within it with some room to spare. Don't be put off by the look of this, and remember that the colour is determined by what you have used to make your pulp

enough water so that it's fully saturated, and let the whole mixture soak overnight so that the papers become really soft and fragile.

The next day, take your bowl and use a liquidiser or stick whisk/electric whisk (we used an old electric whisk, which worked perfectly) and start pulping the paper in slow bursts. Now, this stage can be messy and we'd highly recommend that you wear an apron or something to cover your clothing while you are liquidising the paper pieces or you may find yourself splattered by tiny paper pieces. That said, we found we were covered in tiny pieces even though we took precautions!

> "Let the whole mixture soak overnight so that the **papers become really soft and fragile**"

The longer the paper has been soaking before you start pulverising it, the easier this whole process is, and your 'slurry' of paper will soon take shape after five minutes or so. You really want the mixture to resemble porridge/oatmeal in terms of consistency, so keep going until you have a fairly unattractive bowl of thick gloop in front of you. If any of the paper pieces don't break down, then remove them, as they may contain plastics that we don't want in our new papers. Our final pulpy mixture was a very off-white/grey colour, as a result of the colour of the papers we'd used in the first place.

THE PAPER TRAIL

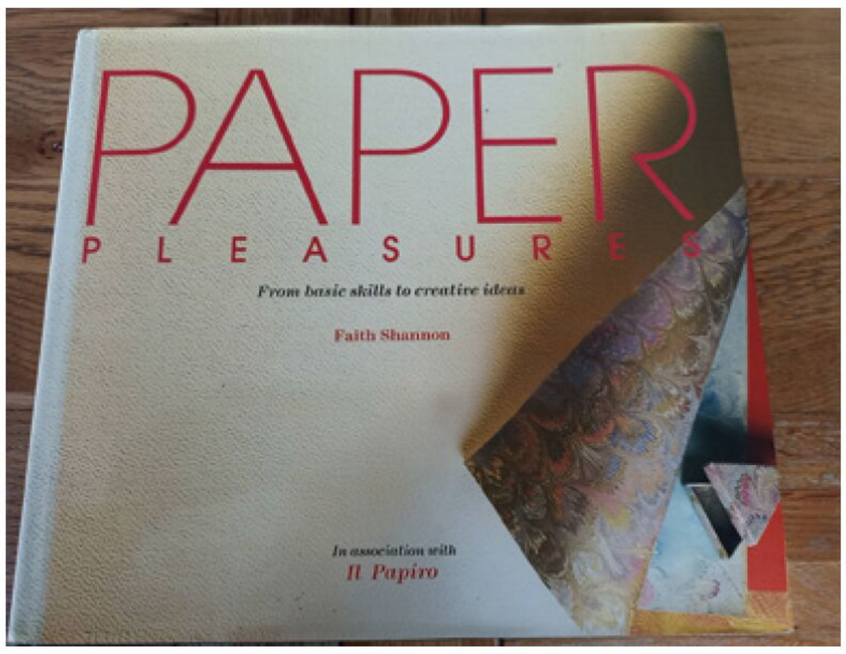
Many of us will have learnt about papyrus at primary school, a somewhat thicker 'relation' of modern paper that was used in ancient times by the Egyptians, amongst others, around 3000 BCE. It was made from the grass-like papyrus plant, and was also utilised by the ancient Greeks and by the Romans. This form of 'paper' was made by splitting the tall, thick papyrus stalk into small fibres and then, after some lengthy soaking, pressing them back together. It can be argued that it was really a precursor to today's paper, and is worth mentioning in this very quick look back at how paper came into existence.

However, it is generally recognised that paper, as we know it today, first originated in China in around 105 CE. Around 2000 years ago, a form of paper was crafted and was reported to the Chinese Emperor of the time by a court official/dignitary named Cai Lun. Now, whether this individual was actually the person who invented paper is not absolutely clear, but whoever was responsible for the initial invention, it's likely that these first handmade papers were made of a very literal mishmash of old rags, tree barks, other plant materials, and even perhaps parts of old fishing nets.

By around the 6th century, Japan joined the handmade paper chase and began to create a pulp made from mulberry bark to make their own version. The Arab world followed, but it wasn't until around the 11th century that Europe finally jumped on the paper bandwagon. One European town that played an important role in the development of paper was Fabriano in the Italian region of Marche, where papermakers used cotton fibres in the 12th and 13th centuries to make paper, and where they also initiated use of gelatine to act as a paper adhesive. Interestingly, Fabriano is also where they invented a form of 'watermarking' with translucent designs to certify the uniqueness, quality, and authenticity of their papers.

What's important to remember is that the history of paper is linked inextricably to cultural and scientific advancements – fundamentally, it has played a crucial role in the development of education, allowing knowledge to be recorded and spread. In order to mass-communicate on a huge scale, the industrial manufacture of paper in the 19th century meant that books and newspapers could be accessible to so many more people, with literacy levels exploding. Paper is, arguably, one of the most significant inventions in history.

We've just papered over the cracks here, as this is a huge subject area, so take some time to read more about paper's history, for it is an invention that has literally helped to shape this world of ours. In particular, this book is worth searching out and appreciating: *Paper: Paging Through History* by Mark Kurlansky.



Right
You can't go wrong with an instructive book on any crafty subject, and this one, *Paper Pleasures* by Faith Shannon, spans the gamut from making your own pulp to making books, gift bags, and even jewellery from your own handmade paper. This is just one author who is trying hard to keep the traditional craft of papermaking accessible, passing on simplified versions of traditional skills

YOU'LL NEED

- **A mould and deckle**
- **A leakproof container that is *larger* than your mould and deckle** (e.g. a washing-up bowl)
- **A blender/liquidiser** (ideally, an old one that you can just use for craft projects)
- **A sponge**
- **Scrap paper** (e.g. old newspapers, books, envelopes, printer paper)
- **Something to add colour/texture** (e.g. dried flowers, grains etc.)
- **Plastic covering/towels for your work area**
- **An old towel/curtain to dry the paper on**
- **Acrylic paint/spray paint to colour the paper** (optional)
- **Seeds/grains/lavender/dried flowers etc. to decorate** (optional)
- **An apron/protective clothing!**

PAPER PROTAGONISTS

Around the world, from large companies to individual paper artists, here are a few of the players and creators who are a lot more than just paper pushers:

- In terms of the main paper and pulp producing countries of the world, or 'paper(heavy)weights' if you will, the table is topped by China, closely followed by the US. Given that it is generally recognised that the paper that we know today was 'invented' originally in China, it's no surprise that China still remains a prolific paper producer. Japan also continues to produce a great deal of paper, and has its own rich and deep-rooted papermaking history. In Europe, Germany leads the way in the making of board and paper.
- International Paper is a US-based pulp and paper company and a world-leading producer of fibre-based products. It is also the largest firm of its type in the world, and has its headquarters in Memphis, Tennessee. The company developed as a result of the merger of a number of pulp and paper mills in the northeast of the United States in 1898, so the organisation has an impressive 125 years' worth of knowledge, expertise, and experience in the paper and pulp field.
- On an individual level, there are a number of hugely talented people who make a living out of transforming paper into something quite magical. These include Helen Musselwhite (**helenmusselwhite.com**), a UK paper-cut artist with an "affinity with paper", much of whose work is inspired by the British countryside. Her layered creations are stunning, with colour, design, and texture being key to each work of art. Another paper artist is Calvin Nicholls (**calvinnicholls.com/studio**), a Canadian creator who essentially 'sculpts' paper, often into wildlife sculptures. Take a look at the website link, as the fur and feathers details are truly exquisite and, unsurprisingly, very time-consuming to produce.

A CLEAN SHEET

Now, before we can make a paper sheet, we might need to add some more water to the concoction, just to 'thin' the mixture a little. How much water you add comes down to practice and seeing what you prefer in terms of the thickness of paper that you'd like to produce. That done, you now need to grab your mould and deckle, which is the key piece of equipment in our papermaking process. You can see from the image of the mould and deckle that it is a very simple frame, one side of which has a mesh pulled over it. You can very easily hack your own version of a mould and deckle if you wish, but these items are also very cheap to purchase online.

Submerge the mould and deckle into the mixture and then lift, leaving it to drain. If you have any patches where the pulp is thinner or has not covered the mould thickly enough, dip it back in and make sure you are happy that the mesh is covered adequately. Once you are content with the thickness of your work, remove the mould and deckle from the water, drain over the bowl to get most of the water out of your pulp, and then flip the whole thing over onto a dry towel, so that the new paper sheet is face down on the towel – perhaps do this task outside if the weather allows, as it will avoid making a mess inside and the sun will help dry the pulp.

...AND RELEASE

We really need to remove as much water as possible before we remove the mould so that the paper dries much faster, so grab a sponge or an old tea-towel

Below
This is the very inexpensive mould and deckle that we purchased online in order to aid our papermaking project (hsmag.cc/MouldDeckle). It's basically just two very simple rectangular frames with mesh stretched over one side – a home-hacked version should be made of a wood that won't rot or warp too much (e.g. mahogany) and possibly some curtain netting or silkscreen mesh



and move it very gently over the paper to pick up the excess moisture. Once it feels as though a lot of the water has been absorbed by the sponge, release the paper sheet from the mould and, fingers crossed, you should have a complete sheet of slightly soggy paper in front of you. Leave it alone for at least 24 hours and you should be able to peel it off the towel. Turn it over in case the other side is not quite dry, and leave again for another 24 hours.

You will, after some practice, get to learn how thick you like your paper sheets to be, and you can try all sorts of things to add texture and colour to your work, as we detail in the 'Variations on a theme' boxout. For example, we have some dried lavender that we will be adding to our next batch, which should give a very pretty effect.

So, recycle some of that old paper that you are looking to throw away – you could even try using shredded paper from your paper shredder, as you won't need to pulp it for so long – and see what you can create. You may even progress to adding plant materials to your recycled paper pulp – for example, leeks or rhubarb can be boiled until the stalks break down into strands and you can add these to pulp once the excess moisture has been removed for some added interest.

Below
Once you've turned the paper sheet onto a towel, press down with a sponge to remove the excess moisture still within the pulp. This process will also help the pulp filaments meld together – as it dries, the fibres will literally knit together

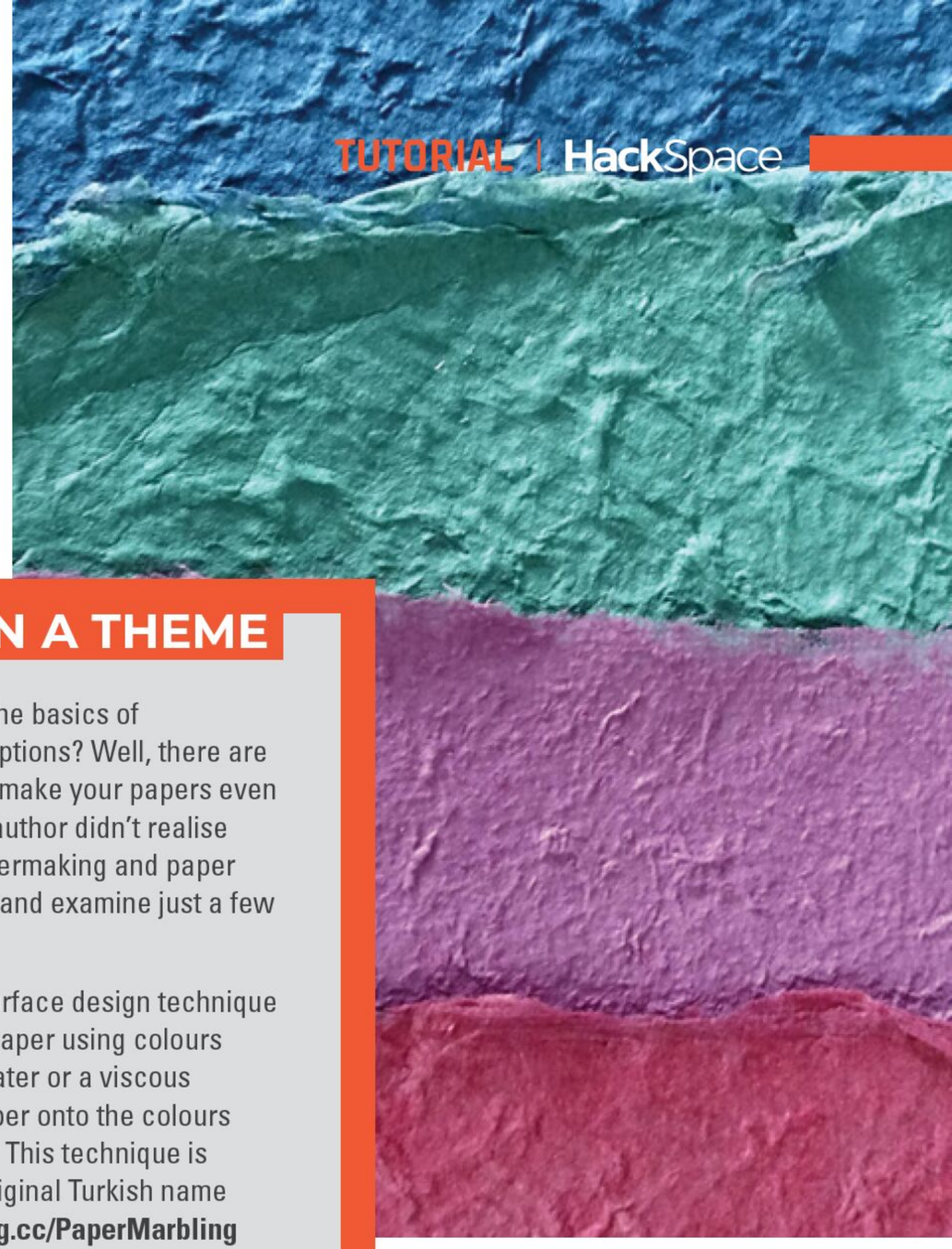


VARIATIONS **ON A THEME**

So, once you have mastered the basics of papermaking, what are your options? Well, there are plenty of things you can do to make your papers even more interesting. In fact, this author didn't realise what a huge subject area papermaking and paper decorating is, so let's delve in and examine just a few of the options:

- Marbling is an aqueous surface design technique where you can decorate paper using colours floated in a liquid (plain water or a viscous solution), by laying the paper onto the colours so that they are absorbed. This technique is sometimes called by its original Turkish name – ebru. The guide at **hsmag.cc/PaperMarbling** will take you though the stages required, and some of the effects that you can achieve are truly incredible, particularly if you use some really bright and punchy colours. Just ensure that the tray you use is slightly bigger than the sheet of paper you are marbling.
- Spattering or spraying your handmade papers is fun as well as decorative, but do make sure that you are wearing suitable clothing and are nowhere near that antique heirloom rug your great aunt left you. This painting technique essentially involves flicking paint onto your papers, so every single one will be completely unique. If you mask off an area of the paper, you can create a neat border effect, and the creative possibilities are pretty endless.
- Adding plants and botanicals to your work gives a very natural, original, and charming look to your papers, and one way of doing this is to use some dried flower heads or rose petals, sprinkling them over the pulp you've made before you agitate it. You will probably need to press and dry these papers under some form of weight. The effects can be very pretty and each plant paper will be a complete original. Don't just think traditional 'flowers' either, as it's perfectly acceptable to use some dried garden 'weeds' such as dandelions and leaves or other greenery, as they give a similar effect. You could also throw in some dried herbs or even colourful spices such as turmeric, and see what effect that gives the finished paper.
- You could also add grains to handmade papers, colourful threads, confetti, shredded pieces of paper, skeleton leaves (**hsmag.cc/SkeletonLeaves**), shredded cotton, tea or coffee grounds, or linen pulp… your creativity should have no bounds!

Basically, you can add all sorts of things to your handmade papers and you can decorate the finished product in a multitude of ways. Your papers can be quirky, eccentric, distinctive… that's simply the beauty of making your own paper.



Above
This selection of handmade papers that we purchased a few years ago gives some idea of range and depth of colours and textures that you can make yourself at home. Handmade paper invokes a kind of tactile awareness, as each sheet will have its own distinctive and very unique character

QUICK TIP

It's definitely not advisable to throw any excess water from your papermaking down the drain, as your pipes might become clogged. Instead, water your garden plants with the excess liquid (as long as it doesn't contain any toxins, of course).

ONLY THE BEST

Storage solutions

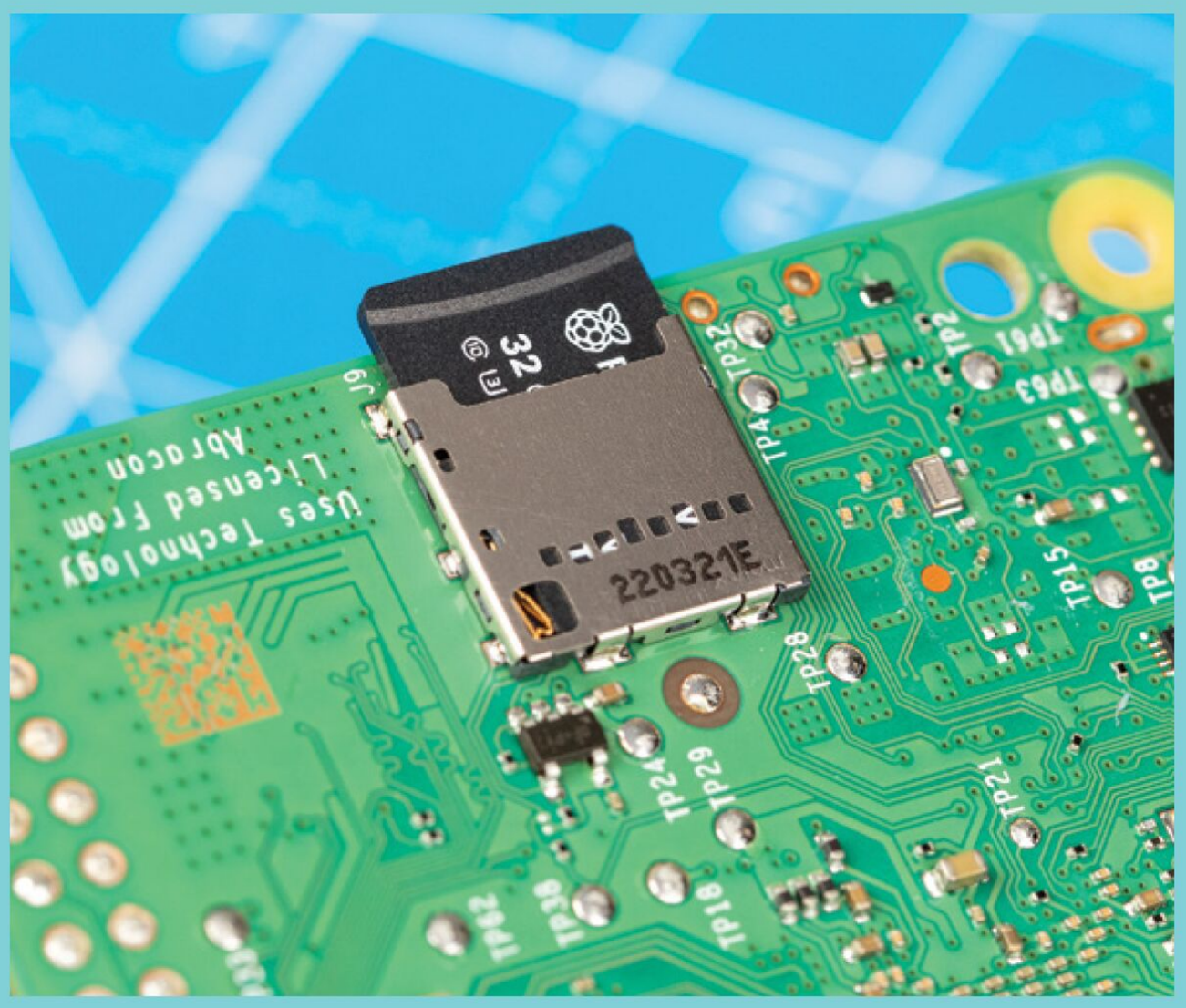
Add extra storage and a speed boost to your Raspberry Pi

By **Phil King**

Traditionally, Raspberry Pi single-board computers have relied on an SD card to host both the operating system and its storage. While this is perfectly adequate for many projects, the SD card's limited read/write speeds can slow down the system.

If you need a large amount of speedier storage, such as for a media centre or home server, a USB-connected SSD (solid-state drive) has been the go-to choice. Now, with the addition of the PCIe slot on Raspberry Pi 5, you can get improved performance due its lower latency and higher data transfer speeds. For this, you'll need an adapter board to connect a standard M.2 NVMe SSD. We look at a few of the many available options here, along with some alternatives and accessories.

Note that while the PCIe interface on Raspberry Pi 5 is set to Gen 2.0 mode by default, you can switch it to the (not officially supported) faster Gen 3.0 with a quick change to the **/boot/config.txt** file. You can also install the OS to the SSD and boot Raspberry Pi from it by changing the boot order in raspi-config.



NVMe Base vs HatDrive! Nano

PIMORONI £14 / $14 | pimoroni.com

PINEBOARDS £9 / $9 | pineboards.io

Connecting to Raspberry Pi 5's PCIe slot via a short flexible ribbon cable, the NVMe Base enables you to add an M.2 NVMe SSD. While most such adapter boards sit on top of Raspberry Pi 5, this slimline adapter is positioned underneath, hence the 'Base' in its name. This means it won't obstruct a cooling fan (such as the official Active Cooler), if you want to use one, and you can easily add a HAT on top of Raspberry Pi as per usual.

Unlike some, the board is long enough to accommodate 2280 size (i.e. 80 mm long) SSDs, and has mounting holes for this and 2230, 2242, and 2260 drives. You can buy the NVMe Base on its own or bundled with a compatible 250GB, 500GB, or 1000GB SSD, although it should work with most others. Read/write speeds depend on the SSD used – check out Pimoroni's own test results at **hsmag.cc/NVMeBaseTests**. There's also the NVMe Base Duo which enables connection of two SSDs.



Left
The NVMe Base comes with fixings, a flexible PCIe cable, and four rubber feet

Below
The HatDrive! Nano is half the size of most NVMe adapter boards

If you're after something a little smaller for your project, the HatDrive! Nano is about half the size of most M.2 adapter boards. Measuring a mere 55×34 mm, it'll even fit inside most Raspberry Pi cases. If using the official Raspberry Pi 5 case, you'll need to remove the latter's fan section, but you can still use an Active Cooler. Note that unlike some M.2 boards that cover the Active Cooler, this one leaves most of its fan unobstructed, so cooling performance should be unaffected. The GPIO pins and camera/display ports are also uncovered and therefore easy to access.

A tiny ribbon cable is used to connect the Nano to Raspberry Pi 5's PCIe slot. Once you've enabled PCIe Gen 3.0 mode, read and write speeds are similar to those with other Raspberry Pi 5 M.2 boards, depending largely on the SSD model used. The only limitation is that, due to the HatDrive! Nano's smaller size, you're limited to 2230 and 2242 drives.



VERDICT

NVMe Base

The Base design means Raspberry Pi's top is totally unobstructed.

HatDrive! Nano

An inexpensive, smaller M.2 HAT with no loss in performance.

Argon ONE V3 M.2 NVME PCIE Case

ARGON £40 / $49 | argon40.com

Want to create a Raspberry Pi 5 media centre, games machine, or home server? The Argon ONE V3 M.2 NVME PCIE Case is an ideal all-in-one solution, providing a smart-looking enclosure for Raspberry Pi 5 along with a built-in PCIe to NVMe adapter – just open a panel in the base to slot in your SSD, up to 2280 size. As a bonus, that removable panel doubles as a heatsink for the SSD.

As with other Argon ONE models, a special daughterboard extends Raspberry Pi's ports to the exterior of the case for ease of access – including full-size HDMI ports. The extended GPIO pins are found under a removable magnetic panel, complete with helpful labelled strip. The case itself is robust and well ventilated, while a Raspberry Pi RP2040 chip handles active cooling – with a PWM-controlled 30 mm fan – and power management. The case even has an infrared receiver that can be used with an optional IR remote.

VERDICT

Argon ONE V3 M.2 NVME PCIE Case

A superb all-in-one solution for a media centre with SSD storage.

TALL PUSH-FIT STACKING HEADER

THE PI HUT £2 / $2 | thepihut.com

If you're using an official M.2 HAT+, it mounts onto Raspberry Pi 5's GPIO pins. Fortunately, it has a pass-through header; so, by using an extra-tall GPIO stacking header like this one, you can extend Raspberry Pi's GPIO pins through it. This should enable you to use the pins as normal, to mount another HAT or connect electronic components and circuits.





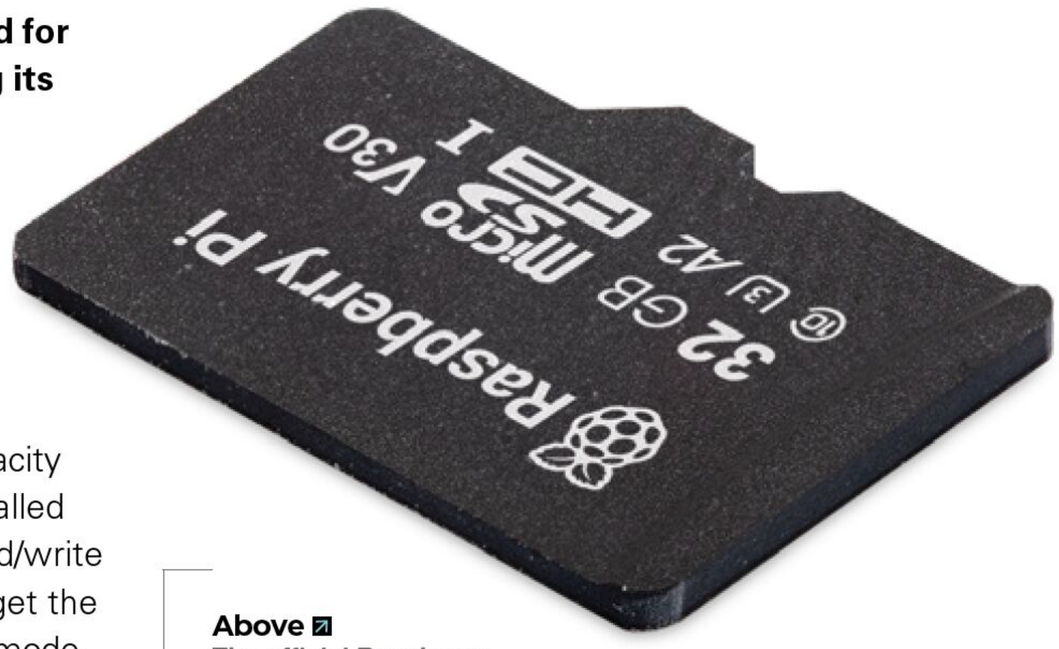
Left
Just remove the panel on the underside of the case to insert an SSD

Raspberry Pi SD Card

RASPBERRY PI From £10 / $10 | raspberrypi.com

If you want to stick with a microSD card for your Raspberry Pi storage (and hosting its OS), there are countless third-party options available. The trouble is, choosing one can be a bit of a lottery, as some work much better than others in terms of reliability and speed.

To make it easier, Raspberry Pi has recently launched its own range of official SD Cards. Available in 32GB, 64GB, or 128GB capacity – and with or without Raspberry Pi OS pre-installed – these are Class A2 cards that offer faster read/write speeds on all models. On Raspberry Pi 5, you get the bonus of support for CQ (Command Queuing) mode for even higher performance – read more about the technical details at **hsmag.cc/RPiSDcards**.



Above
The official Raspberry Pi SD Card comes in 32GB, 64GB, and 128GB flavours

VERDICT

Raspberry Pi SD Card

Fast and reliable microSD card storage.

SSD to USB 3.0 Cable

THE PI HUT £6 / $6 | thepihut.com

An alternative to an M.2 NVMe drive for adding extra storage to your Raspberry Pi is to use an external SSD connected via USB. If the drive doesn't come with a USB connection, you'll need an adapter. This one enables you to connect a standard 2.5-inch SATA SSD to a USB 3.0 port on Raspberry Pi 4 or 5. So if you have a spare SATA drive kicking around, it's an inexpensive way of repurposing it.

The downside is that you're limited to USB 3.0 maximum data transmission speeds and increased latency, so it won't be quite as fast as a PCIe-connected NVMe SSD on Raspberry Pi 5, but it's ideal for Raspberry Pi 4. You can also use it with other models, but will be limited to USB 2.0 speeds.



Left
Connect a spare 2.5-inch SATA SSD to Raspberry Pi with this adapter cable

VERDICT

SSD to USB 3.0 Cable

Great for repurposing a spare SATA drive.

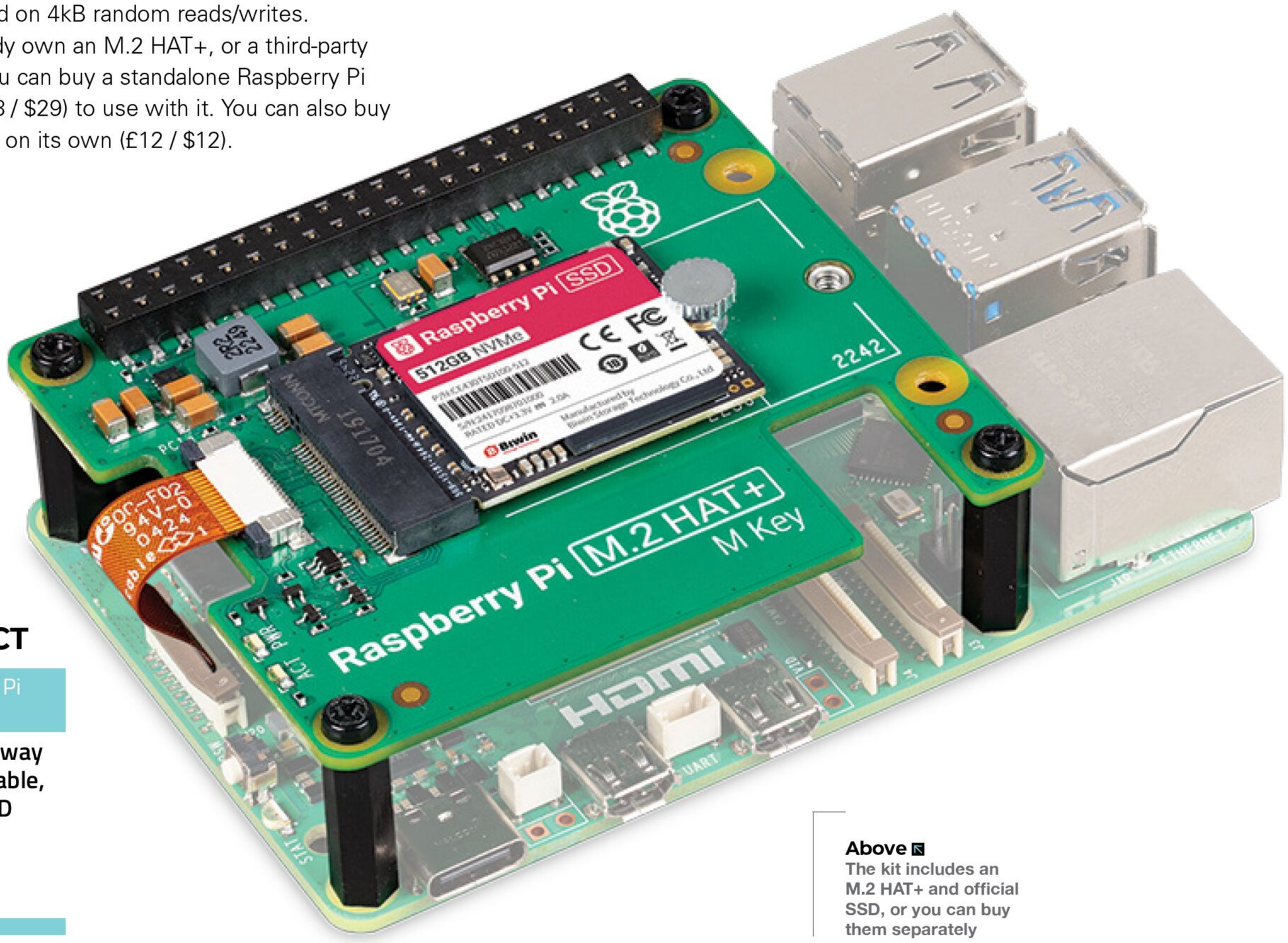
Raspberry Pi SSD Kit

RASPBERRY PI From £ 37 / $39 | raspberrypi.com

As well as offering its own SD Cards, Raspberry Pi has launched an SSD Kit for Raspberry Pi 5 which bundles an official M.2 HAT+ with an official Raspberry Pi SSD to slot into it.

Using the compact M.2 2230 form factor, the SSD comes in 256GB and 512GB flavours; as well as boasting double the storage, the latter offers slightly improved read/write performance: 50k/90k IOPS (input/output operations per second) vs 40k/70k, based on 4kB random reads/writes.

If you already own an M.2 HAT+, or a third-party alternative, you can buy a standalone Raspberry Pi SSD (from £28 / $29) to use with it. You can also buy the M.2 HAT+ on its own (£12 / $12).



Above
The kit includes an M.2 HAT+ and official SSD, or you can buy them separately

VERDICT

Raspberry Pi SSD Kit

An official way to add reliable, speedy SSD storage.

The parts we sell help get you there safely

Today’s cutting-edge vehicles can contain hundreds of sensors for systems that keep you comfortable, entertained, informed, and most importantly, safe.

The sensors we sell help engineers create these systems, but helping you enjoy your journey safely is what really drives us.

Find sensors for any application at digikey.co.uk

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we get technical

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Supporting The Authorized Channel

Raspberry Pi Audio

Raspberry Pi enables you to build low-cost audio recording and playback devices. Audio recording and playback is incredibly rewarding

By Lucy Hattersley

Raspberry Pi is a powerful and energy-efficient computer system with a wide range of accessories and applications.

This expandable nature makes Raspberry Pi hardware the ideal choice for home studios and audio systems. You can quickly drop a Raspberry Pi into a recording environment and use it alongside professional audio equipment.

This month, Raspberry Pi audio aficionado K.G. Orphanides has started to build a home recording studio with Raspberry Pi 500 at its heart. This can be used for podcasting and other audio recording endeavours. We will be following this build over the next few months and to help you get started, we've covered some of the best equipment around for Raspberry Pi playback. Here, we look at some of the software and hardware you may want to consider when starting out with Raspberry Pi audio.

Whether you want to make music, record your voice, or hear high-quality audio playback, Raspberry Pi is the way to go.

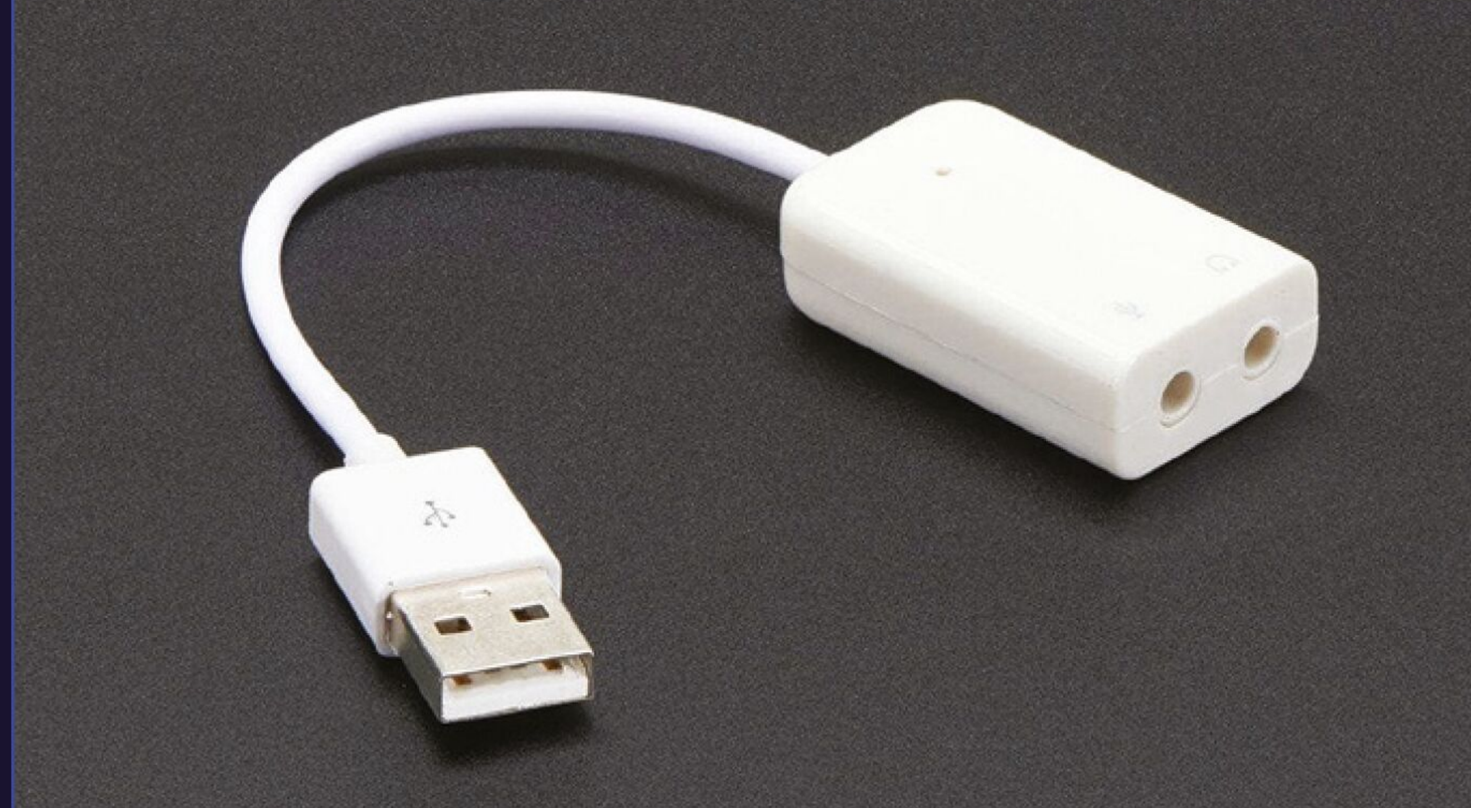
USB Audio Adapter

£4/$4

Recent models of Raspberry Pi removed the on-board audio jack, so you'll need an USB Audio Adapter. Even with previous models, buying one of these USB Audio Adapters is a good idea because a USB audio card vastly improves the sound quality and volume.

This is because Raspberry Pi's on-board audio is generated by a PWM (pulse-width modulation) output that is adequately filtered but can be improved upon. PWM is a modulation technique that generates an analogue signal from a digital source, and this device produces a better analogue signal. The input is a mono line, making it ideal for audio recording.

→ magpi.cc/usbaudioadapter



Pirate Audio: Dual Mic for Raspberry Pi

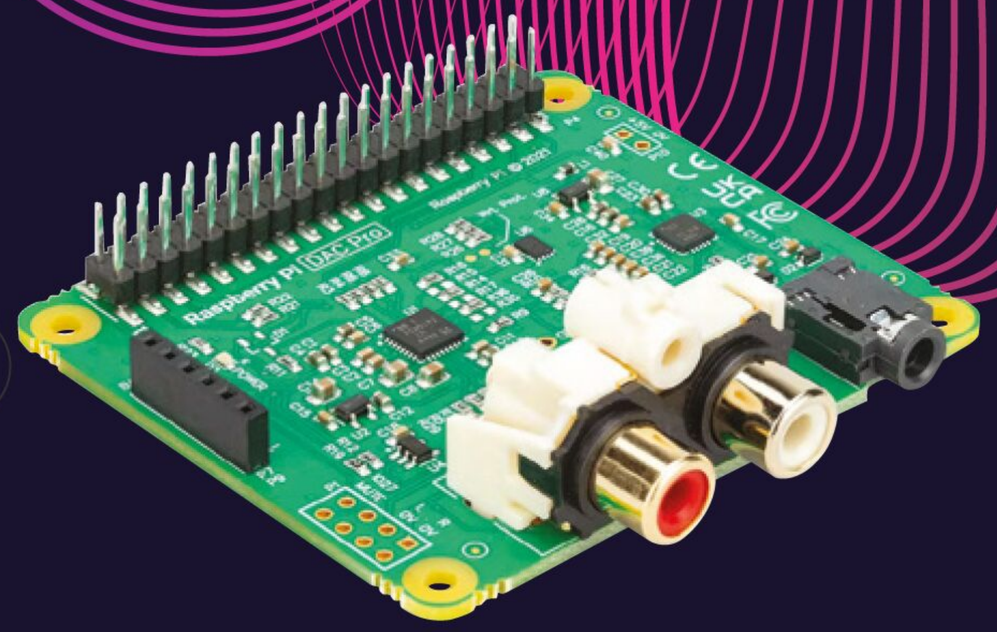
£27/$28

While it lacks audio output (for that you'll still need the USB Audio Adapter) this dual-mic HAT enables you to record audio on the go. It has an integrated 1.3-inch colour LCD screen surrounded by four push-buttons. Located on either side of the board are two tiny digital microphones. These feature a SiSonic acoustic sensor, a serial ADC (analogue to digital converter), and an interface to convert the signal into the industry-standard 24-bit I2S format. In our tests, Phil King found that they "recorded sound with crystal-clear quality, although the mics aren't that far apart so the stereo effect is limited."



→ magpi.cc/piratemic

DAC Pro



£24/$25

If you want to seriously improve the quality of your audio output, invest in a DAC (digital-to-analogue converter). This Raspberry Pi DAC Pro (previously known as IQaudio DAC Pro) is the best around.

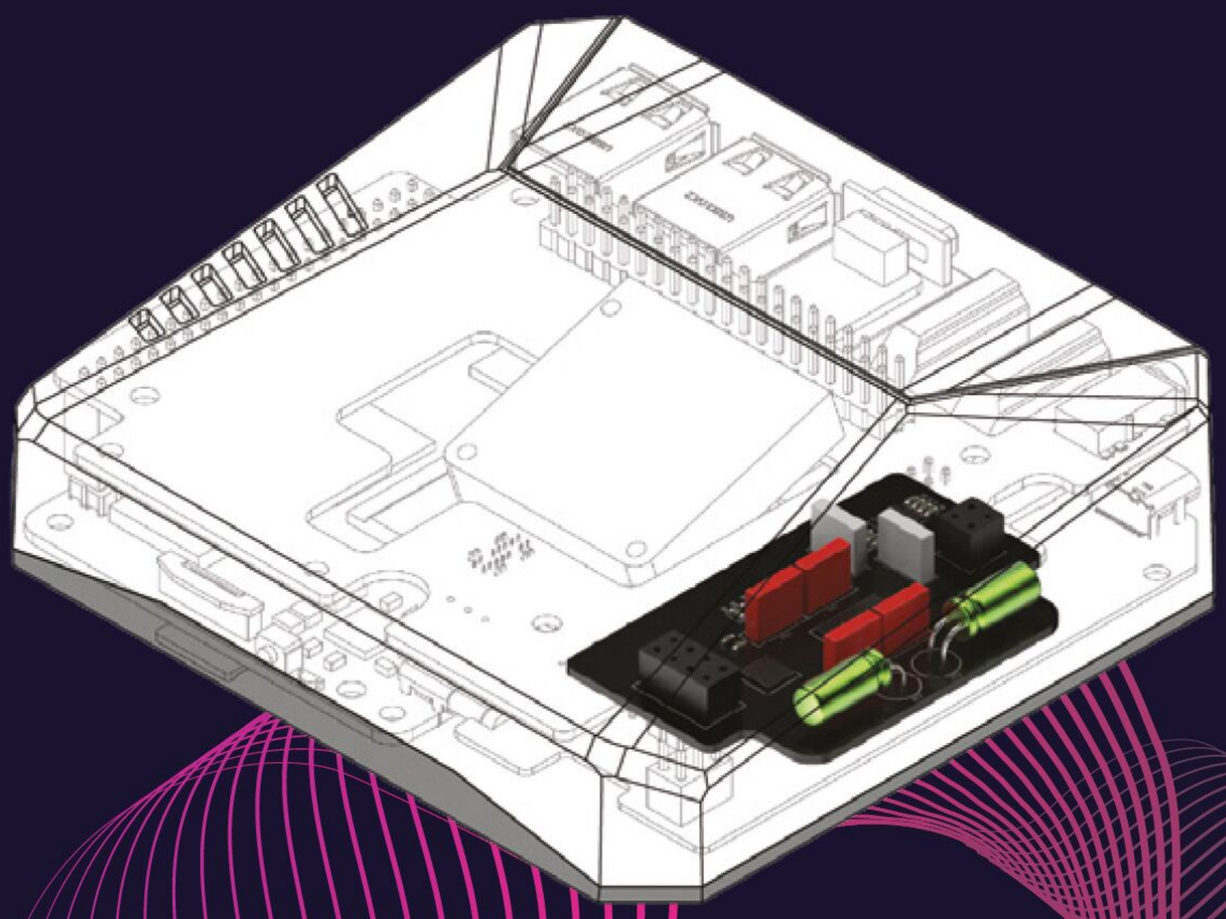
All speakers and headphones are ultimately analogue devices. An analogue wave is converted into sound by pulsing a speaker cone. The wave determines how fast and far the cone pulsates to create audio. Meanwhile, all computers – including Raspberry Pi – are digital devices. At some point the hardware needs to convert the 0s and 1s of digital audio into analogue waves, which is what a DAC is for. The better your DAC, the better the audio wave, and the better the sound quality.

As the product sheet says: "Raspberry Pi DAC Pro is our highest-fidelity audio HAT, and is compatible with any Raspberry Pi computer that has a 40-pin GPIO header. With the Texas Instruments PCM5242, the DAC Pro provides an outstanding signal-to-noise ratio (SNR) and supports balanced/differential output in parallel to phono/RCA line-level output. It also includes a dedicated headphone amplifier. The Raspberry Pi DAC Pro is compatible with any Raspberry Pi computer that has a 40-pin GPIO header."

→ magpi.cc/dacpro

Argon BLSTR DAC

£21/$25



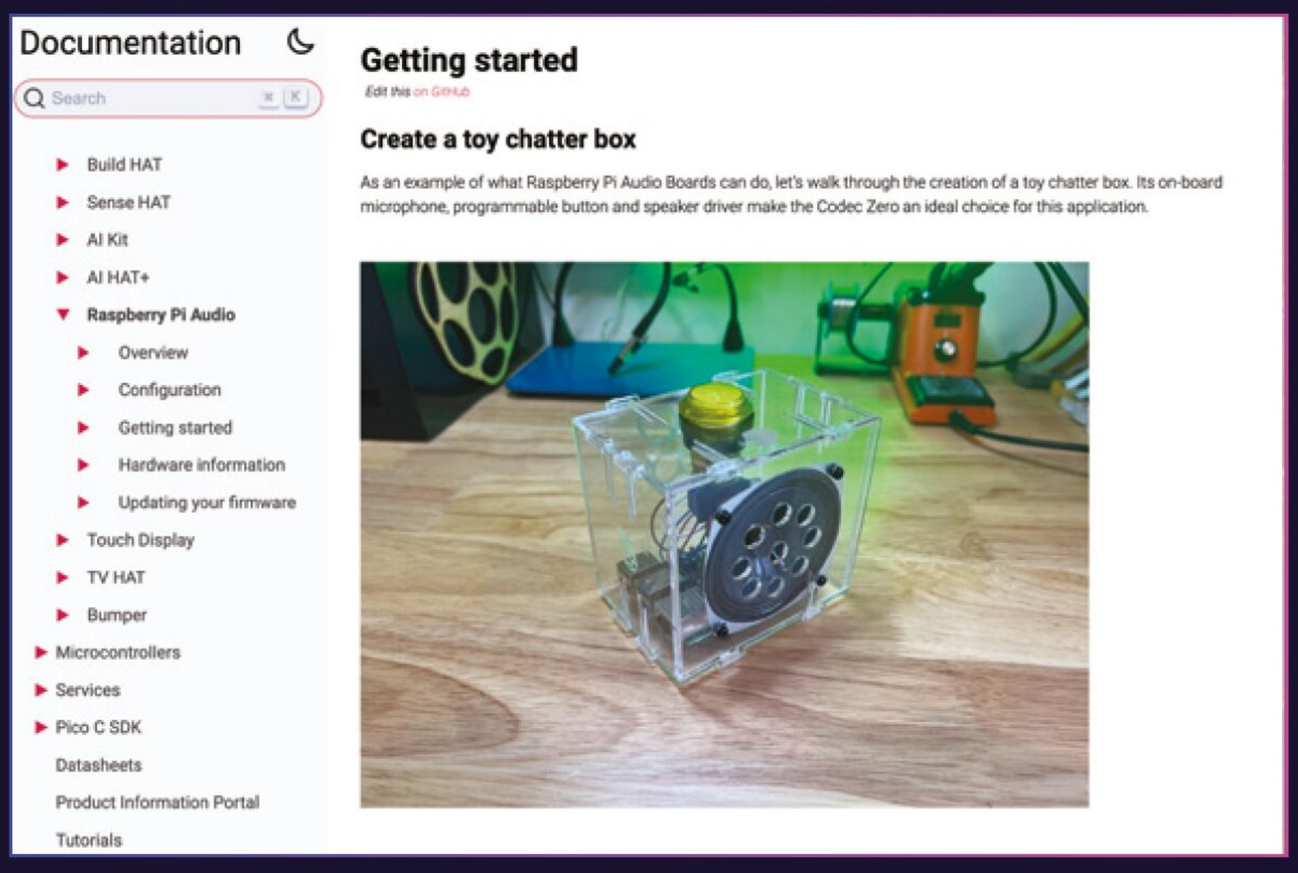
Powered by Texas Instruments PCM5122 digital-to-analogue converter (DAC), this add-on from Argon enables you to add a powerful DAC to a Raspberry Pi and place it neatly into an Argon case. You'll need to purchase an Argon ONE V3 case and a Raspberry Pi 5 separately, and there is also an Argon IR remote control available. So while the whole setup requires a few different parts, the result is a neat all-in-one DAC and audio player that can also house an M.2 NVMe drive to store all your music. It's worth looking into if you want to build that all-in-one music system.

→ magpi.cc/argonblstrdac

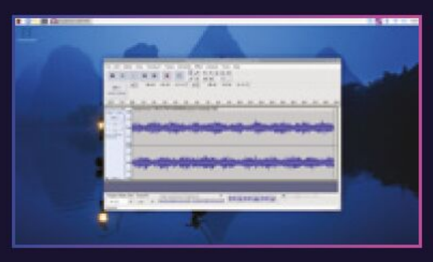
Raspberry Pi Audio Documentation

Raspberry Pi's extensive documentation has a detailed section on Raspberry Pi Audio. This covers each of the DAC boards that Raspberry Pi creates. It includes detailed configuration and an example project, a 'toy chatter box' that records audio and plays it back. It uses a Raspberry Pi, a button, and a small speaker.

→ magpi.cc/rpiaudiodocs



Add Audacity



You can record and playback audio on a Raspberry Pi directly from the command line using `arecord` and play it back with `aplay`.

These command-line tools are great for integrating recording and playback with your own projects, but for most home recording setups you'll want to record and playback with dedicated software.

Fortunately, one of the most powerful audio recording suites around is available for Raspberry Pi: Audacity. Install it with:

```
sudo apt update
sudo apt install audacity
```

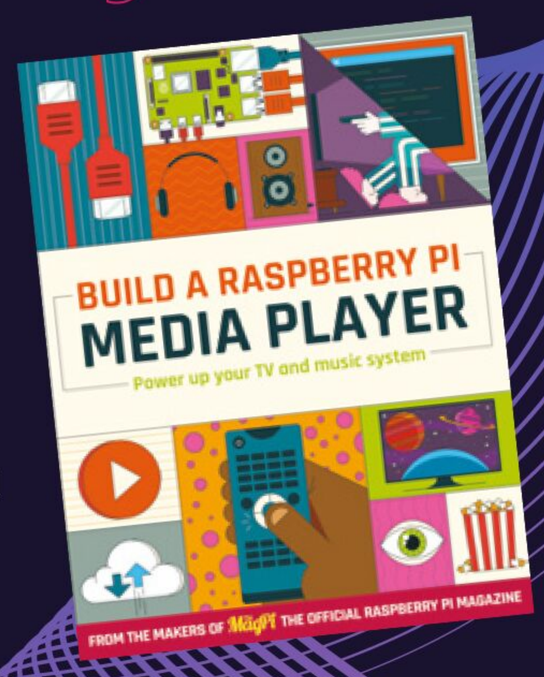
You'll find Audacity under menu > Sound & Video.

→ audacityteam.org

Build a Raspberry Pi Media Player

We've covered a lot of audio projects and builds over the years and most of it is collected in our free book: *Build a Raspberry Pi Media Player*. This book is packed with detailed projects for TV and audio. In it you can build a media centre, TV system, home server, and an incredibly powerful music system.

→ magpi.cc/mediaplayer



Build a Raspberry Pi 500 home recording studio

Silent and powerful, Raspberry Pi 500 is a perfect recording studio computer. In this series, we'll build a sound-absorbing recording setup for vocal and simple instrument recording. By **KG Orphanides**



MAKER

K.G. Orphanides

K.G. got audio production qualification once upon a time, but mostly presses buttons at random until things sound good. Check out their Soundcloud: **soundcloud.com/1351**

eldritch.cafe/@HauntedOwlbear



Pay special attention to corners and joins between hard surfaces when placing acoustic-dampening materials

You don't have to use purpose-made acoustic materials – hanging curtains can greatly improve the sound reflectivity of hard surfaces

You'll Need

- 30×30×5 cm acoustic foam tiles **magpi.cc/acousticabsorb**
- 3M VHB 5952 foam tape **magpi.cc/vhb5952**
- Scissors, scalpel, cutting board

This feature focuses on voice recording and very basic instrument recording – if you need to record a full band on a regular basis, you're looking at a more involved studio setup with a full room which should lean into techniques like building rockwool panels and bass traps. A garage is both the stereotypical rehearsal and recording space, and a good choice. But if, like us, you don't have an unused indoor garage going spare, you can turn a wide variety of small spaces into studio environments. We equipped a small nook in a converted loft space next to a flight of stairs.

01 Find a space

In principle, when recording voice or acoustic instruments through a free-standing mic, you don't want to be too near a wall, and

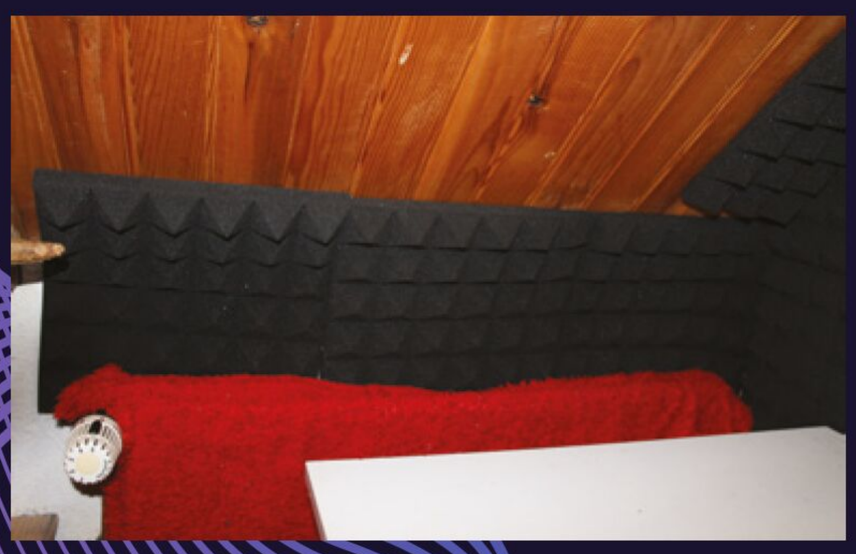
you should especially avoid corners. However, the realities of DIY recording spaces that can be created within your average home means that you'll have to make compromises regarding both what kind of acoustic modifications are practical and permitted to make. You'll want a space that's as isolated as possible from external sources of sound, ideally without windows. Pay particular attention to surfaces directly in front of your mics and to the corners of the room. These are where your sound-absorbing material will make the greatest difference.

02 Furniture & gear

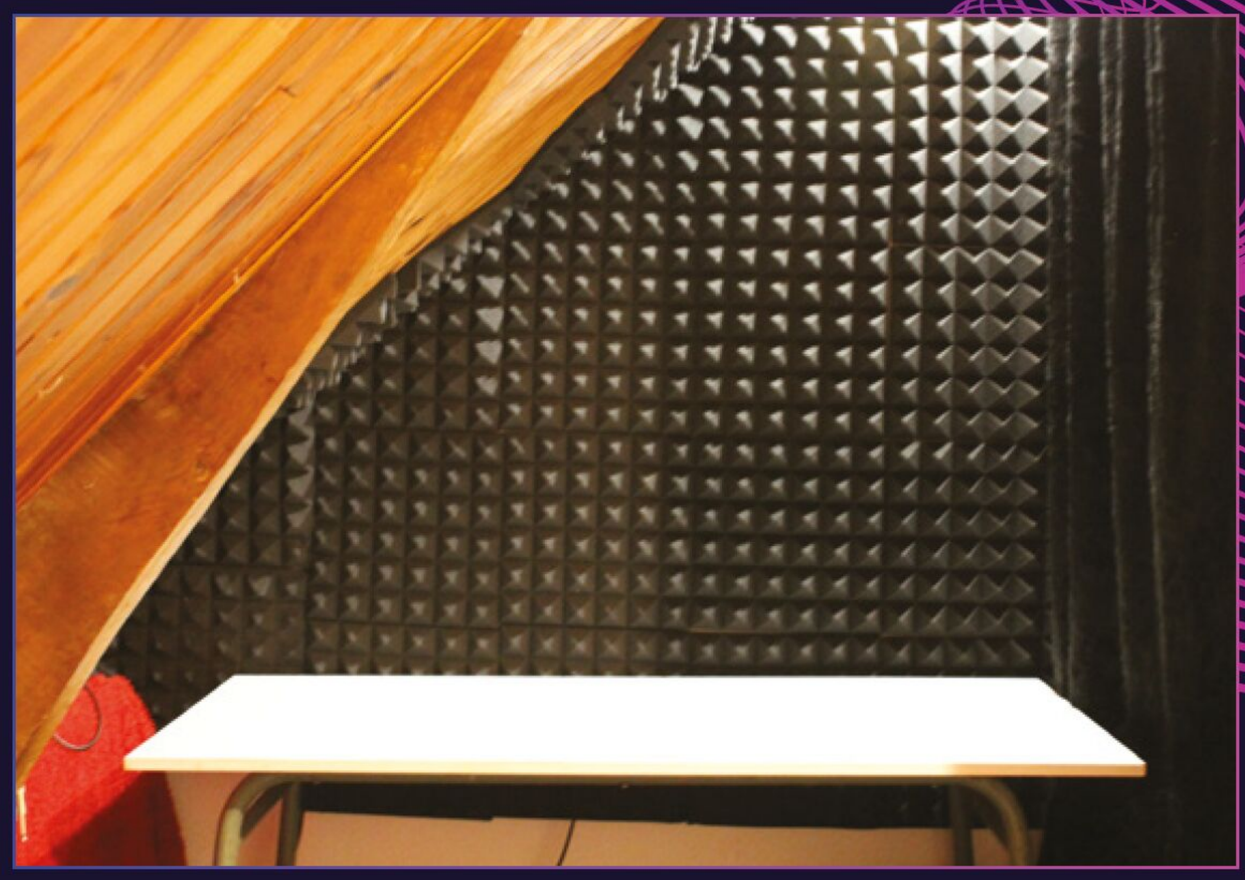
You want to work out what furniture and – to a certain extent – equipment is going into place before you start soundproofing. This both allows you to ensure that your furniture will still fit after soundproofing, and that you can soundproof the right spaces. Consider issues that might affect your acoustics and your requirements. Will you primarily be recording voice, or will instruments come into play? What kind of desk and instrument or equipment racks will you have? Will your mic be on a boom arm or on a stand on your desk? Where will you be sitting or standing when you record your voice? What computer equipment will be in place and how much noise does it make?

03 Assess hard surfaces

In our future studio space, a cupboard-lined storage area under a roof, the main reflective surfaces were a hard wall right in front of us, built-in wooden shelves on the left, the wood-surfaced sloped interior ceiling of a pitched roof, and a metal radiator on one wall. In our case, the



▲ Radiators can produce ringing echoes. Because we also like being warm, we covered ours with a fleece blanket for easy removal



essential thing to soundproof was the wall right in front of our mic, a hard surface that reflects our voice straight back into the microphone. This alone dramatically improved the quality of our voice recordings, and, in the right space, is a minimum viable acoustic setup.

▲ It took £36 of tiles, £8 of tape, a £5 table from a charity shop, an old curtain, and a fluffy fleece blanket to produce an adequate voice recording studio for just under £50

04 How to mount acoustic foam

If you have walls that reflect sound back into your microphones, which you almost certainly do, you'll need to soften those surfaces. The easiest way to do this is to use acoustic foam, also known as 'eggbox foam'. It's available in sheets, rolls, and tiles. We opted for the latter to add basic acoustic absorption to our walls, largely because it's easy to fit. Budget eggbox foam tiles usually come vacuum-compressed and can take anywhere from a couple of days to over a week to return to shape. Once they have, apply thick double-sided tape – 3M's 1.1mm thick VHB 5952 foam tape is ideal for this. For application to our papered and painted partition wall, 2cm strips in each corner worked well, but you'll need more tape for other kinds of surfaces.

05 Take the corner

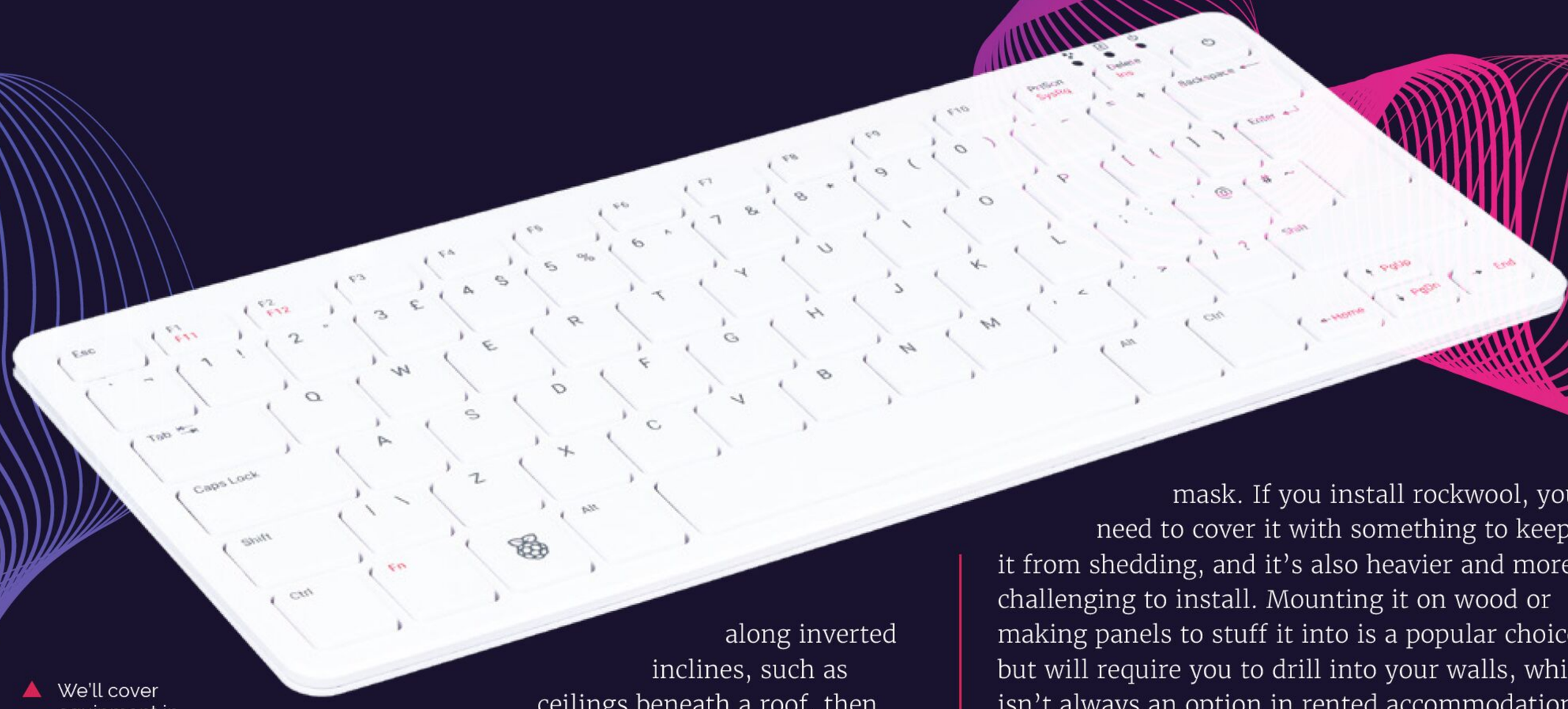
Pay special attention to corners where walls and ceilings join, as sound bounces between these hard surfaces, creating more unwanted echoes than a flat wall.

If, like us, you're dealing with irregular, angled spaces, you can cut acoustic foam tiles along the diagonal to meet at the corner and into other shapes to fill inconveniently placed gaps. Note that if you're going to be sticking tiles upside down or

Warning!
Sharp objects

Only use craft knives to cut tiles or peel off tape backing if you're steady-handed and comfortable with doing so.

magpi.cc/knifesafety



▲ We'll cover equipment in the next instalment of this guide, but quieter is better, which is why we've chosen Raspberry Pi 500 as our studio PC

along inverted inclines, such as ceilings beneath a roof, then you'll need to run longer strips of foam tape along them to ensure good adhesion.

06 Alternative materials: rockwool

Acoustic-specific spun fibreglass insulation – most ubiquitously made by rockwool (**magpi.cc/acousticinsulate**) – is another popular material for acoustic absorption. It's very cheap, and while acoustic foam mostly absorbs high frequencies, rockwool will also reduce unwanted mid-range and bass frequencies.

However, it's a skin irritant and obnoxious to work with – you'll want to wear gloves and a mask. If you install rockwool, you'll need to cover it with something to keep it from shedding, and it's also heavier and more challenging to install. Mounting it on wood or making panels to stuff it into is a popular choice, but will require you to drill into your walls, which isn't always an option in rented accommodation.



▲ VHB 5952 tape is amazing, but it's so adhesive that its own backing can be hard to get off. We used a scalpel blade to peel up one corner of the plastic backing

07 Panels and air gaps

Professional studio installations often use acoustic panels suspended from the ceilings and walls. That's a bit much for DIY, but if you've got a large enough space – if you're converting a garage or have an entire room, for example – then free-standing or air-gapped wall-mounted acoustic panels are an outstanding choice. While you ideally want an air gap behind your panel roughly equal to its width (see **magpi.cc/avairgaps**), for a home installation this is far less of a concern than simply having acoustic panels at all. If you have woodworking tools and skill, you can build a box, fill it with rockwool, and cover it with fine mesh screen material. However, acoustic screen panels are also an option, whether you DIY them or buy pre-made ones. You'll as often find these sold as office furniture as recording studio gear, and if you can find some of the former being sold off cheaply, they're worth considering.

> "Improve excessive sound reflection by hanging curtains on walls"

08 Irregular surfaces

Although purpose-made equipment is great, you can dramatically improve excessive sound reflection by hanging curtains on walls and cupboards. Acoustic fabric is best, but at around



▲ Make particularly sure to add foam to corners – here, we've applied acoustic foam to the join between a wall and low ceiling

£20 per metre, you might prefer to see if you can acquire heavy standard curtains made of velvet, fleece, or similar textiles. Favour fabrics that you can't easily breathe through – anything dense enough to make this difficult can also reflect sound. We used a fur fabric curtain on a built-in cupboard, and an old fleece on an inconveniently located radiator – some people use towels on radiators, and these can ring in response to high-frequency sounds.

09 Flooring

You'll hear a surprising amount of online debate about how you should approach flooring in a recording environment, with some people suggesting thick carpeting, but the general consensus is that hard floors such as sealed concrete are best. In our budget DIY setup, we found our wooden second-story floor covered with laminate flooring to be absolutely fine, particularly for voice recording and isolated guitars rather than a full band. If you're going to be recording at a table, it's genuinely not a major issue.

10 Bass traps

If you are going to be recording instruments – particularly drums, acoustic instruments, or miked-up speakers – then you might want to get into more DIY construction by making bass traps for the corners of your space, as an alternative to buying expensive pre-made ones. You'll need to build a box at right angles to fit into a corner, stuffing it with rockwool and covering it with strong mesh. For a room-scale studio build, it's recommended that you stack these from floor to ceiling in each corner, although this isn't necessarily something you'll need for a smaller setup. See **magpi.cc/diybasstraps** for an example of construction methods.

11 If you can't build a studio

Recording in your car, already a soundproof space, can be a great stopgap or on-the-road solution if you're using a portable recorder to make a podcast, but it doesn't lend itself to a full studio setup.

Also popular is the blanket fort setup, the most bare-bones version of which is a duvet over your head and a sock over your phone's mic to act as a pop filter. Some podcasters swear by dragging a fleece blanket over both themselves and a USB mic. However, many people find this to be hot, claustrophobic and unpleasant, and it doesn't work too well for a lot of hardware configurations.

12 Portable acoustic optimisation equipment

If you don't have space or permission to start putting up acoustic foam tiles or the tools to build movable rockwool-stuffed boxes, you can buy dedicated acoustic absorption screens that'll fit most mics and can in turn be mounted on a mic stand, which have come down to around £60 in recent years; for instance, t.bone's Micscreen range (**magpi.cc/micscreenxl**). You can also pick up clones for around £30 (**magpi.cc/micisolator**) or potentially DIY something using acoustic foam if you're handy – we've seen builds using spray or hot glue and everything from old ring binders (**magpi.cc/2minmicsheld**) to cardboard or plastic storage crates (**magpi.cc/diymicshield**) to mount your foam on.

Top Tip

Measure acoustics

If you have an x86_64 PC, speakers, and a mic, you can use Room EQ Wizard to quantify your space's acoustic characteristics: **roomeqwizard.com**.

Top Tip

Manage your expectations

Acoustic foam only makes a significant difference to high-frequency audio reflections, but can be a great help in a small space.

Pi Terminal

▶ Elecrow ▶ **magpi.cc/piterminal** ▶ £148 / $180

A Compute Module 4-powered industrial IoT touchscreen terminal from the makers of the CrowPi line of displays. **Rob Zwetsloot** pokes around

SPECS

SOC:
Raspberry Pi Compute Module 4 with 4GB RAM

DISPLAY:
7″ IPS LCD, 1024 × 600, 5-point capacitive touch

WIRELESS CONNECTIVITY:
Wi-Fi, BLE 5.0, GPS, LoRa (with expansion), LTE (with expansion)

WIRED CONNECTIVITY:
GPIO, Relay, DO, DI, CAN, RS485, ADC, RS232, USB-C, USB 2.0, Gigabit Ethernet, HDMI, 3.5mm headphone jack, TF card, SIM card, CSI (for camera)

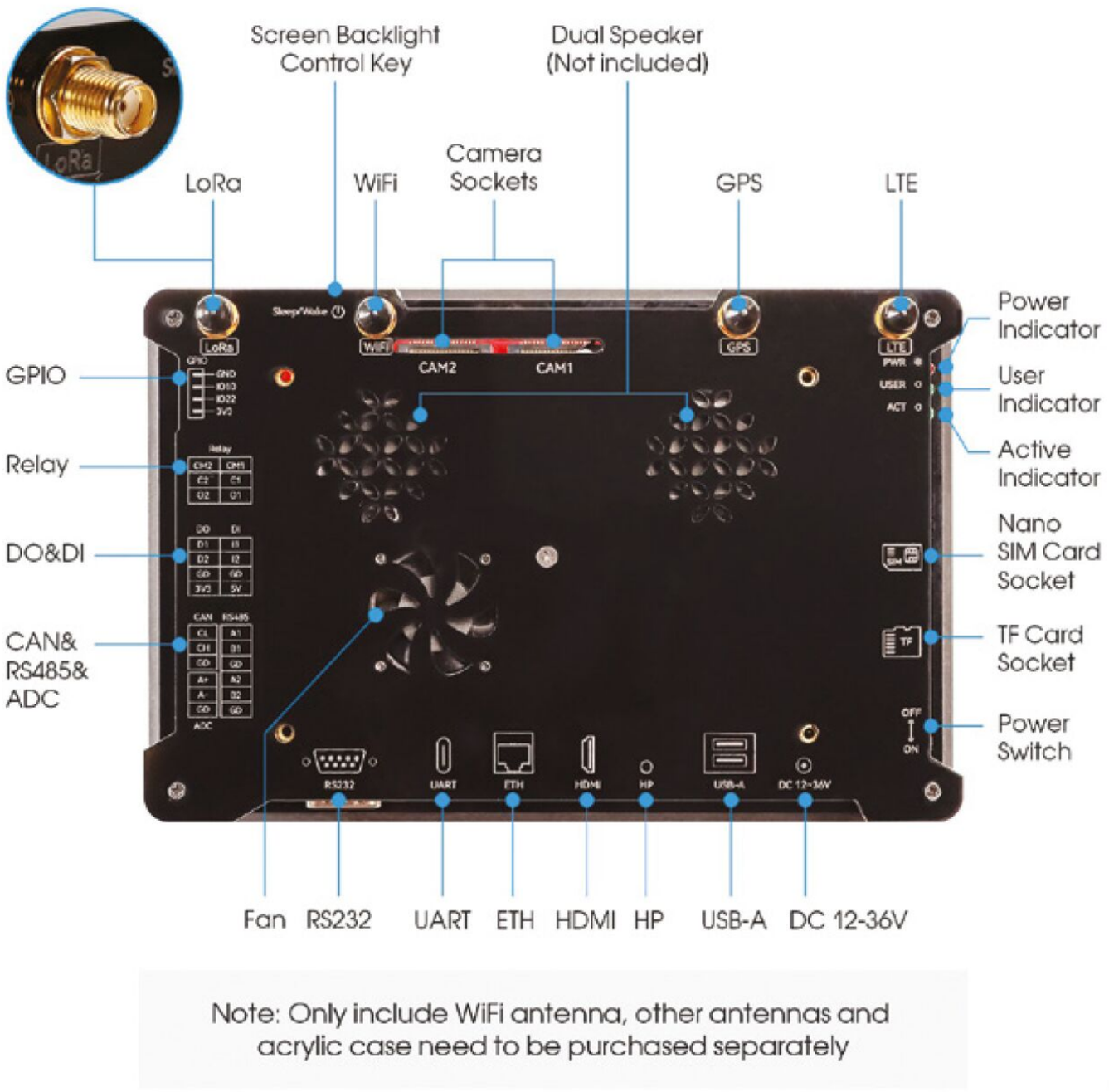
We've seen a few IoT panels for industrial purposes over the last couple of years powered by Compute Module 4 – and for good reason: CM4 is very powerful and very flexible. Elecrow is the latest company to throw its hat in the ring, with a slightly cheaper version of some of the terminals we've seen.

Elecrow has seemingly managed this by making a device that, while well-suited for these industrial IoT tasks, doesn't quite look the same as the professional reTerminals from Seeed. You shouldn't judge a book by its cover, though: despite the slightly hobbyist look of an acrylic base, PCB open to the air, and screen attached on-top, it does have an all-important IP65 dust and waterproof rating and high-quality components to allow it to survive in the environment it is designed for.

It also has the equally important connectivity requirements of modern industrial automation. From your classic terminal pins, serial connector, Ethernet, etc., there's also access to the built-in Wi-Fi and Bluetooth of CM4, along with a GPS antenna add-on, and you can expand it with LoRa or LTE for more radio connections.

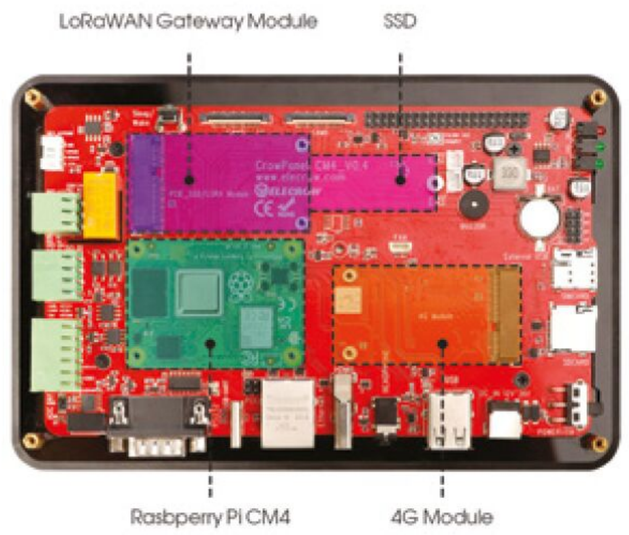


▶ Powered by Compute Module 4, the Pi Terminal features a 7-inch touchscreen



Note: Only include WiFi antenna, other antennas and acrylic case need to be purchased separately

The Pi Terminal offers a host of ports and connections





Extra modules can easily be installed if needed

> It's a very nice piece of kit, and very flexible thanks to its wide array of connectivity and Raspberry Pi base

Ready to go

There's no construction required for the device – unless you want to add LoRa, LTE, or an SSD module, but that's exceptionally easy – and there's even a little demo to help you get to grips with how the interface could work. It's powered by a 12V~36V barrel jack which is a more old-school standard than USB-C, but does allow for a lot more taxing components to be attached to the various ports littered around the side.

Extra antennas are included to help increase range, which is always very handy. Fortunately, every port is also well labelled, so it is unlikely that you'll accidentally plug an antenna into the wrong radio port.

The demo shows that the screen is sharp, colourful, and very responsive as well. It's programmed in Node-RED, which may not be everyone's cup of tea, but the whole system is built upon Raspberry Pi OS, so you can create an interface in any language that Raspberry Pi/Linux can support. So, all of them.

Biggest fan

It's a very nice piece of kit and very flexible thanks to its wide array of connectivity and Raspberry Pi base. Unlike other similar devices, it does lack physical buttons as standard, so everything will have to be touchscreen unless some switches are added by the user. The fan is also very loud when it gets up to speed, which may not matter for some noisy industrial environments, but was very distracting in a quieter setting. Still, it's a robust and very capable device. The acrylic plates are incredibly strong and everything else is very sturdily constructed too. You also could easily create a 3D-printed case for it, if the need arose.

Verdict

A great piece of kit at a good price that is stronger than it looks, although it does have its own minor quirks.

8/10

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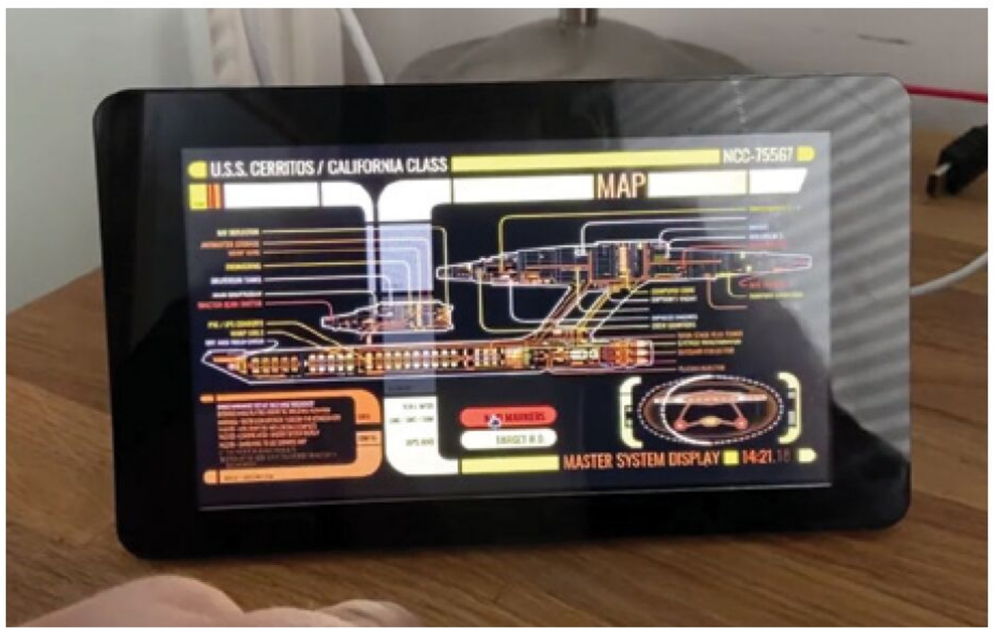
Email Charlie Milligan at: **charlotte.milligan@raspberrypi.com**

10 Amazing:

Raspberry Pi monitor projects

Use a screen and Raspberry Pi to do incredible things

At the end of 2024, the official Raspberry Pi monitor was released. It's not the first display specifically made for Raspberry Pi – even by Raspberry Pi Ltd itself – and people have been using dedicated displays, monitors, and more to do cool stuff with Raspberry Pi since day one. Here are some of the best...



▲ PiRitos

Cali-class LCARS

Based on the 24th century computer interface created for *Star Trek: The Next Generation*, this specific version evokes the interface used on the USS Cerritos in the fantastic *Star Trek: Lower Decks* animated show.

magpi.cc/piritos



▲ PC resource monitor

Gaming gauges

Don't want to Alt-Tab away to bring up the task manager? This Raspberry Pi-powered resource monitor will show you just how much juice your game is taking up without fully taking away from your playing.

magpi.cc/resourcemon



◂ Possessed Portrait

Halloween horrors

This motion-sensing frame is actually a video of a portrait that becomes a lot more ghastly once someone walks past. It's a great haunted house device – in fact we've seen similar used in Disneyland Paris's Phantom Manor attraction.

magpi.cc/possessedpic

▼ Raspberry Pi Zero Recipe Kiosk

Kitchen komputer

A dedicated machine in your kitchen to show you recipes without having to fuss about with a tablet computer and its subpar browser, and you can mount it to the underside of a cabinet to save counter space. Smart!

magpi.cc/recipekiosk





Digital information screen

Data kiosk

If you have a spare screen and a spare Raspberry Pi, keeping track of important info through the day is an easy way to make use of them. This specific project is used in a school's science department, but can be easily modified.

magpi.cc/digiinfo

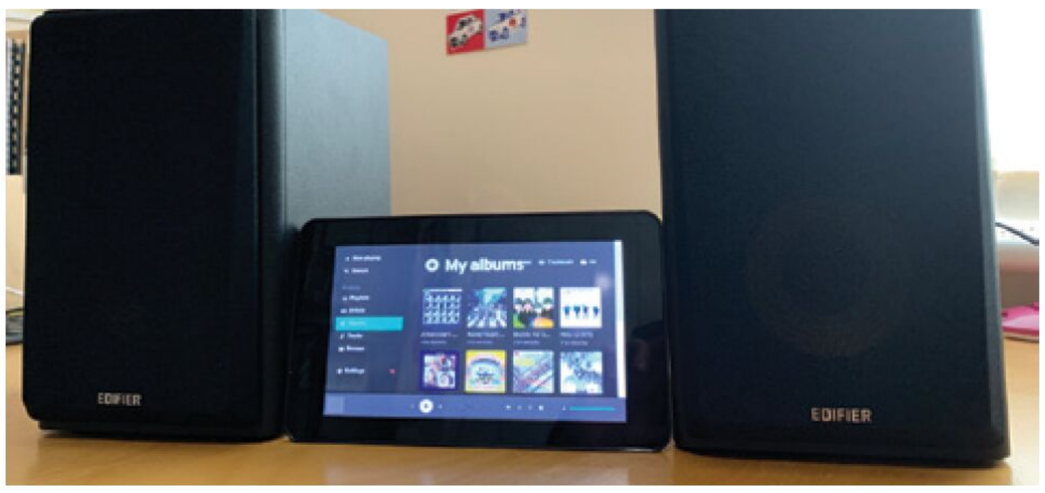
Train time display



Departures and delays

Find out just how much time you have left enjoying your morning cup of tea before dashing out the door for your train with this live timetable of train departures from your chosen station. Delayed? Enjoy another cuppa.

magpi.cc/traintimes



Home music system

See your songs

Stream audio around your home from the touch of… a screen, thanks to this great tutorial series from PJ Evans. You'll need to supply some good speakers and a library of greats songs too, of course.

magpi.cc/homemusic

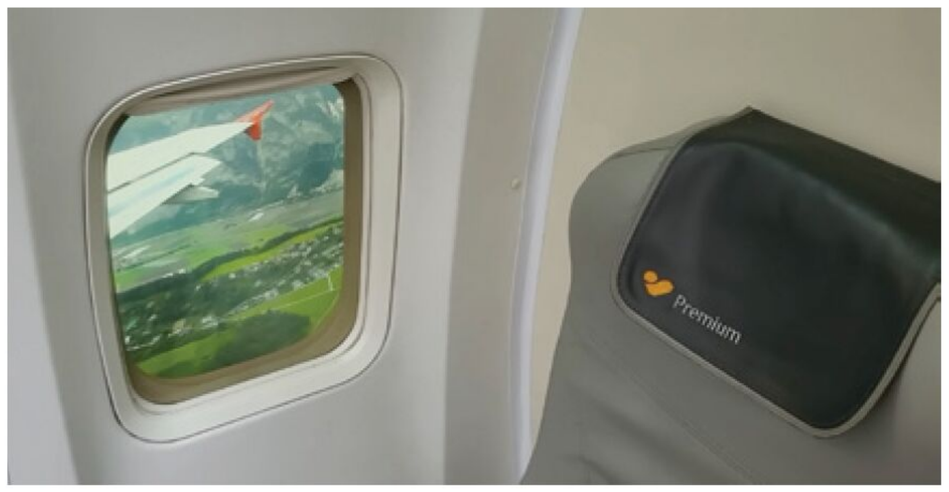


Home automation

Home health

Home Assistant is a specific operating system that has been built for Raspberry Pi that helps you control your own home. It perfectly maps to a touch display too, and there are even some hardened IoT devices well suited to it.

home-assistant.io



Alternative flight simulator

Window browsing

No, you're not simulating flying the plane, you're simulating riding the plane. This charming project gives you your own window seat to the flight of your choice – although we recommend a shorter more scenic flight.

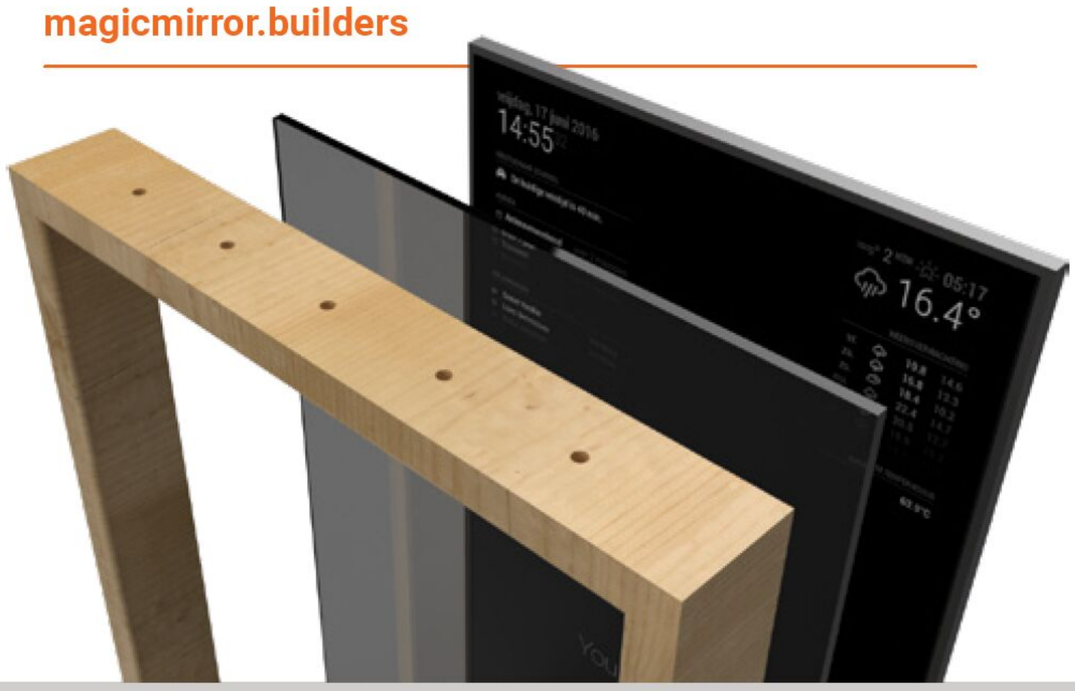
magpi.cc/alexairvideo

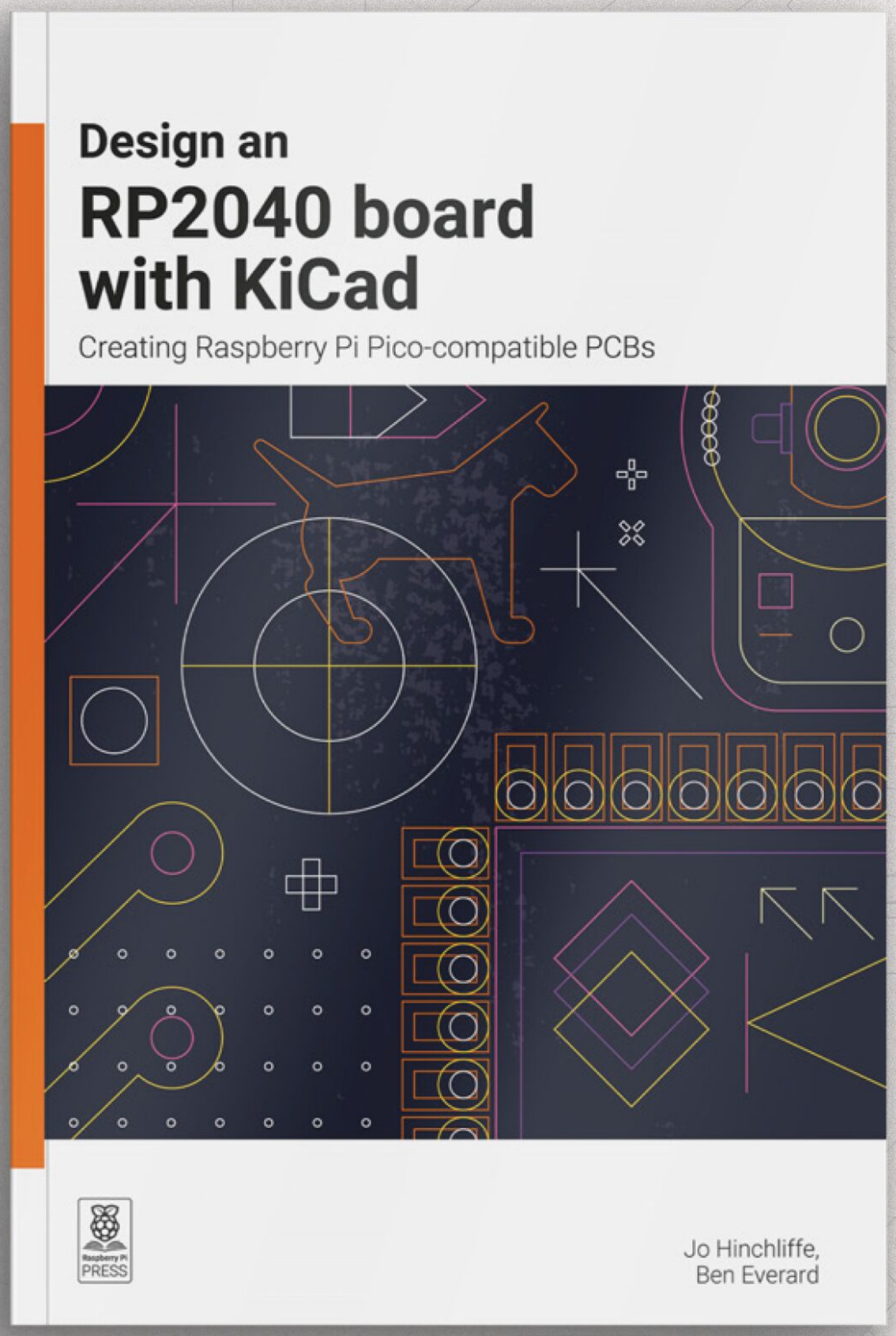
Magic Mirror

Vanity project

A classic of the genre, smart mirrors are one of those projects that are achievable yet extremely cool, reminding one of futuristic technology while also being very practical. The hardest part is the physical construction – the software is all there!

magicmirror.builders





KiCad is an amazing piece of free and open source software that allows anyone, with some time and effort, to make high-quality PCB designs.

- ***Create a schematic for a microcontroller board using Raspberry Pi's RP2040***
- *Select the right components*
- ***Customise the hardware for your needs***
- *Lay out and route the PCB design*
- ***Prepare your board for manufacture and assembly***
- *Write software to get your design working*

Buy online: magpi.cc/kicad2040

MagPi Monday

Amazing projects direct from social media!

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

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

01. The model railway upgrades continue with a new project

02. Kevin makes amazing things, but he also does nice simple bits like this. Practical!

03. That is one way to upcycle a radio – make one out of LEGO

04. Alessio informed us this was running at -10˚C

05. A very normal-looking robot, as I'm sure you'll all agree

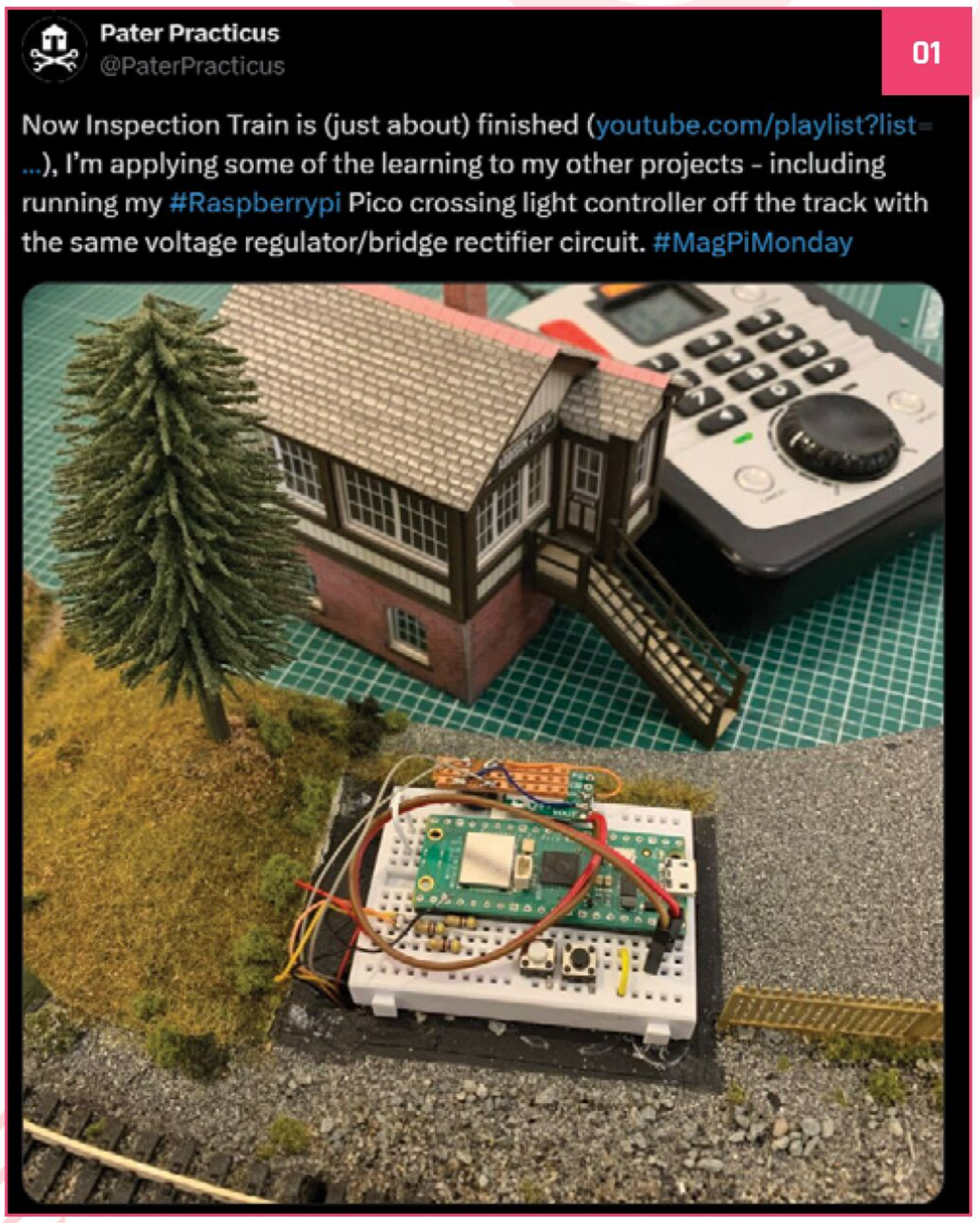
06. All clocks should look like this. We definitely have not been influenced by *Back to the Future*

07. It's never too late to look at festive projects that people made

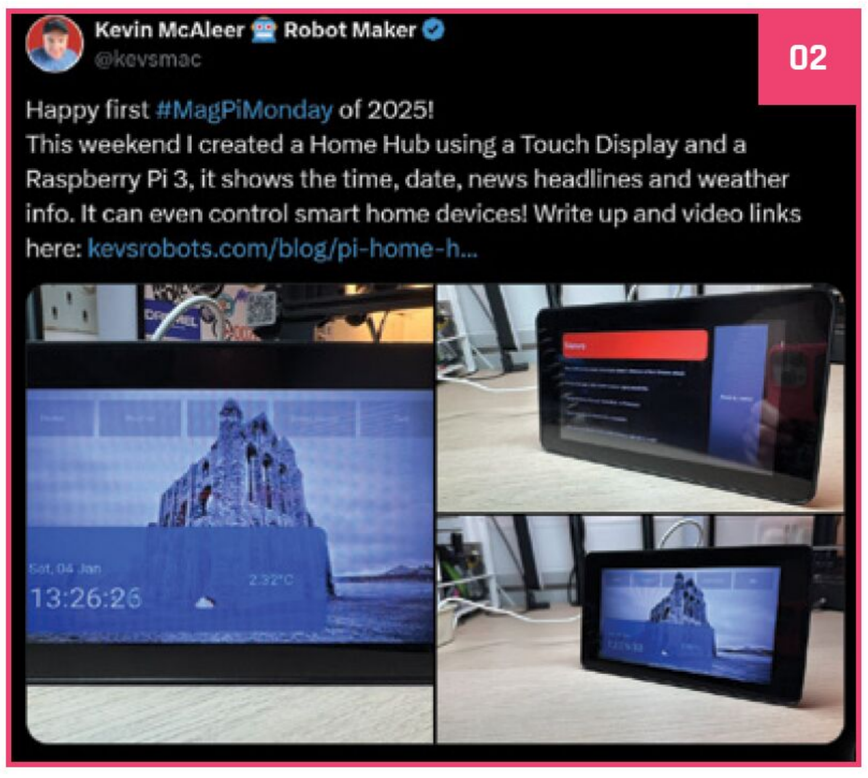
08. It's surprising how hackable the Game Boy Camera seems to be all these years later

09. We don't think this robot looks stupid at all! Sometimes function matters

01



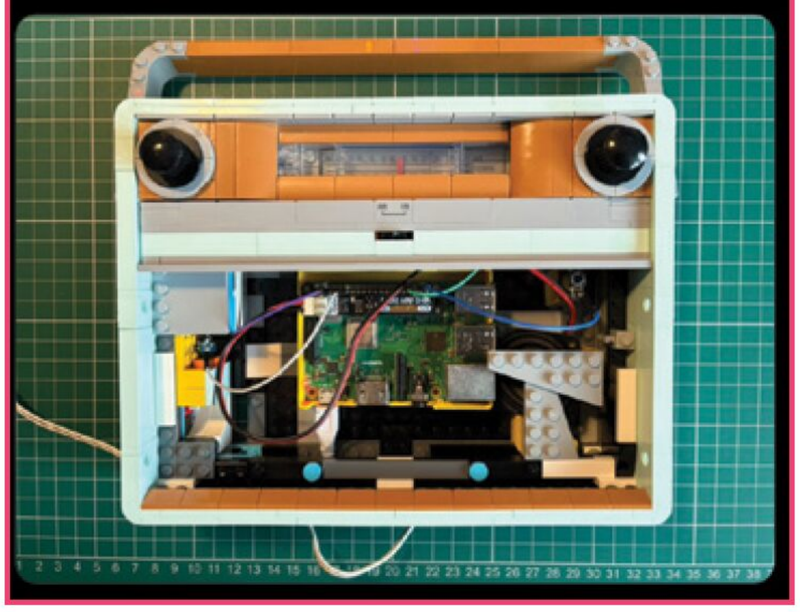
02



03

Sean McManus | Tech Writer
@musicandwords

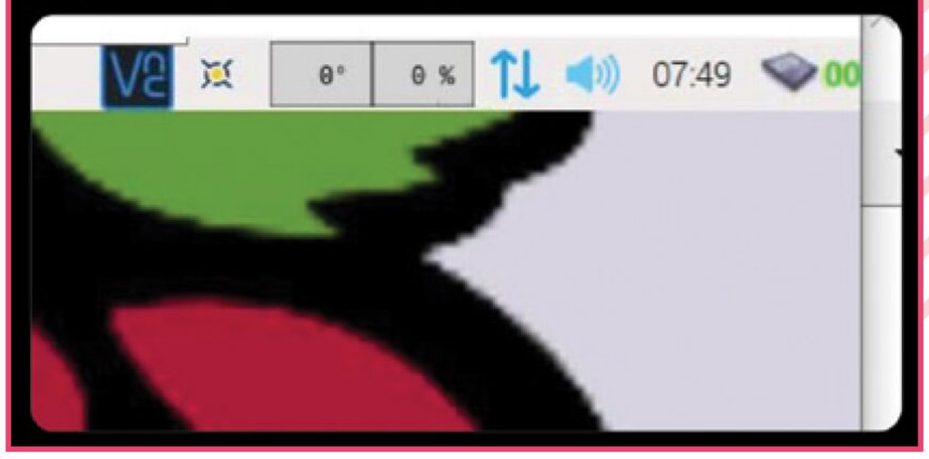
I put Raspberry Pi inside the Lego Retro Radio set and connected it to the tuning knob so now it plays my own music, and changes the song when I turn the knob. Build instructions here: sean.co.uk/raspberry_pi/l...



04

Alessio Minotti
@alemino13

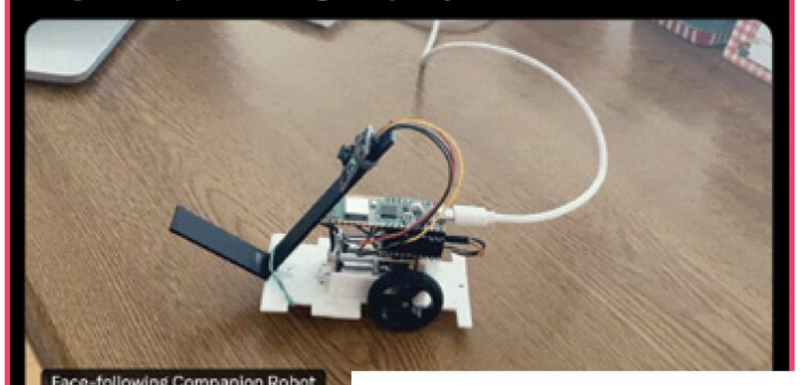
#MagPiMonday only testing how a @Raspberry_Pi works in cold temperatures ... (work like a charm)



05

knaveen
@knaveen

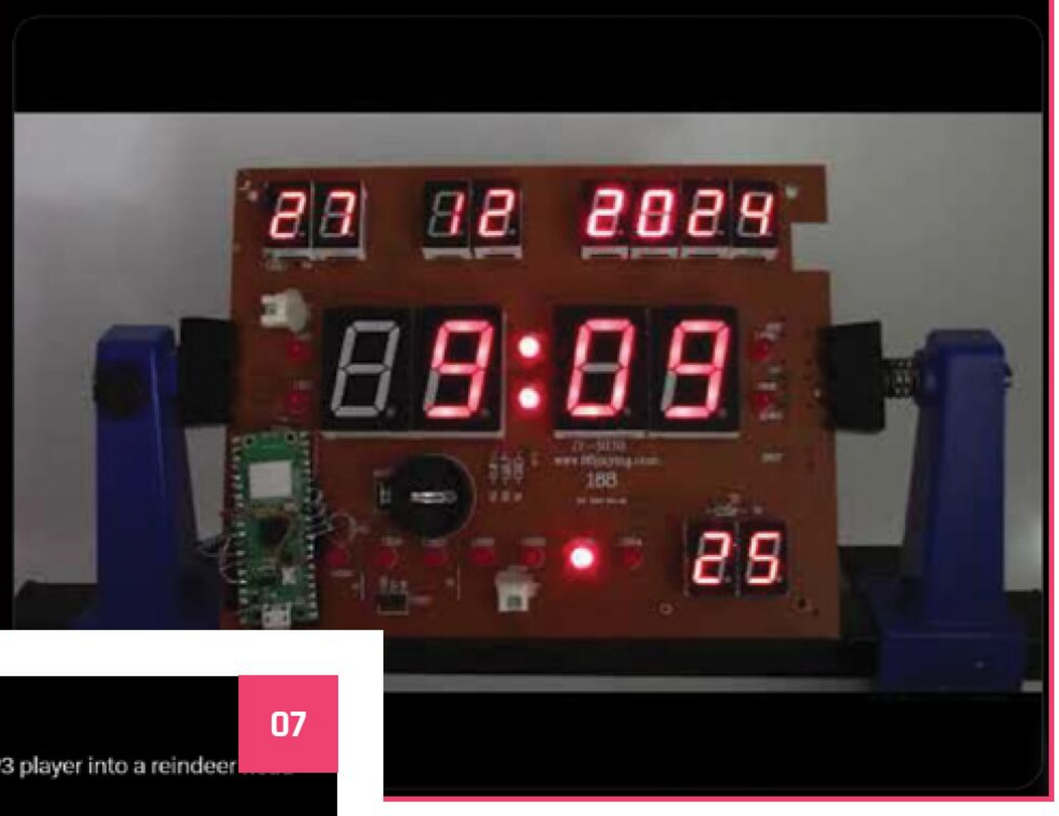
#MagPiMonday A robot using a Raspberry Pi Pico W:



06

Rodrigo Feliciano
@pakequis

Converted a regular wall clock into a NTP clock using a Raspberry Pi Pico W.



07

Stewart Watkiss
@stewartwatkiss

I've put a Raspberry Pi Pico 2W and an MP3 player into a reindeer [illegible] as a festive project.

I can now play Christmas music using a web browser which along with flashing LEDs on the reindeer antlers.

penguintutor.com/projects/pico-...

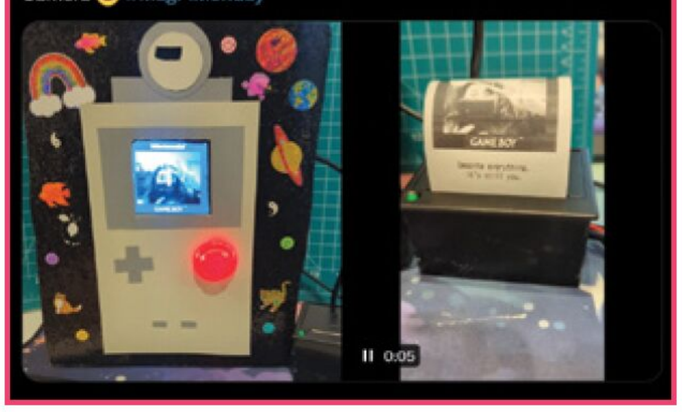
#christmas2024



08

Alicen Lewis
@alicen_lewis

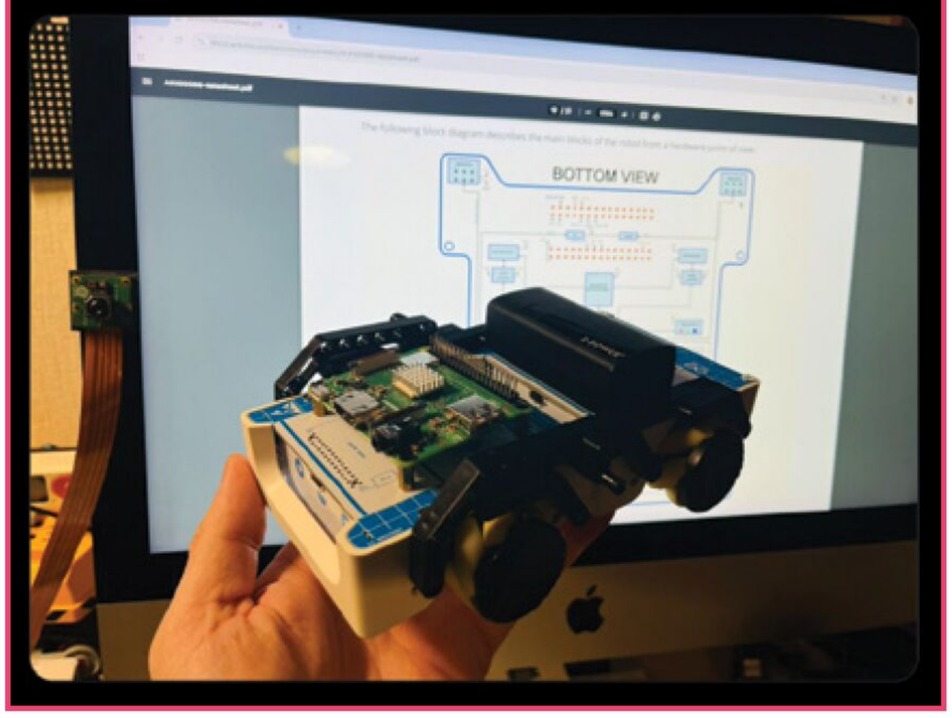
I finished my homage to the very first selfie machine, the Game[illegible] Camera 😊 #MagPiMonday



09

Roland Schulz 🧯⚡🤖
@r_schulz_maker

Hi @TheMagPi , don't call me an idiot 🤭. Maybe the stupidest idea I ever had. What's better than one @arduino Alvik? Right, two Alvik robots 🤖. Looks like a ugly cyber truck with mecanum wheels and a @Raspberry_Pi 3 Model A+ on top. #MagPiMonday #maker #micropython



Bluetooth HID Arcade Machine

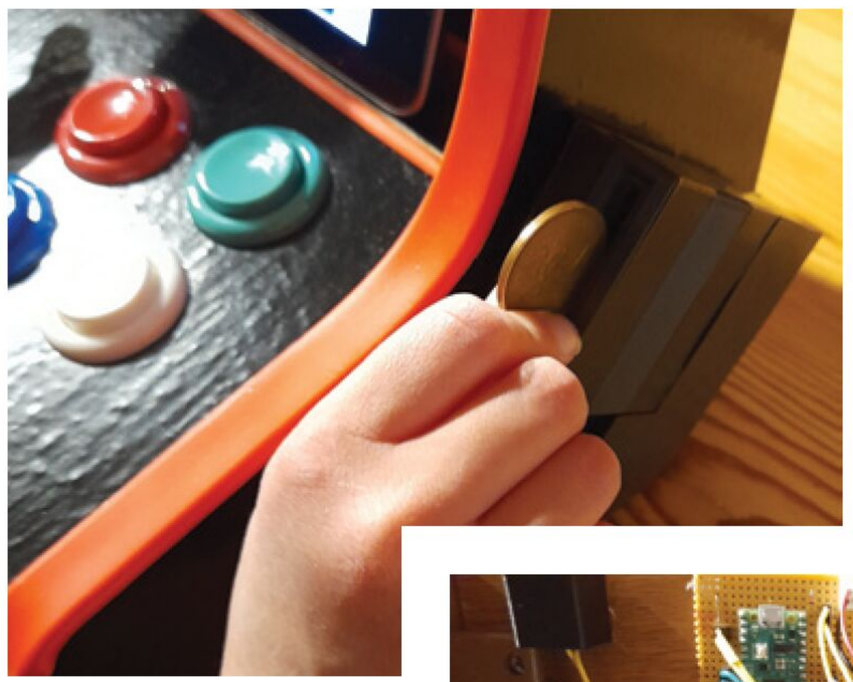
Building retro gaming projects at the weekend at Code Club

Originally submitted for #MagPiMonday over email (yes, you can do that, send 'em to magpi@raspberrypi.com if you don't have social media), we decided this one deserved a little more space.

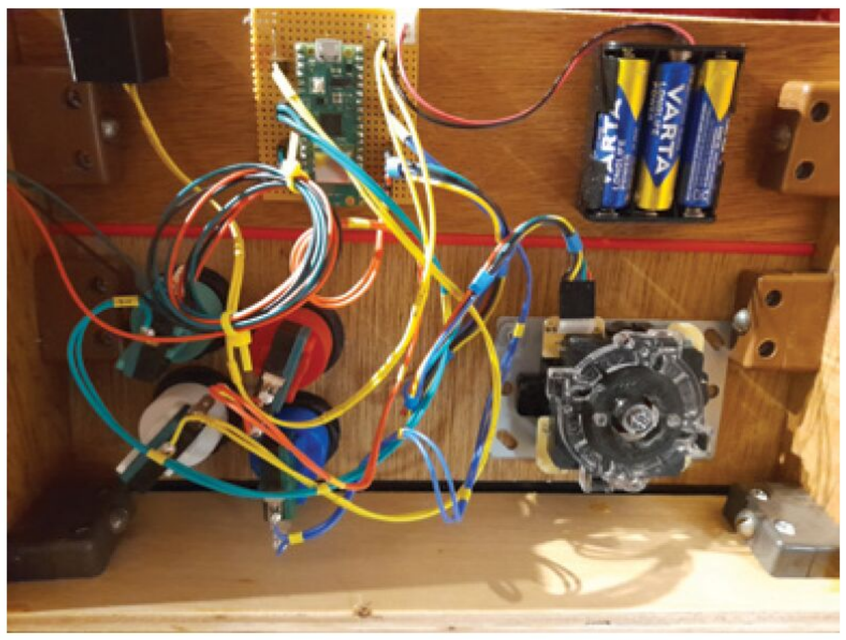
"I thought I would share my recent weekend project," Robert MacLaren says. "My daughter and I have been creating arcade games at the local code club. To showcase our work, I built an arcade cabinet. Thanks to the recent Raspberry Pico VS code extension, I have been able to build a Bluetooth HID controller that links to an iPad for playing our Scratch creations. I have even added a coin mechanism for registering 'payments'." M



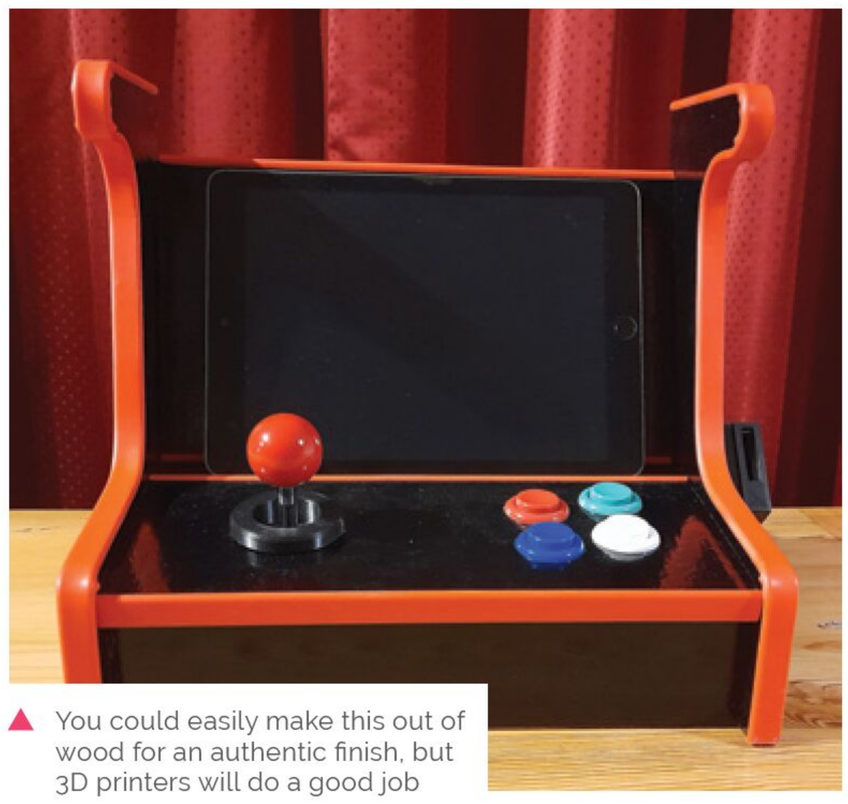
▼ Play Scratch games on iPad via Pico... amazing



▲ Give the real feeling of putting coins on the machine to let folks know you're next



▶ Pico is very well-suited for arcade inputs – no extra HATs required!

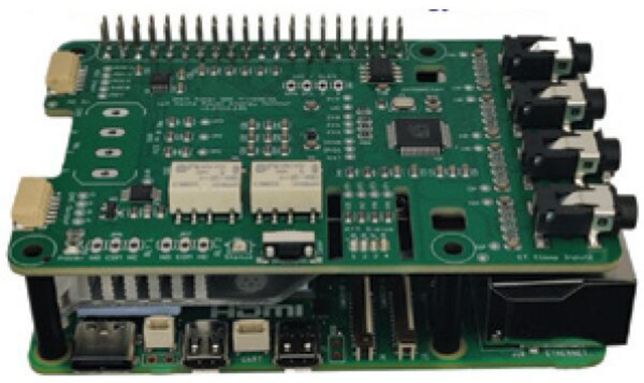


▲ You could easily make this out of wood for an authentic finish, but 3D printers will do a good job

Crowdfund this

Great crowdfunding projects this month

IPEM PIHAT ATM90 MAINS POWER ENERGY MONITOR



"As an extension to my STEM ESP32-based Home Automation Power Energy Monitors, a new expanded version has been designed for flavours of the Raspberry Pi – the IPEM PiHat… a Power Energy Monitor is hardware that essentially safely samples and collects data via one or more CT Cable Clamps. This then allows the user, through the software, to report and analyse electric energy usage. Some other examples of my monitor boards are shown below."

▶ **kck.st/3Pqc38X**

PILET



"Pilet is a retro-futuristic, open-source mini-computer powered by the Raspberry Pi 5. With 7-hour battery life and fully modifiable hardware and software, it's built for tinkerers, creatives, learners, and coders who want total freedom. Escape the limitations of closed devices and locked-down systems and bring the fun back into computing."

▶ **kck.st/426lJNt**

Together we can make a **difference**



Give young people the opportunity to learn about technology

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

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

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Raspberry Pi Foundation

Your Letters

Hardware thoughts

Unless I misunderstand the specification, Raspberry Pi 500 does not have facility for SSD storage – surely there is room on the PCB? Also, it comes with 8GB of RAM, yet I see that the new Compute Module will soon have a 16GB of RAM option, as well as an SSD storage option on the IO board. Maybe I should wait until the 16GB Compute Module 5 is available and use that as my desktop device?

On a slightly different topic, but hardware related: monitors. I know why monitors are landscape format – the original devices used CRT tubes from TV and these were landscape devices to show films (which have always been landscape in format). Yet (almost all) books and publications are portrait format. I see the new touchscreen device is natively a portrait device, but is a bit small – I am looking for a natively portrait monitor to act as the output for reading PDF and other similar documents while using [the] least desk space so I can follow their content while working at another monitor. Any thoughts? To turn a landscape device through 90 degrees is not really an option as the edges look wrong and the speakers are north / south, not east / west.

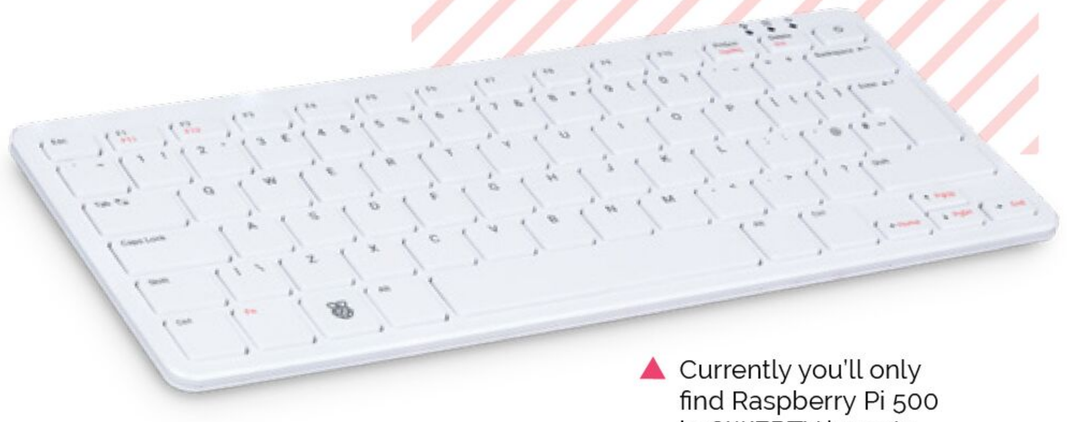
Peter via email



One of the sights in the office for a while was someone who had mounted the official monitor to their work monitor in portrait mode

When it comes to hardware choices on something like Raspberry Pi 500, it's a bit above our pay-grade unfortunately! Eben and the rest of the hardware team consider every option for things like that, though, and they will have very good reasons, sometimes cost saving to keep the price reasonable for users. I'm not sure a Compute Module 5 is the best option for a desktop anyway – it's more for development – and 8GB is plenty for Raspberry Pi OS and such.

As for monitors, that is a bit of a tricky one. Usually we find people repurpose other monitors by 3D-printing a new case for them, or something like that. You can buy monitors that do not have a frame on them, and we've used this one for portrait stuff, like the CrowVision (**magpi.cc/crowvision**). Peter also asked us if this is more taxing on the graphics processing – we've not done any specific tests ourselves, but having used many portrait-orientated monitors over the years, we'd have to say no.



▲ Currently you'll only find Raspberry Pi 500 in QWERTY layouts

En français

I'm writing to inquire about the availability of the Raspberry Pi 500 with an AZERTY keyboard layout. I'm particularly interested in using this device in French schools due to its high-quality construction and integrated screen, which would make it an ideal tool for both students and their parents.

Could you please provide information on the following:

• AZERTY availability: is the Raspberry Pi 500 currently available with an AZERTY keyboard layout? If so, where can I purchase it?

• Keyboard modification: if an AZERTY version is not readily available, is there an official or community-supported tutorial on how to swap the keys on the existing QWERTY keyboard to create an AZERTY layout?

I'm confident that many French users would find this information valuable. Thank you for your time and assistance!

Sébastien via email

There isn't an AZERTY keyboard layout right now for Raspberry Pi 500 and we've not seen any conversion modification guides, although the standard Raspberry Pi keyboard does come in an AZERTY flavour and Raspberry Pi 400 did come in a French version too.

It may just be a case of rearranging some of the keys on the board for now and setting the language to French in Raspberry Pi OS.

We also just want to mention that Raspberry Pi 500 does not have an integrated screen: you need to supply your own monitor.

Contact us!

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

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Community Events Calendar

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

01. PLUG Monthly talk/seminar

- Tuesday 11 February
- Riff/Spacecubed, Perth, Australia
- **magpi.cc/plug150**

Perth Linux Users Group are a not-for-profit for anyone interested in Unix, Linux, Free Software, Open Source software & Technology. They have many members all over Western Australia.

02. Perth Raspberry Jam

- Tuesday 11 March
- Riff/Spacecubed, Perth, Australia
- **magpi.cc/prj150**

The evening will be mostly informal, but there will be an opportunity for lightning talks, so if you would like to give a short presentation about your Raspberry Pi project, please let the committee know by email to **committee@plug.org.au**.

03. 7th Annual Raspberry Jam West Virginia

- Saturday 15 March
- Geary Student Union, Charleston, WV, USA
- **magpi.cc/rjwv150**

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

04. Hobby-X

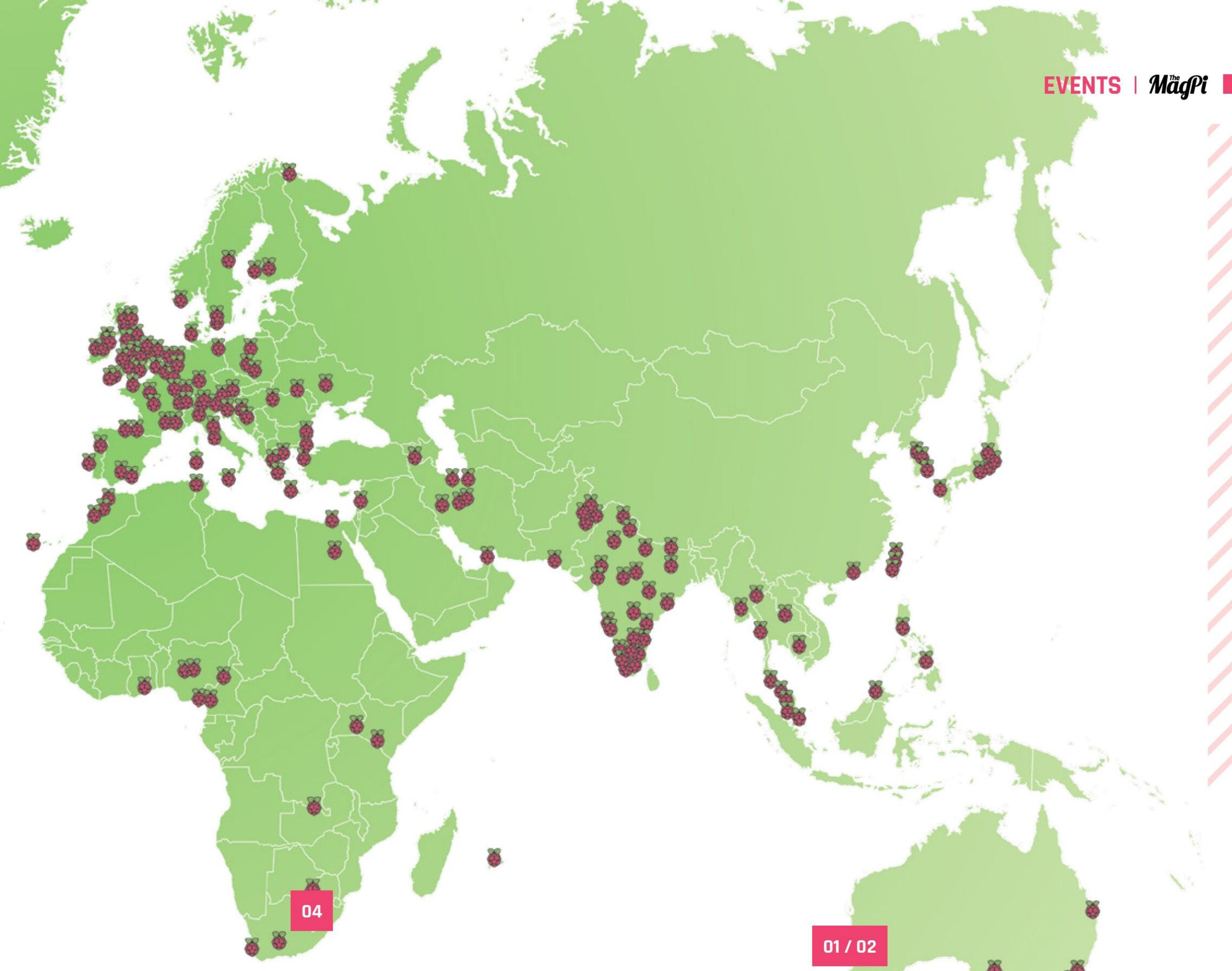
- Thursday 1 May to Sunday 4 May
- Kyalami Grand Prix Circuit, Johannesburg, South Africa
- **magpi.cc/hobbyx25**

Raspberry Pi Approved Reseller PiShop is hosting an exhibit at Hobby-X, a trade and consumer show that showcases a variety of hobbies and crafts. At Hobby-X, visitors can explore the latest products and supplies related to their favourite hobbies and crafts, learn new techniques, and connect with other hobbyists and experts in their field.

FULL CALENDAR

Get a full list of upcoming community events here:

magpi.cc/events



Embedded World 2025

- Where **Messezentrum 1, Nürnberg, Germany**
- When **Tuesday 11 March to Thursday 13 March**



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

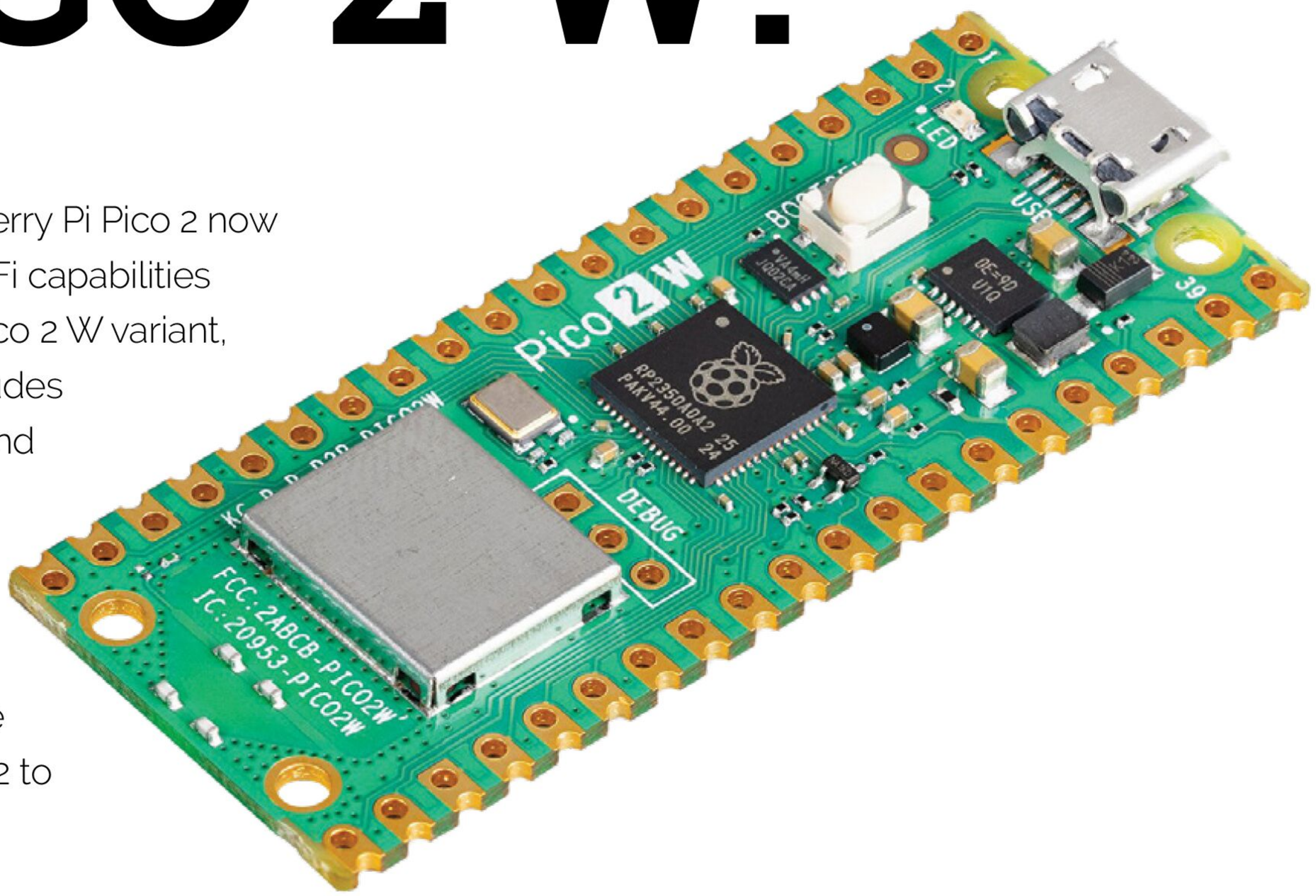
You'll be able to see how companies around the world use Raspberry Pi to support their industrial applications and discover how Raspberry Pi can help you with your own solutions.

magpi.cc/ew2025

The MagPi | COMPETITION

WIN 1 OF 15 RASPBERRY PI PICO 2 W!

It's here! Raspberry Pi Pico 2 now has built-in Wi-Fi capabilities with the new Pico 2 W variant, which also includes Bluetooth 5.2, and is supported by both C and MicroPython right now. We have 15 of these upgraded Pico 2 to give away.



Head here to enter: magpi.cc/win | Learn more: magpi.cc/pico2w

Terms & Conditions

Competition opens on **29 January 2025** and closes on **27 February 2025**. Prize is offered to participants worldwide aged 13 or over, except employees of Raspberry Pi Ltd, the prize supplier, their families, or friends. Winners will be notified by email no more than 30 days after the competition closes. By entering the competition, the winner consents to any publicity generated from the competition, in print and online. Participants agree to receive occasional newsletters from The MagPi magazine. We don't like spam: participants' details will remain strictly confidential and won't be shared with third parties. Prizes are non-negotiable and no cash alternative will be offered. Winners will be contacted by email to arrange delivery. Any winners who have not responded 60 days after the initial email is sent will have their prize revoked. This promotion is in no way sponsored, endorsed or administered by, or associated with, Instagram, Facebook, Twitter or any other companies used to promote the service.



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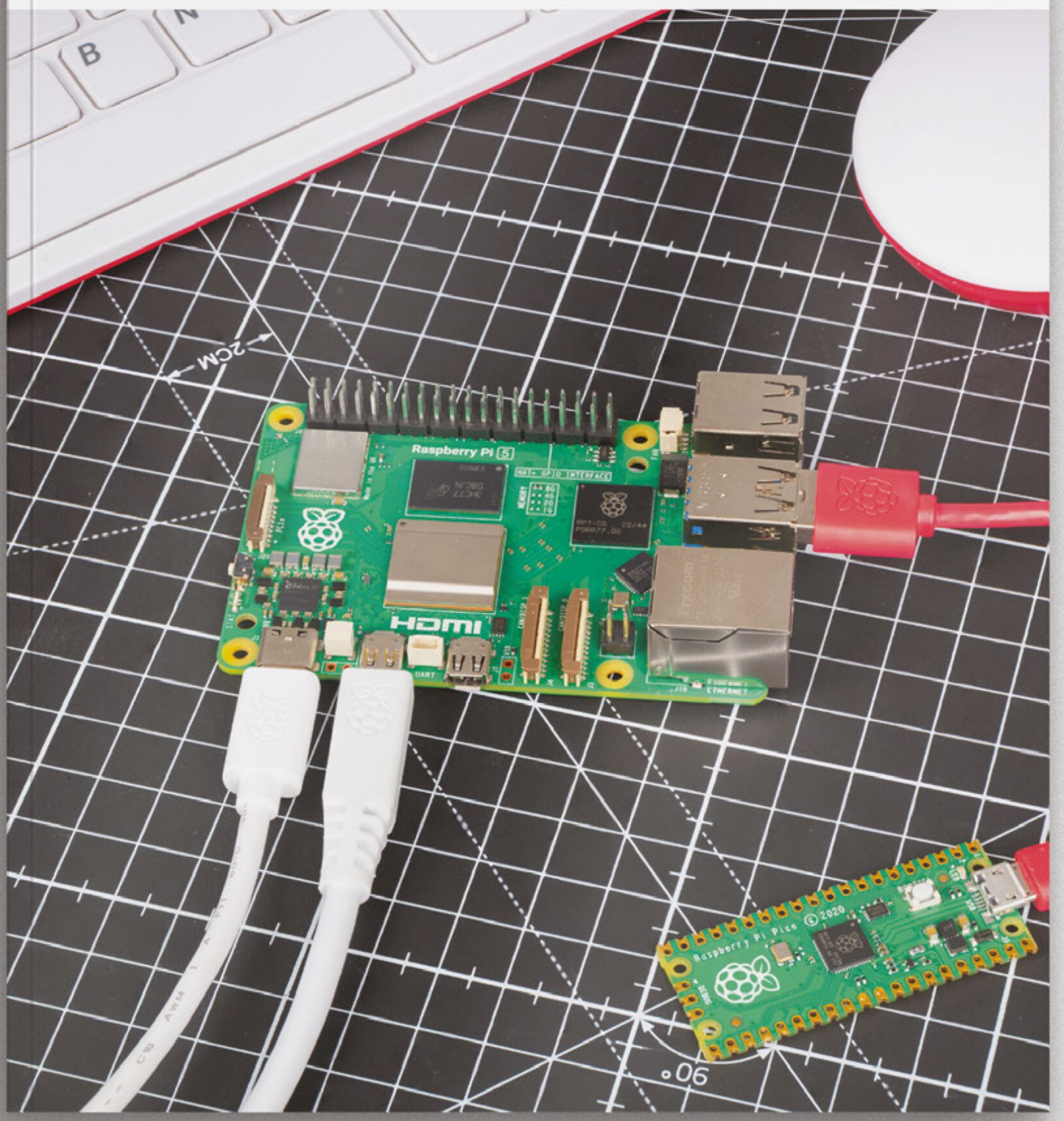
Retro Gaming
magic Mirror

Get bang on time
with **Python dates**

10 Amazing
Cooking projects

Raspberry Pi

Official Magazine
#151 | March 2025



Raspberry Pi Official Magazine



We have big news. Next month we are changing the name of the magazine to Raspberry Pi magazine.

We've always been tremendously proud of *The MagPi*. Our magazine started out as a community fanzine and was handed over to Eben Upton, Raspberry Pi's co-founder. From issue 31, we have always referred to ourselves as "The official Raspberry Pi magazine".

Now we're making it legitimate. This is a big and significant move for us. We think it's absolutely the right thing to do.

Raspberry Pi magazine exists to unite the community around this fabulous computer that we all build and share projects with.

Every year a lot of new Raspberry Pi owners discover us. Especially coding and engineering newcomers who are building projects with a computer for the first time. They need to be able to find us quickly so we can help them get into making with a community of like-minded people. Having a name that is synced with Raspberry Pi will help us do that.

Being called Raspberry Pi magazine also better reflects who we are. The team that makes this magazine is part of Raspberry Pi Towers in Cambridge. This gives us unparalleled access to the incredible teams of people who make this amazing computer. We get to tell the official story of Raspberry Pi. We are part of Raspberry Pi.

We believe this official name will enable us to continue making this brilliant magazine for many years to come. Most of our readers subscribe to the magazine (**magpi.cc/subscribe**), and we make PDFs available, hang out on most digital platforms, and you can always read us in the Bookshelf app in Raspberry Pi OS.

We're going to take this opportunity to redesign the magazine and harmonise the design with our incredible documentation.

Just look at how cool that cover is!

The Raspberry Pi design team is amazing and we're proud to work with them!

Everything else in the magazine will remain the same. We'll still cover all the great projects you build, review new products, and bring you the behind-the-scenes interviews and news from Raspberry Pi. Content-wise we will remain the same. We will continue from issue 151 so we do not lose our running streak.

I hope you'll be supportive of this change. We're absolutely open to feedback of all forms. Please feel free to email me or drop us a line on the Raspberry Pi forums (**magpi.cc/forum**).

Lucy Hattersley, Editor

lucy@raspberrypi.com

Raspberry Pi magazine #151 On sale 27 February

Plus!

- RISC OS on Raspberry Pi 500
- Ubuntu on 16GB Raspberry Pi
- Getting smart with AI HAT+

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Raspberry Pi PRESS

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A new look

Goodbye The MagPi, hello Raspberry Pi magazine! By **Rob Zwetsloot**

Well, the secret is out – from next issue, we'll no longer be *The MagPi* but instead transform into Raspberry Pi magazine. I understand change can be scary, so straight away I want to assure you that you'll still get the same selection of amazing projects, brilliant tutorials, expert reviews, and community round-ups that you've come to expect from the magazine over the last decade.

Ever since we absorbed HackSpace into *The MagPi*, we've been trying to figure out how to integrate the articles into the joint magazine. Personally, the kind of things we got out of a HackSpace section have been the kind of articles we've been missing in the magazine for a little while, so I was excited to see them in *The MagPi*. However, the separate HackSpace section was always going to be temporary as we figured out how to get consistency throughout the mag.

This has resulted in the rebrand. Everything is going to be integrated together in some way or another, making the magazine flow better in my opinion.

Fresh makeover

Ever since we moved design in-house a year or so ago, we've been thinking about doing a little redesign of *The MagPi* as it was. The last time we did a refresh of the design was a very long time ago by magazine industry terms, and our new team thought we should be more efficient in the way design is handled.

While we're not starting the design from scratch, a rebrand like this lets us take a deeper look at what we want to change. I do read all your emails regarding the current design and I have been relaying this feedback as we tweak stuff. The results so far have been a clean refresh more in line with materials put out by the rest of Raspberry Pi, and using a little more of the space on the page too. You can get a glimpse of what we're cooking by flipping the page back.

> "With the redesign, we'll be able to deliver to you the great stuff we've always had but in a better package"

We'll likely still be tweaking stuff as we go, as is the nature with magazine design, but we have a strong foundation to start from.

The MagPi + HackSpace

With the redesign, we'll be able to deliver to you the great stuff we've always had but in a better package. Consistency and a unified look will make the magazine more cohesive and coherent too, making it a better reading experience. We're also not resetting the number – Raspberry Pi magazine will be issue 151, so your collection will not be wasted and can continue for another 150 issues (at least, maybe, I hope).

We're also very open to hear about your suggestions for what you'd like to see in this refreshed magazine, as this is the magazine for the Raspberry Pi community after all. As always, you can contact us at **magpi@raspberrypi.com**.

I'll see you next issue for a whole new world of Raspberry Pi.

AUTHOR

Rob Zwetsloot

Rob has been working on *The MagPi* since it became the official magazine a decade ago, and is excited for the bold new direction.

magpi.cc

HiPi.io

HIGHPI PRO

The new case from the HiPi.io team



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

PiShop.us PiShop.ca PiShop.mx ThePiHut Pi-Shop.ch Welectron.

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

PiKVM

Remote control **redefined**

Manage your servers or PCs remotely!

Powered by Raspberry Pi

PiKVM V4 Mini

Small, cost-effective, and powerful!

- Power consumption in idle mode: just 2.67 Watts!
- Transfer your mouse and keyboard actions
- Access to all configuration settings like UEFI/BIOS
- Capture video signal up to 1920x1200@60 Hz
- Take full control of a remote PC's power

PiKVM V4 Plus

The most feature-rich edition

- More connectivity
- Extra storage via internal USB3.0
- Upgraded powering options
- More physical security features
- Extra HDMI output
- Advanced cooling solution



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

Available at the main Raspberry Pi resellers

core ELECTRONICS · PiShop.ca · RPishop.cz · Welectron. · elektorstore · PIMORONI

Pi-Shop.ch · The PiHut · PiShop.us · CloudFree · KUBII · Cytron Marketplace

ROBU.IN Your ideas, Our Parts · NETTOP COMPUTERS & ELECTRONICS · netsket mall · DIREKTRONIK · RaspberryPi.dk

HiPi.io

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

List of official resellers by country: