THE OFFICIAL RASPBERRY PI MAGAZINE

The MagPi + HackSpace

Issue 145 | September 2024 | magpi.cc

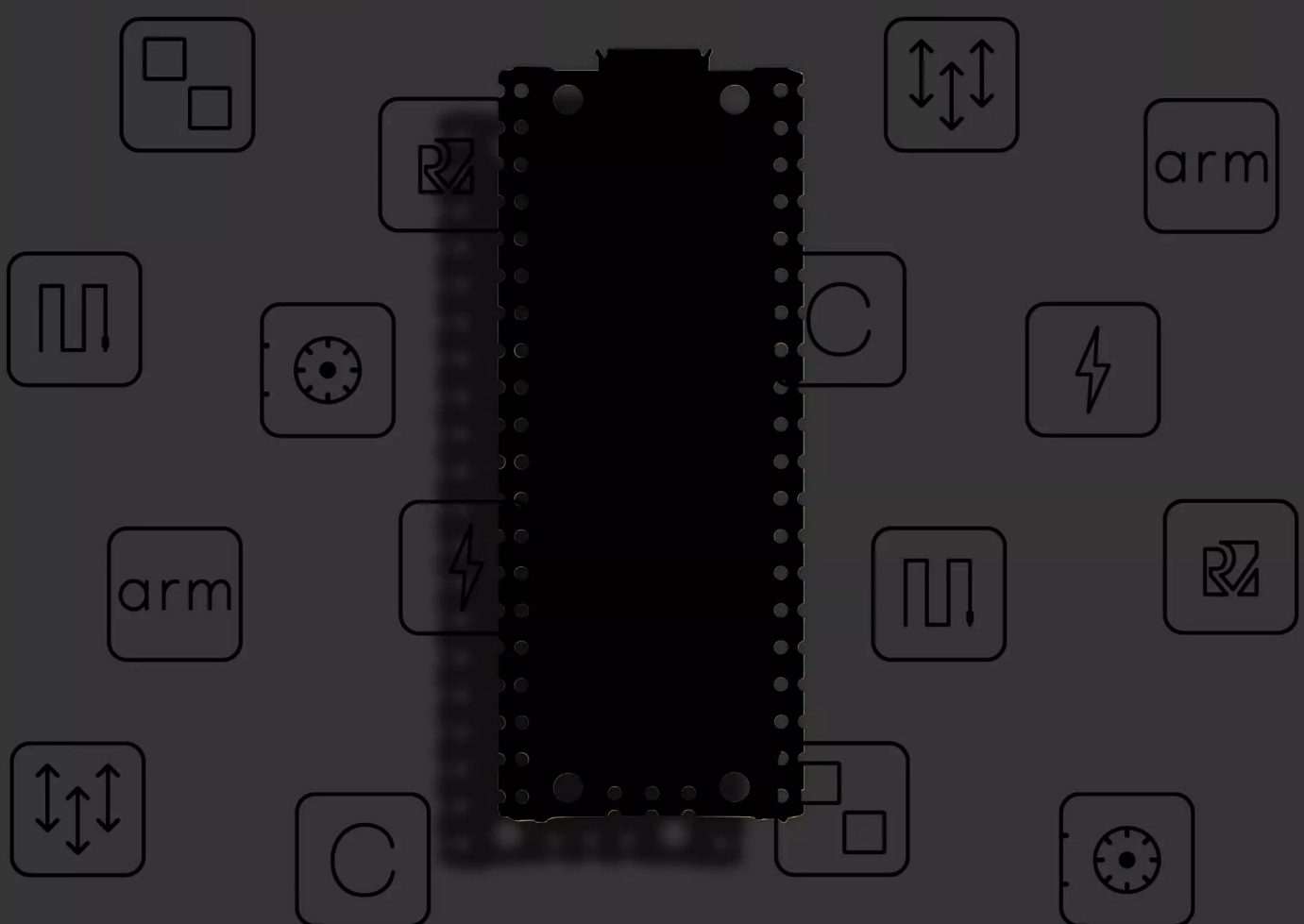
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Raspberry Pi Pico 2

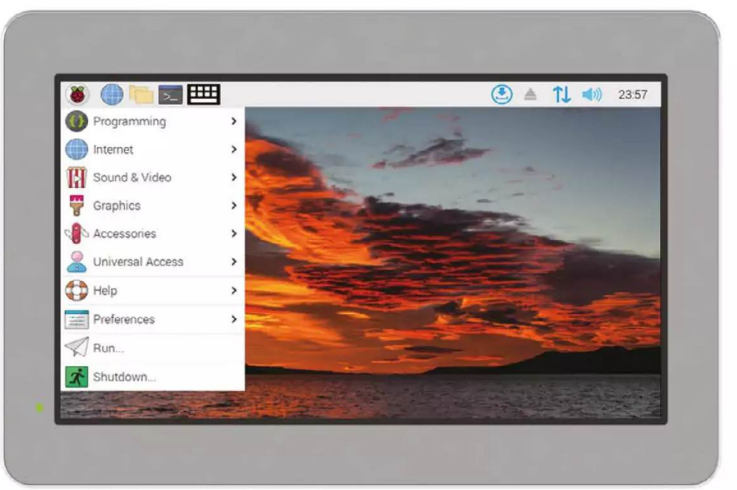
Ultra-fast Arm & RISC-V Cores • **Incredible** Energy Efficiency • **Enhanced** Security



EXCLUSIVE! PICO 2 ENGINEERING INTERVIEWS

Industrial Raspberry Pi
ComfilePi





UL LISTED

Powered by Raspberry Pi

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

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

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COMFILE TECHNOLOGY

WELCOME
to The MagPi 145

This is an important issue! This month: Pico 2 and its RP2350 microcontroller are our cover stars. The new RP2350 chip offers us an incredible way to learn the fundamentals of computing. And we can apply these engineering skills to the real world.

RP2350 is faster, more secure, and has both ARM and RISC-V cores inside. Andrew has written a great feature with interviews with the engineering team: read it on page 40. Elsewhere, companies have been quick to adopt RP2350 and it's now inside dozens of devices. Rob has a round-up of all the RP2350 kit on page 92.

The MagPi is bigger than ever, and now includes projects and tutorials from *HackSpace* magazine: I talk about this more on page 130. With *The MagPi* including *HackSpace* we've got a bigger, better magazine with a very bright future ahead of it. We hope you enjoy it.

Lucy Hattersley Editor



EDITOR

Lucy Hattersley

Lucy is the editor of The MagPi and for the last few months has been playing with Pico 2. She wishes she could talk about this stuff in advance, but you know how it is with lawyers.

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GET A RASPBERRY PI PICO W WITH A SUBSCRIPTION! PAGE 38



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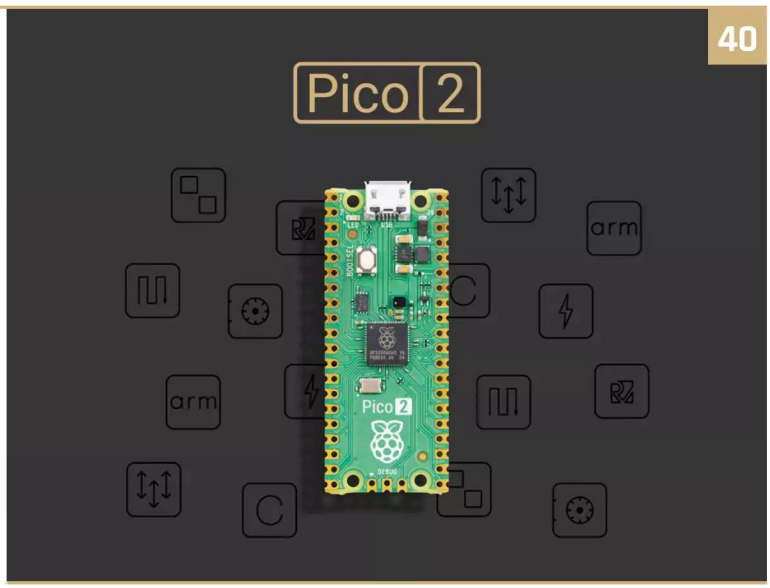
ECIA MEMBER
Supporting the Authorized Channel

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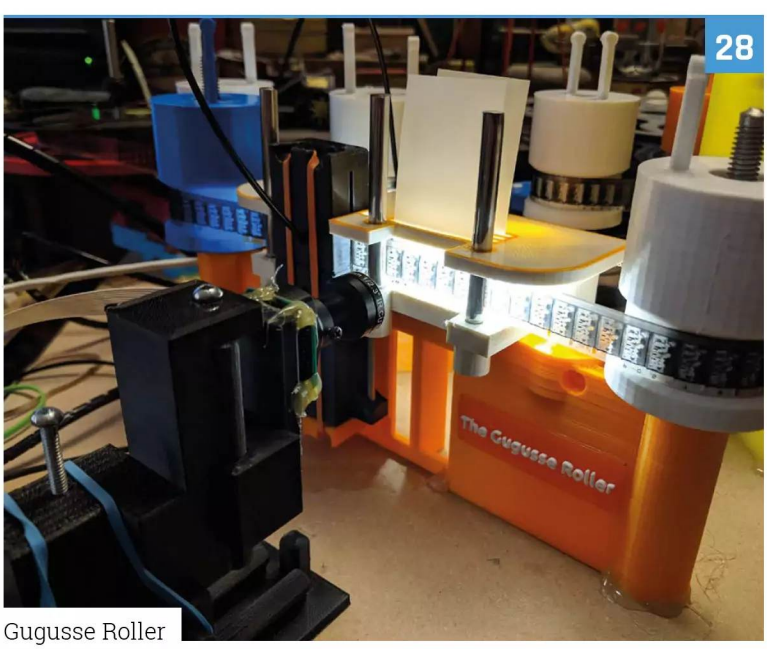
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Poetry cam



Gugusse Roller

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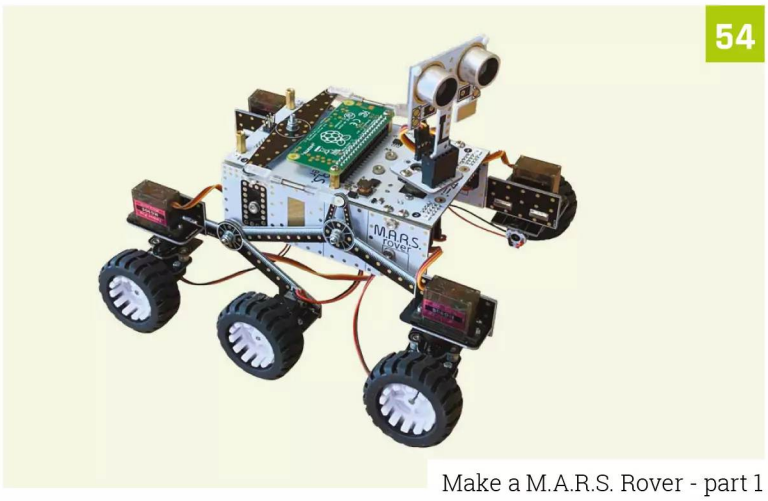


Hydroponic tower

Best of Breed



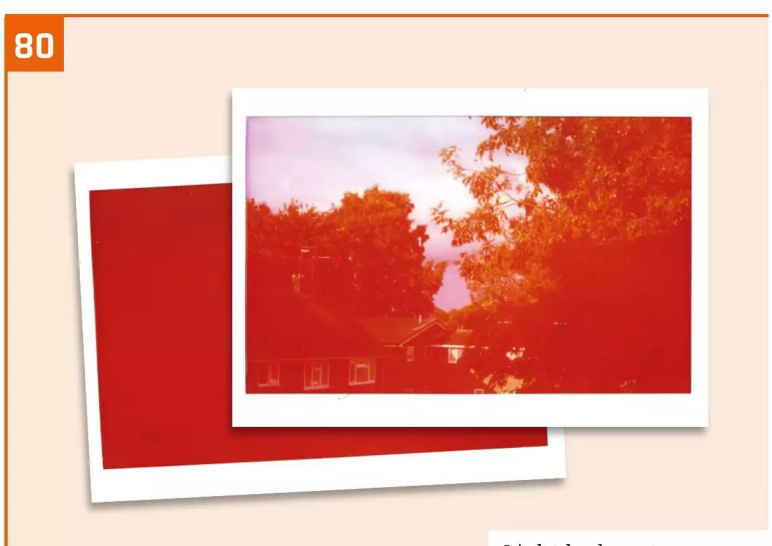
Powering your projects



Make a M.A.R.S. Rover - part 1



Tiny PC

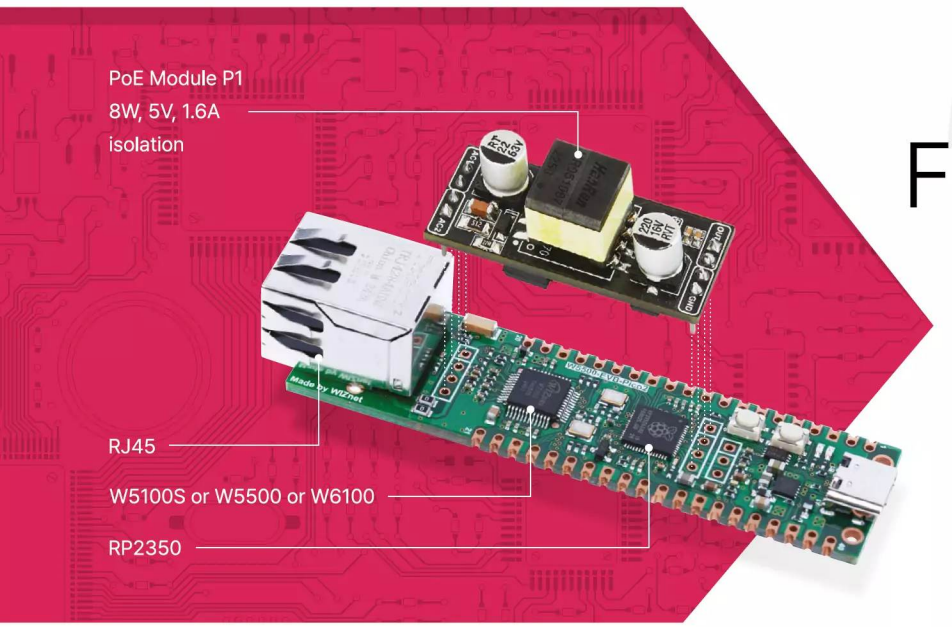


Light leaks retro camera

WIZnet

Ethernet connectivity solution
for **RP2350**

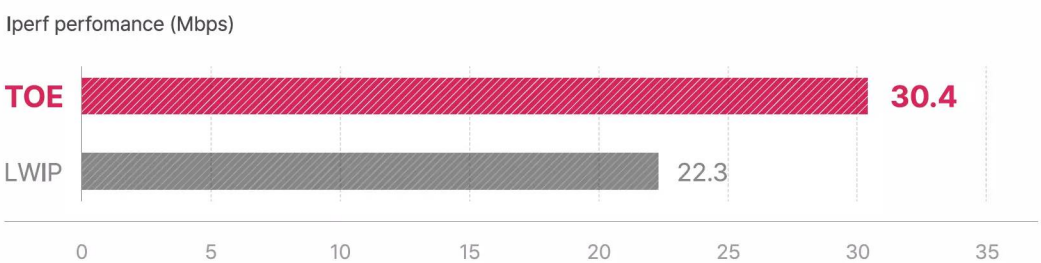
EVB-Pico2
Family boards



Features

- Available in W5100S, W5500 or W6100 version
- PoE enabled via add-on module
- Identical pinout with Raspberry Pi Pico
- USB Type C
- Run button available

TOE vs LWIP comparison



Tests were done using
RP2350 (150Mhz) and
W6100 (SPI set to 37.5Mhz)

PoE Module specifications

WIZPoE - S1



IEEE802.3af compliant
Mode A(Endspan), Mode B(Midspan)
Wide input voltage range 40Vdc ~ 60Vdc
High DC/DC conversion efficiency

Non-Isolation
Internal build in 2 channel
bridge rectifiers
5V/8W Output

WIZPoE - P1

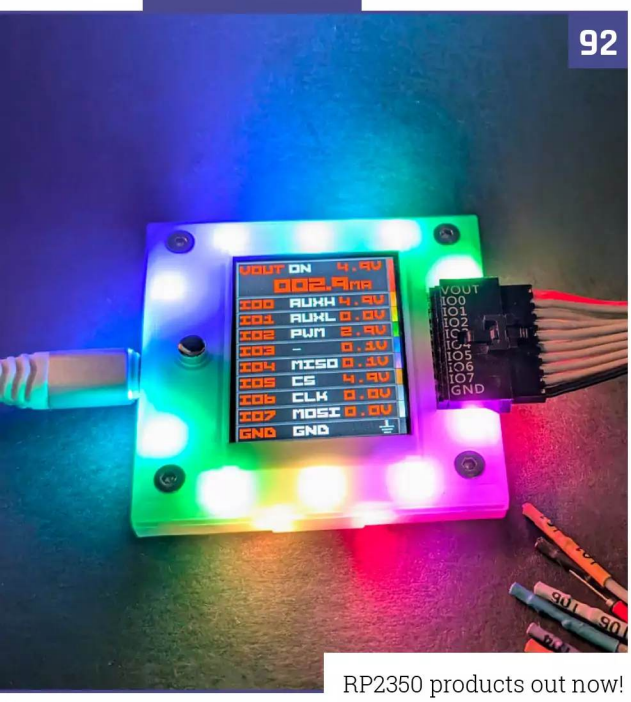


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Wide input voltage range 40Vdc ~ 60Vdc
High DC/DC conversion efficiency

Isolation
Internal build in 2 channel
bridge rectifiers
5V/8W Output

For reselling & bulk purchases, please contact direct@wiznet.io

The Big Feature



RP2350 products out now!



Thumby Color

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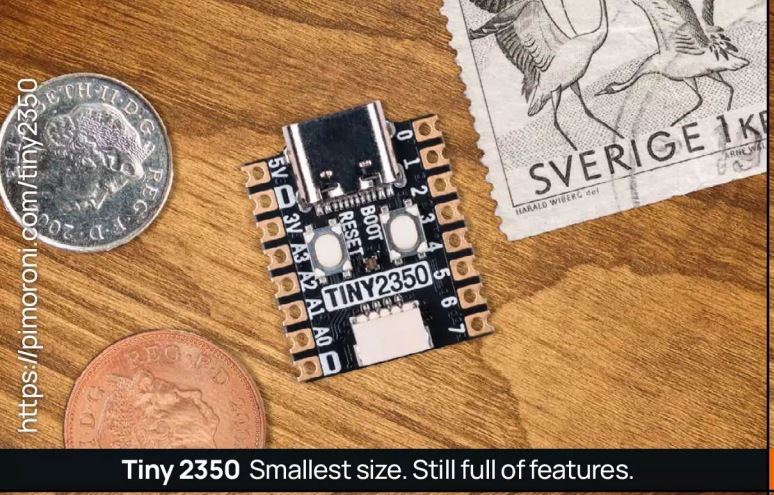
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Andrew Gregory interview

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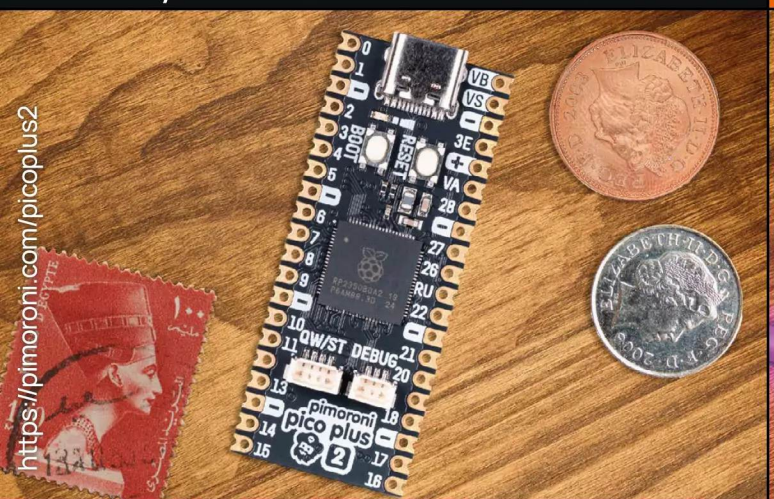
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Tiny 2350 Smallest size. Still full of features.



PGA2350 Breaks out 64 RP2350B pins. Ultimate hacking



Pico Plus 2 Top-spec dev board. 16MB flash. 8MB PSRAM



Plasma 2350 Dedicated LED strip driver board



Pimoroni Explorer Portable Electronics Playground



Pico Jumbo A working 350% size Pico 2. Banana not included.

Our Motley Crew **RP2350**

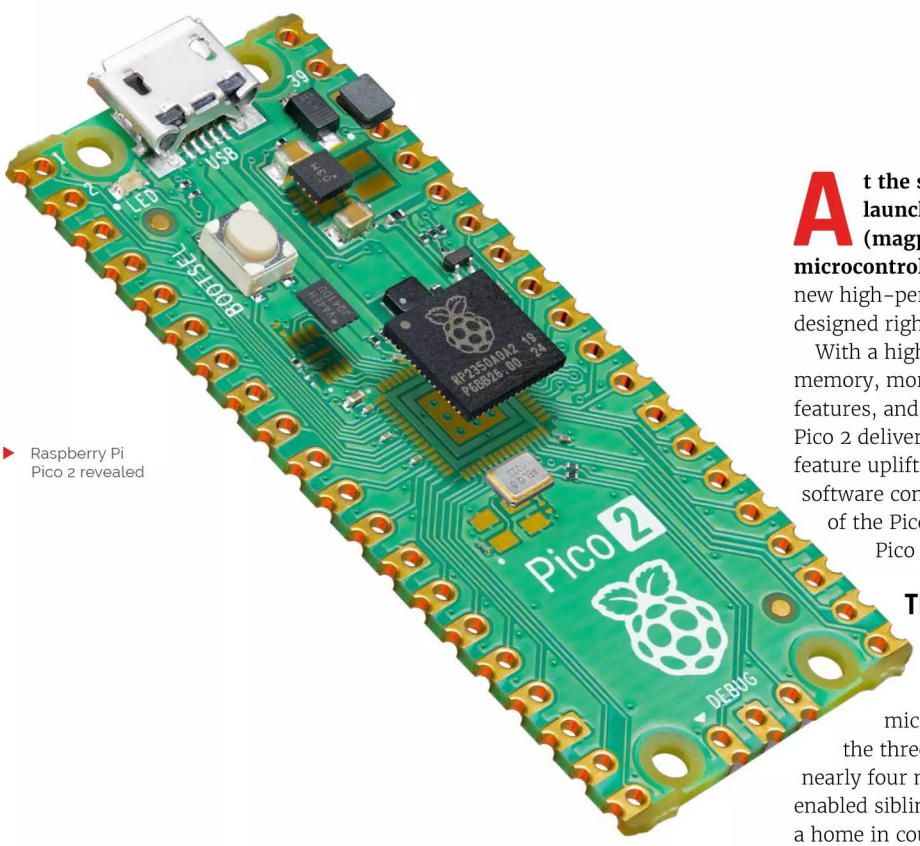
PIMORONI

Made in Sheffield, UK, by pirates

Raspberry Pi Pico 2

Our new $5 microcontroller board, on sale now

By **Eben Upton**



▶ Raspberry Pi Pico 2 revealed

At the start of August, we announced the launch of Raspberry Pi Pico 2 (magpi.cc/pico2), our second-generation microcontroller board. It's built on RP2350: a new high-performance, secure microcontroller designed right here at Raspberry Pi.

With a higher core clock speed, twice the memory, more powerful Arm cores, new security features, and upgraded interfacing capabilities, Pico 2 delivers a significant performance and feature uplift, while retaining hardware and software compatibility with earlier members of the Pico series.

Pico 2 is on sale now, priced at $5.

The engineer's microcontroller

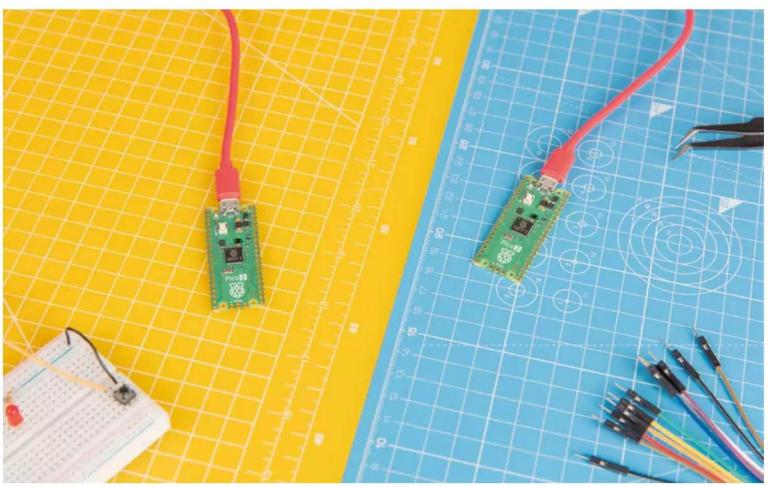
Back in January 2021, we surprised everyone with the launch of the original Pico, and our RP2040 microcontroller (**magpi.cc/rp2040**). In the three and a half years since, we've sold nearly four million units of Pico and its wireless-enabled sibling Pico W. RP2040 itself has found a home in countless third-party development boards, and in OEM products from pinball tables to synthesizers.

We've used a lot of other microcontrollers over the years, and we built RP2040 to be the microcontroller we'd always wanted: two fast 32-bit cores, lots of on-chip RAM, and flexible interfacing – courtesy of our programmable I/O (PIO) subsystem – all tied together by deterministic bus fabric which lets the best developers squeeze every drop of concurrent power out of the system. We've seen some amazing demonstrations of that power: from our very own Graham Sanderson's port of *Doom* (**magpi.cc/rp2040doom**); to Dmitry Grinberg's port of PalmOS (**magpi.cc/palmos**); to Kevin Vance's 'CPU-less' Commodore 64 cartridge (**magpi.cc/c64pico**).

But while RP2040 has succeeded beyond our wildest dreams, we always knew we could do better. There were features on our own list that didn't make the cut first time round: on-chip storage; lower-power idle states; package options. And there were new features requested by the army of RP2040 users: faster cores; more RAM; code protection.



▲ The new RP2350 microcontroller



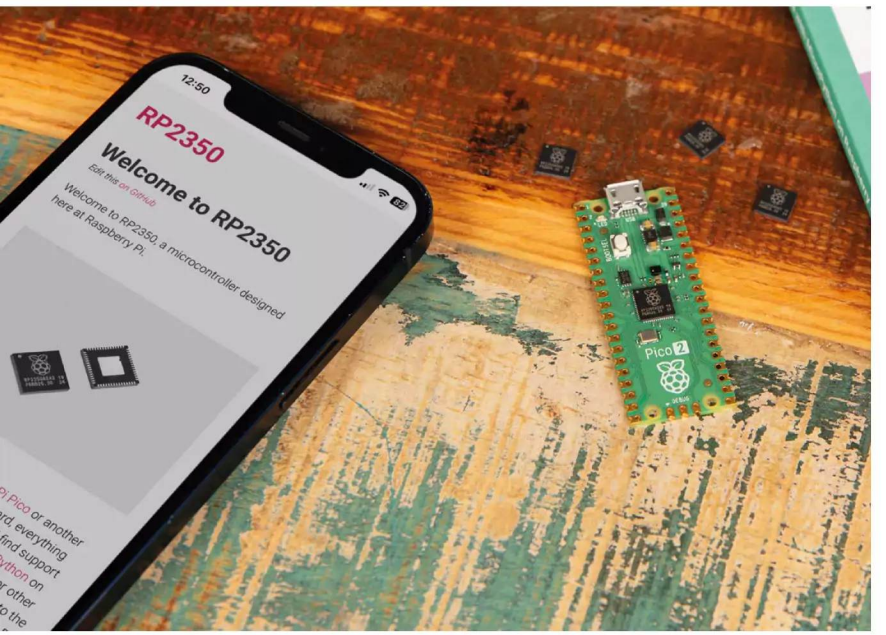
▲ Pico 2 brings more speed and security

> Pico 2 delivers a significant performance and feature uplift

Enter RP2350

So, two years ago, with the RP1 I/O controller for Raspberry Pi 5 in the bag, the Raspberry Pi chip team started work on what would become RP2350 (**magpi.cc/rp2350**). This is a vastly more sophisticated design than RP2040, featuring:

- Two 150MHz Arm Cortex-M33 cores, with floating point and DSP support
- 520KB of on-chip SRAM in ten concurrently accessible banks
- A comprehensive security architecture, built around Arm TrustZone for Cortex-M, and including:
- Signed boot support
- 8KB of on-chip antifuse one-time-programmable (OTP) memory
- SHA-256 acceleration
- A hardware true random number generator (TRNG)
- An on-chip switch-mode power supply and low-quiescent-current LDO
- Twelve upgraded PIO state machines
- A new HSTX peripheral for high-speed data transmission
- Support for external QSPI PSRAM



▲ Pico 2 alongside the new Pico documentation

Where RP2040 provides only a single 7×7mm, QFN56 package option, this time we're offering a choice: a 7×7mm, QFN60 package (RP2350A) with 30 GPIOs, or a 10×10mm, QFN80 package (RP2350B) with 48 GPIOs; and variants of each with 2MB of stacked-in-package QSPI flash (RP2354A and RP2354B).

And we've stayed true to our affordable roots: although our silicon die now measures an extravagant 5.3mm², versus 2.7mm² for RP2040, RP2350A will be just 10¢ more expensive, costing $0.80 in 3,400-unit reels, or $1.10 in single-unit quantities. RP2350B will cost 10¢ more than RP2350A, while the RP2354 variants will cost just 20¢ more than their flashless brethren.

▶ RP2350A and RP2350B comparison table

	QFN60	QFN80
No flash	**RP2350A** $0.80	**RP2350B** $0.90
2MB flash	**RP2354A** $1.00	**RP2354B** $1.10

RP2350 will be generally available in volume before the end of 2024. To register your interest, and to participate in our samples program, head over to the product page (**magpi.cc/rp2350**).

Board games

Pico 2 pairs RP2350A with 4MB of external QSPI flash, up from 2MB on the original Pico. It is compatible with the original Pico design in both form factor and electronically.

While there was relatively little stock in the channel on launch day, Pico 2 has been in full-rate production with our friends at Sony since the end of July. Many of our Approved Reseller partners are operating backorder and reservation schemes, and we are shipping units to them on a regular basis.

Before the end of the year, we expect to ship a wireless-enabled Pico 2 W, using the same Infineon 43439 modem as Pico W, and versions of both Pico 2 and Pico 2 W with pre-installed 0.1-inch headers.

Software and documentation

Raspberry Pi is as much a software company as it is a hardware company: developers experience our hardware products through the lens of our software platforms, and we spend an enormous amount of time and money on polishing those platforms up.

As you'd expect, the launch of Pico 2, and RP2350, is accompanied by an updated release of the Pico SDK (**magpi.cc/picosdk**), and by new MicroPython (**magpi.cc/micropythonpico2**) and CircuitPython (**circuitpython.org**) images. And Jonathan Pallant (**magpi.cc/picorust**) and his co-conspirators have been working to bring the Rust language (**magpi.cc/rp2350hal**) to our new platform.

We've been collaborating with the Trusted Firmware (**trustedfirmware.org**) project to establish RP2350 as the reference hardware platform for the Trusted Firmware-M 2.1.0 Long Term Support release (**magpi.cc/tfmlts210**). TF-M provides a reference implementation for PSA Certified on Arm v8-M chips, providing developers with an easy route to secure devices against common attacks. RP2350 will be laboratory tested by a certified, independent lab, with the goal of achieving PSA Certified Level 2 ahead of release in October.

Finally, we're pleased to be teaming up with Google to launch the Pigweed SDK with native support for Pico 2. Pigweed's middleware libraries have shipped in millions of devices, including Google's own Pixel devices and Nest thermostats. Now, the Pigweed SDK makes it even easier for you to use these components when building your projects for Pico 2. Head over to Google's announcement site (**magpi.cc/pigweedsdk**) or turn to page 14 of this magazine to learn more!

As with all our silicon products, RP2350 is accompanied by a comprehensive datasheet (**magpi.cc/rp2350data**). We're also providing a tutorial showing you how to get started with C/C++ development (**magpi.cc/getstartedpico**) using the newly updated Raspberry Pi Pico Visual Studio Code extension (**magpi.cc/picovscode**).

Painting a target on our backs

The cornerstone of the RP2350 security model is signed boot. If security is enabled, it is only possible to boot a binary if it has been signed using a private key, with a hash of the corresponding public key stored in OTP. Preventing an attacker from running arbitrary code greatly complicates the task of extracting OTP contents, including cryptographic keys used for code protection.

> We're offering a $10,000 bounty for the first confirmed break of our signed boot process

Other vendors' track record in implementing boot security is pretty dismal. Broad-market microcontrollers often lack effective countermeasures against modern fault-injection attacks, such as those employed in LimitedResults' Debug Resurrection (**magpi.cc/nrf52resurrect**) attack on Nordic nRF52 devices, and Chris Gerlinsky's work on bypassing Code Read Protection in NXP LPC family devices (**magpi.cc/nxpbreak**).

While RP2350 uses several techniques, including hardware fast glitch detectors and our patent-pending redundancy coprocessor, to protect control flow and data integrity against fault-injection attacks, we fully expect to find, and fix, flaws in our boot process. And we want to find these flaws early, before RP2350 is deployed in critical applications.

Ahead of launch, we commissioned NewAE and Hextree to audit our security architecture. And now we're offering a $10,000 bounty for the first confirmed break of our signed boot process. This will run for a month in the first instance: we may extend the window if no flaw is found, or offer further bounties for further distinct flaws. Full details of the bounty programme can be found here (**magpi.cc/rp2350hack**).

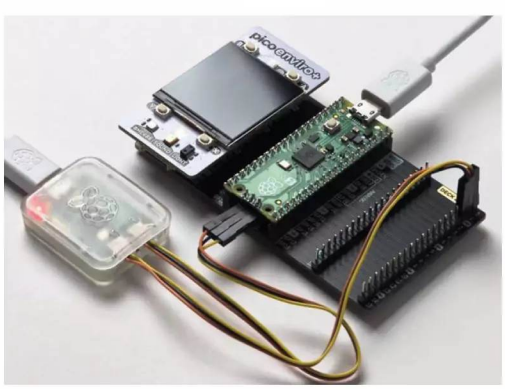
To get RP2350 hardware into the hands of the engineers most likely to find these flaws, we partnered with the DEF CON hacking convention (**defcon.org**), that took place in Las Vegas this August. This year's conference badge was powered by RP2350, and made a great platform for experimenting with our security architecture. Hextree also produced a limited number of boards intended specifically for supply-rail and electromagnetic glitching, so anyone who wanted to participate could do so without the risk of bricking their badge.

Our team was be camped out alongside Hextree in the Embedded Systems Village during the conference: it was great to see so many people!

One more thing

Although we've been a member of RISC-V International for many years, we've never found an opportunity to ship a RISC-V Raspberry Pi product. But that's changing today, thanks to a bonus feature of RP2350: a pair of open-hardware Hazard3 RISC-V cores (magpi.cc/hazard3) which can be substituted at boot time for the Cortex-M33 cores. Our boot ROM can even auto-detect the architecture for which a second-stage binary has been built and reboot the chip into the appropriate mode. All features of the chip, apart from a handful of security features, and the double-precision floating-point accelerator, are available in RISC-V mode.

Hazard3 was developed by Luke Wren, currently a Principal Engineer in the Raspberry Pi chip team, in his free time. As a solo project, it's an intellectual tour de force: a highly optimised three-stage pipelined processor, implementing the RV32I instruction set, and a large collection of standard extensions targeting performance and code density. If you'd like to know more, I recommend a browse through Luke's historical posts on Twitter/X (**x.com/wren6991**), which cover the development process in considerable detail.



▲ Google's demo, built on the new Pigweed SDK, uses Pimoroni's Enviro+ Pack to help show off the neat stuff Pigweed does

In adding Hazard3 to RP2350, we're aiming to give software developers a chance to experiment with the RISC-V architecture in a stable, well-supported environment, and to popularize Hazard3 as a clean, open core, suitable for verbatim use in other devices, or as a basis for further development.

Google Pigweed comes to our new **RP2350**

Pigweed helps programmers and teams of developers build great software for embedded devices. By **Chris Boross**



▲ The Kudzu badge is a great example of what you can build with Pigweed

We love Google Pigweed! Pigweed is an open-source project launched by Google in 2020 (**magpi.cc/pigweed**). We love it because it helps programmers and teams of developers build great software for embedded devices that use microcontrollers like our new RP2350 and its predecessor, RP2040 (**magpi.cc/rp2040**). We are also partial to funny product names around here; we are thrilled that our Pico W has gone down in the community's vernacular as the "pi cow".

We've been working with the Pigweed team for almost a year now, and last month they upstreamed support for build and testing environment Bazel into our Pico SDK, and will continue to maintain it.

Bazel is an important part of the Pigweed project, and the team believes it's going to be the future of embedded software development, making it easier for large, professional embedded development teams to build prototypes and products on top of RP2350. Head over to **bazel.build** to learn more.

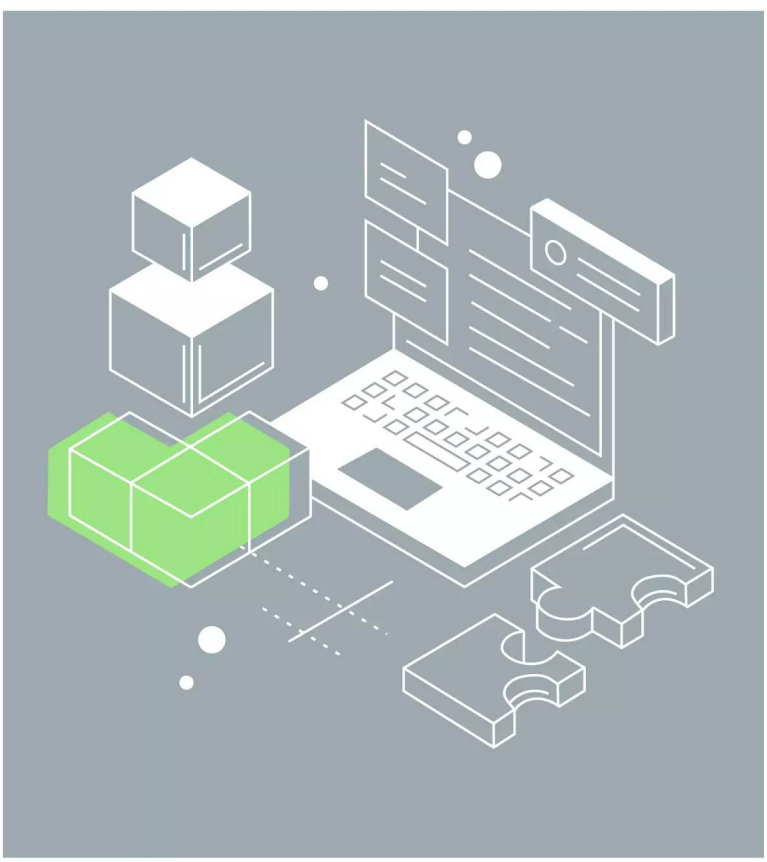
The Pigweed team has also built a great demo for you to try on your Raspberry Pi Pico or Pico 2. This demo shows off lots of complex stuff handled and enabled by Pigweed, including:

- Hermetic building, flashing, and testing through Bazel
- Fully open-source Clang/LLVM toolchain for embedded that includes a compiler, linker, and C/C++ libraries with modern performance, features, and standards compliance
- Structuring your codebase around sensible, hardware-agnostic C++ through Pigweed's extensive collection of libraries
- Communicating with your Pico over RPC
- Viewing Pico logs and sending commands to the Pico over an interactive and customisable REPL
- Authoring in Visual Studio Code with C++, Starlark code intelligence, and Bazel command integration
- Cross-platform builds and toolchains, development on macOS or Linux (Windows support is on its way)
- Device simulation on your host computer
- Continuous building and testing with GitHub Actions

Some hardware fun

We first met this great team of Pigweed folks at Maker Faire Bay Area 2023, when they came to say hi and show off their Game Boy-alike badge, which uses RP2040. This 'Kudzu' badge is a fun example of what you can build with the Raspberry Pi microcontroller and the Pigweed software libraries.

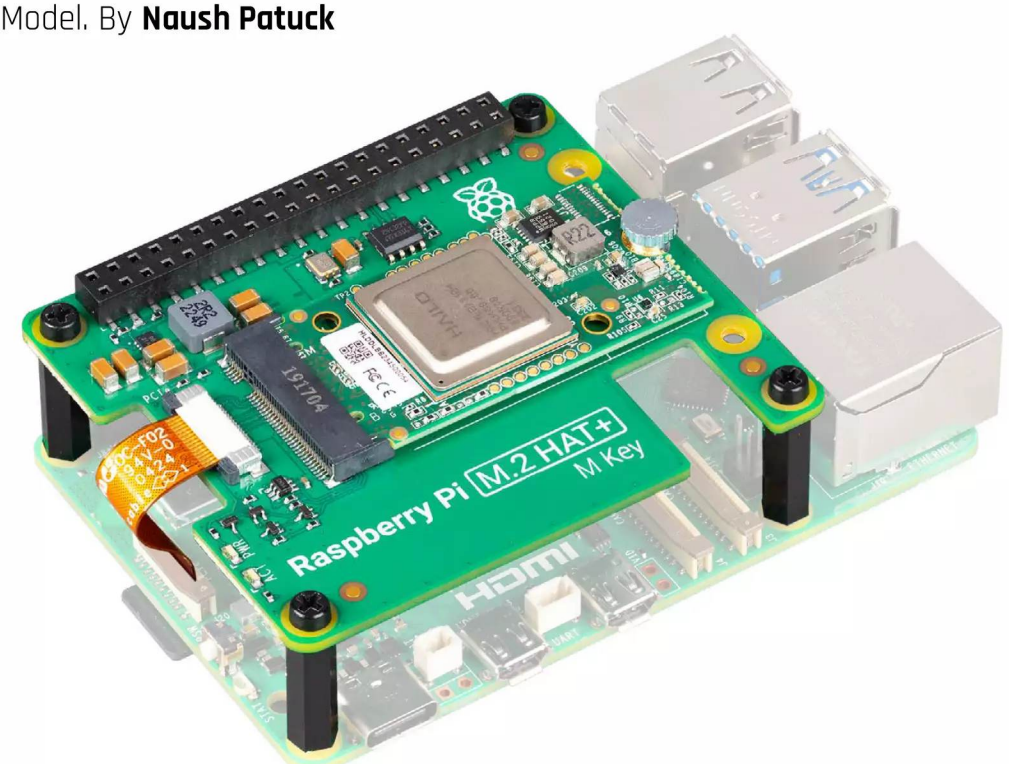
The Pigweed team have open-sourced their design, and it has some cool features such as a QVGA touchscreen and six-axis IMU, plus a LiPo battery and charger.



> The team believes it's going to be the future of embedded software development

Raspberry Pi AI Kit update

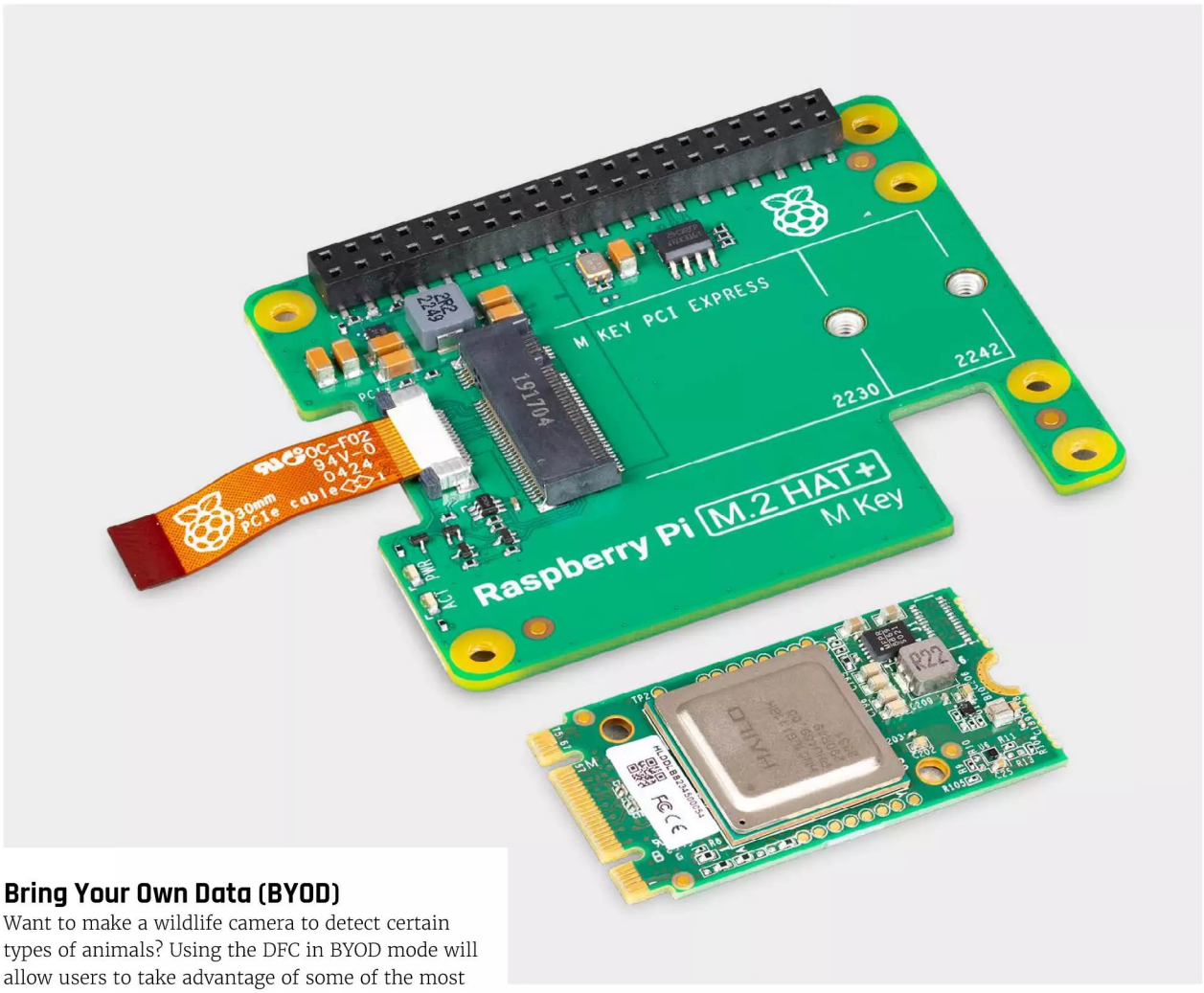
Dataflow Compiler now available: BYOData and BYOModel. By **Naush Patuck**



The AI Kit attaches firmly to the top of a Raspberry Pi M.2 HAT

Our recent release of the Raspberry Pi AI Kit (magpi.cc/aikit) got quite a bit of attention from the community. At launch, we provided a number of computer vision-based AI demos and examples (**magpi.cc/aikitdemos**), built on well known state-of-the-art neural network models. However, our power users quickly asked for more – in particular the ability to re-train these models with their own datasets, or even to compile custom models to run on the Hailo AI accelerator. Hailo has been working hard behind the scenes, and we are excited to announce the release of the Hailo Dataflow Compiler (DFC) (**magpi.cc/hailodfc**). The DFC will allow our users to extend the ability of the Raspberry Pi AI Kit and fine-tune its performance for their specific use cases.

Everything is held together securely, so it's easy to embed this in other hardware.



Bring Your Own Data (BYOD)

Want to make a wildlife camera to detect certain types of animals? Using the DFC in BYOD mode will allow users to take advantage of some of the most popular neural network models, re-trained on their own custom datasets. Hailo has created an end-to-end tutorial outlining how to re-train an existing neural network model (**magpi.cc/hailoretrain**).

Bring Your Own Model (BYOM)

If our existing demos and the neural network models available in Hailo's model zoo (**magpi.cc/hailozoo**) don't do what you want, you can use the DFC to convert and compile models from ONNX or TensorFlow Lite (TFLite) to Hailo's HEF format for running on the Hailo AI accelerator. Not for the faint of heart, BYOM requires a deep understanding of the model and the conversion flow – but some will see this as an interesting challenge. Take a look at the DFC tutorials in Hailo's developer zone (**magpi.cc/dfc327**).

> We are excited to announce the release of the Hailo Dataflow Compiler

What's next?

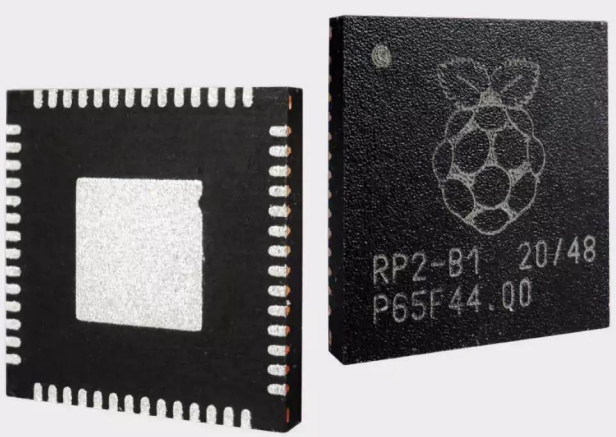
Users have also asked about Whisper, Stable Diffusion, and so on running on the Hailo AI accelerator. These very large network models cannot yet run, but Hailo is working hard to port some of them.

Also coming soon is Python/Picamera2 integration with the Raspberry Pi AI Kit. We intend to make full support for Python and Picamera2, including demos and examples, available in our next package release.

▲ The Hailo accelerator next to Raspberry Pi's M.2 HAT+ hardware

New RP2040 CMSIS Pack

Use Raspberry Pi Pico series boards with all Arm's CMSIS tools. By **William Vinnicombe**



▲ Raspberry Pi's RP2040 microcontroller

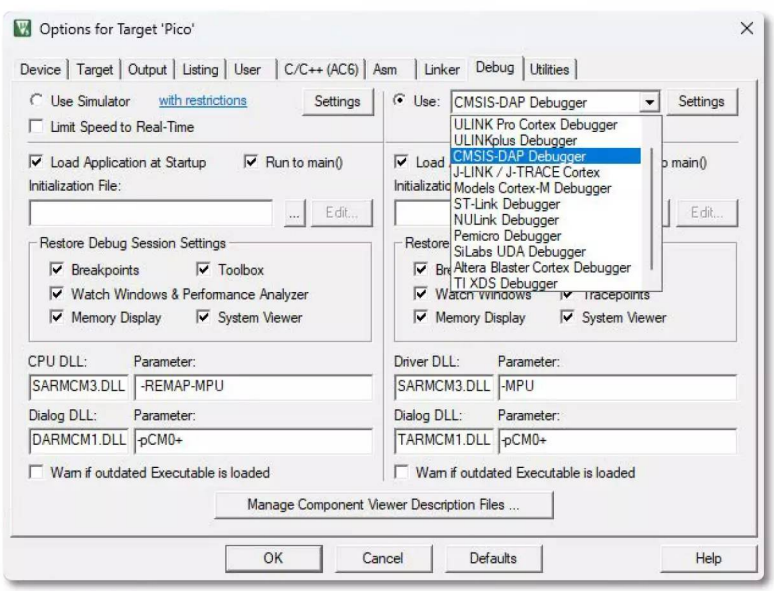
Arm's Common Microcontroller Software Interface Standard (CMSIS, magpi.cc/cmsis) initiative aims to standardise device support across many different vendors' Cortex-M–based microcontrollers, and to provide simple software interfaces to the processor and its peripherals. Arm's Windows-based µVision development environment uses CMSIS "pack" files to understand how to build and debug code on a given microcontroller.

To better integrate with the Arm ecosystem, we're releasing a new CMSIS Device Family Pack (DFP) with support for Raspberry Pi Pico and Raspberry Pi Pico W. With this new DFP, you can now use these boards seamlessly with all of Arm's CMSIS tools, including µVision. Our DFP includes the following:

- header files, startup code, and other support files
- software packages providing device-specific functionality

Instructions

To get started with the pack, download the latest version from GitHub (**magpi.cc/cmsisgit**). If you haven't already installed µVision, follow Arm's instructions here (**magpi.cc/uvisiondoc**) to install it. Then, follow the steps below to install the pack and run the examples:



Arm's Windows-based µVision development environment in action

> To better integrate with the Arm ecosystem, we're releasing a new CMSIS Device Family Pack

1. Open the µVision pack installer. Select File > Import, and import the pack you downloaded from GitHub.
2. Click the refresh button to refresh the page; the pack should now be installed.
3. Click Boards in the left-hand window, and then search for Pico. Click on either Pico or Pico W, depending on which board you are using.
4. Click Examples in the right-hand window and select the copy action next to the Breath_LED example for your board:
5. Select the folder you want to copy it into. Click OK to copy the example into the folder.
6. Once the project loads, open **main.c** to view the code.
7. If you're using the Pico W example, set YourWifiSSID and YourWifiPassword to appropriate values for your Wi-Fi network. Alternatively, delete these lines from the example if you don't want to connect to wireless LAN:
8. Click Build (**F7**) to build the project – don't worry about the Warning: L6306W on Pico W.
9. To use a Raspberry Pi Debug Probe for debugging, update your Debug Probe to the latest firmware (**magpi.cc/debugprobedoc**). Then, select Project > Options for target 'Pico' > Debug, then set Use to CMSIS-DAP debugger and click OK.
10. To run the code, click Start/Stop Debug Session (**CTRL+F5**), then hit Run (**F5**).
11. To view printouts from the device, select View > Serial Windows > Debug (printf) Viewer. This will receive printouts over the SWD interface, so there's no need to connect UART to your Pico.

For more information on using µVision, please refer to the comprehensive user guide provided by Arm (**magpi.cc/uvisiondoc**).

Poetry Camera

A snapper that uses its location and subject to produce poems makes use of Raspberry Pi's AI smarts. **Rosie Hattersley** investigates



Photo credit: Catalina Kulczar

MAKER

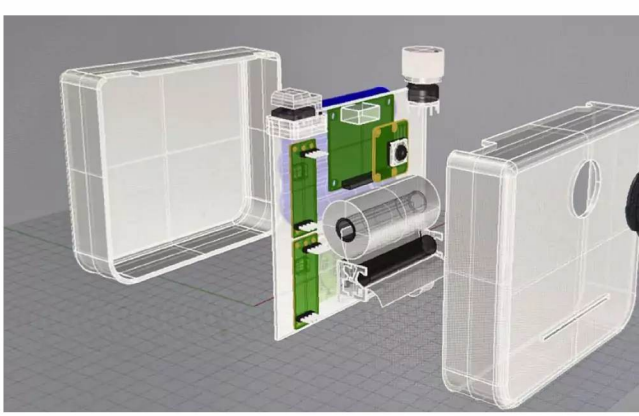
Kelin Carolyn Zhang and Ryan Mather

Kelin Carolyn Zhang and Ryan Mather are "mid-career tech workers" who "just wanted to have fun with technology again".

poetry.camera

As endorsements go, an accolade from none other than Susan Kare, designer of Apple's desktop icons, is about as epic as it gets. "I truly ♥ the Poetry Camera, and imagine that any artist or writer would feel the same way. It's such a positive, creative use of AI."

Take a photo with Poetry Camera and, rather than producing an image, it prints out a poem based on what it captured. You can adjust the poem type with a knob – ranging from sonnets and haikus to alliteration poems," explain its creators Kelin Carolyn Zhang and Ryan Mather of the Raspberry Pi Zero 2W and Camera Module 3-based gadget. Kelin's favourite Poetry Camera composition was about her pet turtles she's had since elementary school. Designing what was originally an art project turned out to be a very smart move. Not only has Poetry Camera caught the imagination of other designers and makers keen to take advantage of the open-source code and instructions (**magpi.cc/poetrycamgit**), but Kelin and Ryan have had plenty of interest from potential customers of the ready-made whimsical camera too.



- The pair have made several revisions to the camera body design
- Exploded CAD view of the design for the original Poetry Camera

A fresh focus

The Poetry Camera began life as an 'AI classifier' and was partly inspired by Kelin's friend Susi Fu's Artist and Machine performances examining how artists and computers can learn from each other (**magpi.cc/artistmachine**). "Susie would draw sketches of the person standing in front of her, while a machine – using Raspberry Pi – printed out AI-drawn sketches of the same subject."

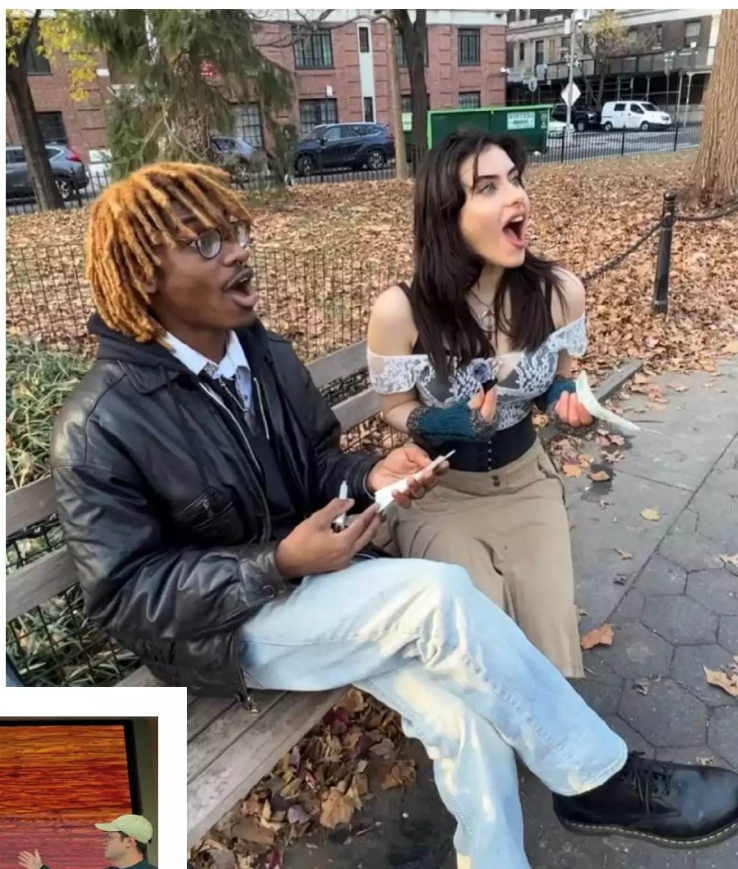


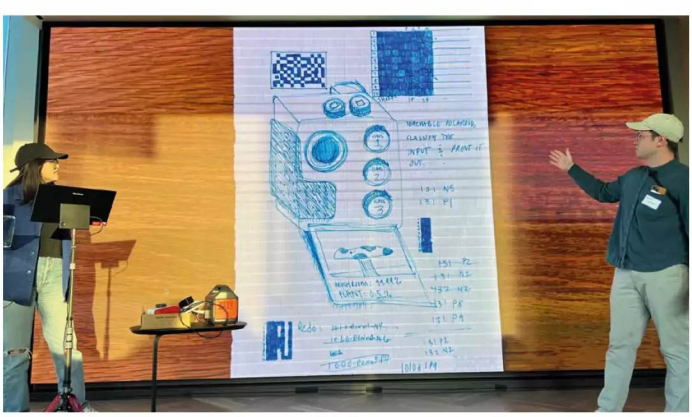
Quick FACTS

- Ryan learned to code on his TI-83 calculator…
- … making games for his friends
- He dreams of one day making a wearable device…
- …that can translate his dog's barking into English
- Maybe a reworked Poetry Camera can oblige!



> Ryan was ecstatic to create something from scratch and prototype it on his home 3D printer





▲ Poetry Camera gets amazed reactions at its first live demo in New York

◀ Kelin and Ryan unveil the concept and design process

An MIT computer science graduate turned digital product designer, Kelin took charge of the Raspberry Pi prototyping, learning how to solder, plus some basic electronics, while designing her first PCB (a HAT for Raspberry Pi). The initial cardboard design took only a few days to complete.

Industrial designer Ryan, meanwhile, has worked as a toy designer and in a creative technologist-type design role at Google where he learned "Javascript and a bit of Python," and was introduced to Raspberry Pi for prototyping, which he'd "definitely recommend" for anyone who wants to build hardware prototypes that need a logic layer.

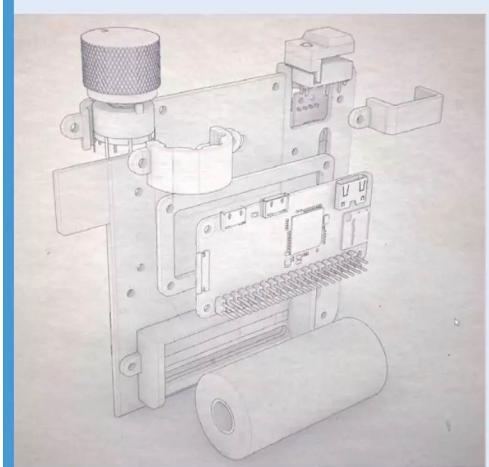
He was "ecstatic to create something from scratch, and prototype it on his home 3D printer". Having started out as pen and paper sketches, Poetry Camera's form was created and iterated on in Rhino.

Power play

As "the brain of the whole device," Raspberry Pi Zero 2 W connects to a Camera Module 3 and a thermal printer via UART. It calls on remote AI models via an API for pointers on poem writing. The idea was that they'd get faster responses this way, but this approach necessitates connecting to Wi-Fi hotspots, which could be challenging depending on where they took Poetry Camera out and about. "In ideal conditions, it works like a well-oiled machine but Wi-Fi networks can be very spotty, especially at crowded events where there's a lot of signal interference". Six AA batteries keep everything powered (the thermal printer can drain batteries fast) with a buck converter to step down the voltage for Raspberry Pi. Kelin and Ryan chose Raspberry Pi for its wireless connectivity and the volume of tutorials on how to interface with cameras and thermal printers, starting with Raspberry Pi 3B+ before switching to Zero 2 W "since it hits a sweet spot in terms of small size and fast processing power". They made use of Adafruit's Python Thermal Printer library (**magpi.cc/thermalprintgit**) and found ChatGPT "very well versed" - pun hopefully intended - for creating code. "We were able to ask a question in our own naive way and get a custom tailored response that often works right out of the box, instantly."

The pair are constantly tweaking and updating Poetry Camera. It's already on version 4, and its creators have been delighted by how well it's been received. "In the future, we're looking forward to letting people customise their cameras' outputs – by updating the poem prompts, or adding images, or using their own servers."

Use your illusion



01 Poetry Camera contains Raspberry Pi Zero 2 W and uses Camera Module 3 to capture an initial image.



02 Next, slide the mounting plate into the chin of the 3D printed camera case and slide the Poetry Camera HAT onto the chin. Attach the knob for the rotary switch to select the poem type.



03 A thermal receipt printer sits in the lower part of the Poetry Camera and presents the results of its AI-generated musings based on what the camera saw. Instructions and AI training code can be found at at **magpi.cc/poetrycamgit**.

Damp deductions

With a damp patch growing on his dining room wall and experts baffled, Roberto Tyley turned detective with the help of a Raspberry Pi computer and some sensors, as **David Crookes** explains



MAKER

Roberto Tyley

An open source enthusiast, Roberto develops software for *The Guardian* and authored the BFG Repo-Cleaner.

magpi.cc/gitdamp

Roberto Tyley's family were enjoying a fun event in the dining room of their London home. The occasion was a birthday party for a toy rabbit – "the children decided it needed one," he says – and this provided a good excuse to take many memorable photos.

When viewing those images later, however, something caught Roberto's eye: the birth of a damp patch that, as time went on, grew ever bigger. "It got uglier too," Roberto says, having watched it consume a sizable area of wall. He and his wife Philippa decided the problem needed to be fixed, but that proved easier said than done.

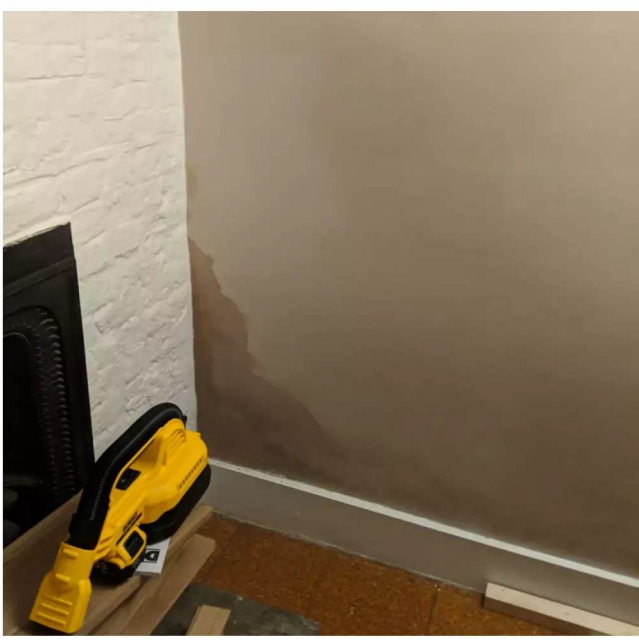
"We called a plumber because we thought there might be a leak but they couldn't find anything," Roberto says. "They told us we needed a leak detection specialist, so we called one and they did a really exciting thing where they drain all the water out of your pipes and replace it with hydrogen before wandering around with a little wand that has a hydrogen sensor at the end looking to see if they can detect where the hydrogen is leaking."

The specialist didn't find a leak. "He said we needed a damp detection specialist, so we called one," Roberto continues. "He surveyed the whole house, wrote a formal report and said it was due to climate change. He said in London we used to have rain and wind but now we have both together, driving water into the side of the house. But I wasn't sure."

Rain man

At this point, Roberto made a big decision. He ignored the problem. "I was really good at this but Philippa would sit at the dining room table staring intensely at it," he continues. "She would draw outlines around the damp patch, come back and see it had grown. The mystery of where the damp was coming from began to consume us!"

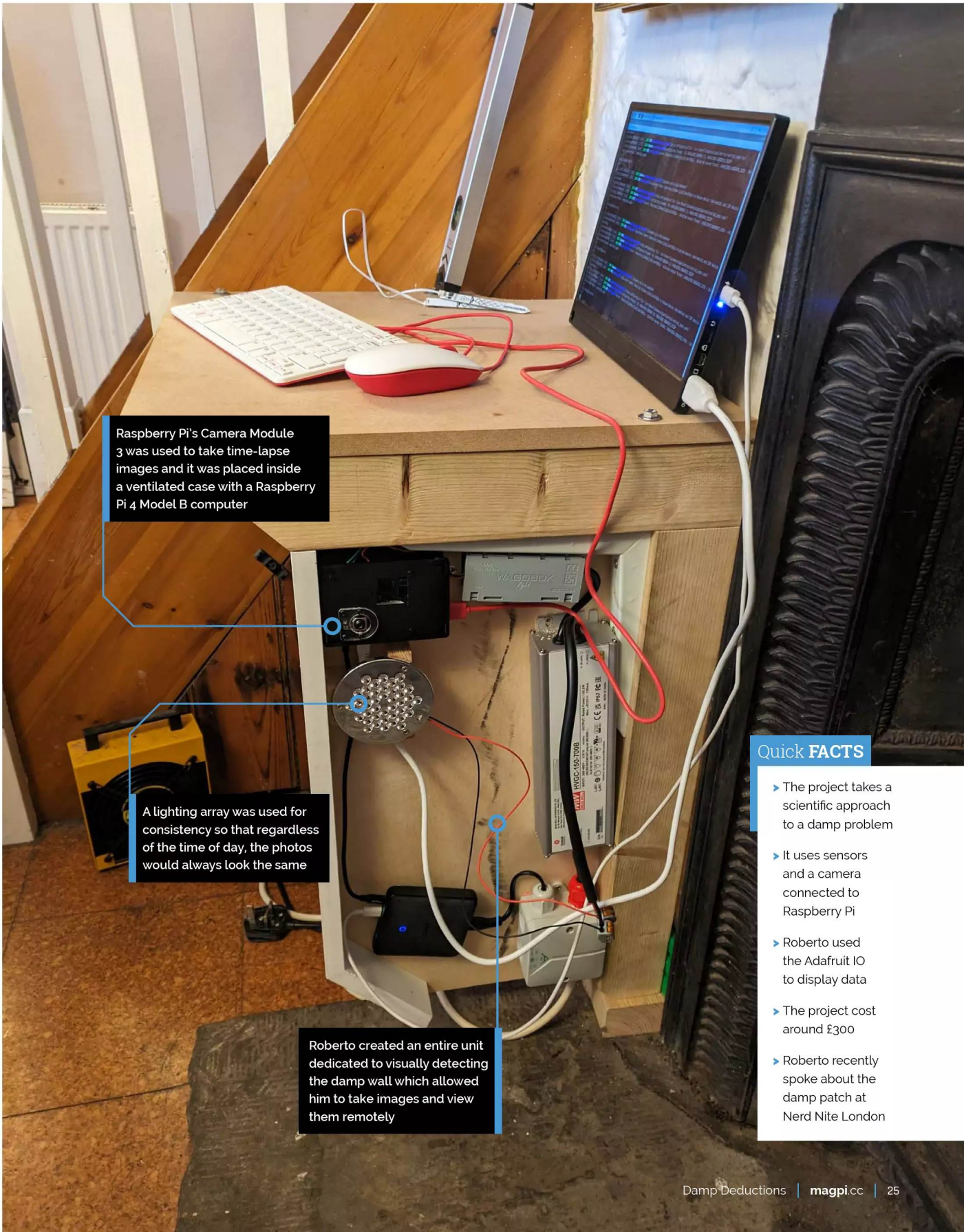
Philippa thought that maybe the problem got worse when it rained, so the couple called in roofers. "They said it was nothing to do with the roof," Roberto says. "But we were desperate, so we asked them to do any possible repairs to the roof they could find, just to rule it out."



The damp patch continued to get bigger, so they checked the drains in case they were overflowing, causing water to seep into the wall. "The drains people arrived, put cameras down, said that probably was the cause, put some dodgy new manhole covers in... and left our dining room smelling of sewage for several weeks!" Roberto adds. Still the damp patch grew.

Exasperated, Roberto placed a tipping bucket rain gauge on his roof. These make use of two small buckets mounted on a fulcrum each holding a set amount of precipitation. Water is collected and distributed into the buckets which tip, empty and trigger a switch to record the volume of water.

▶ The damp patch in the basement dining room of Roberto's home started off small but grew very quickly and conventional explanations didn't help



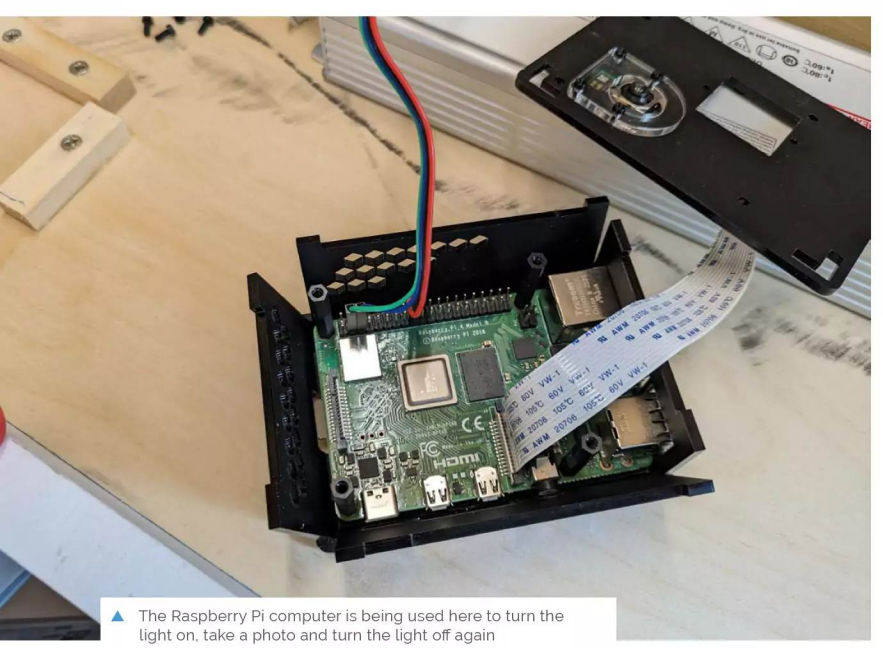
Quick **FACTS**

- The project takes a scientific approach to a damp problem
- It uses sensors and a camera connected to Raspberry Pi
- Roberto used the Adafruit IO to display data
- The project cost around £300
- Roberto recently spoke about the damp patch at Nerd Nite London



Roberto initially used a digital multimeter to measure the moisture levels in the wall and found it was very high

> I wrote code to analyse the damp patch with an image-processing algorithm



The Raspberry Pi computer is being used here to turn the light on, take a photo and turn the light off again

"The switch was connected to a wire which ran to a Pimoroni Enviro," Roberto explains. "It would count how many times the seesaw was tipped and the data could then be sent to a real-time analytics service called Adafruit IO."

Flash of light

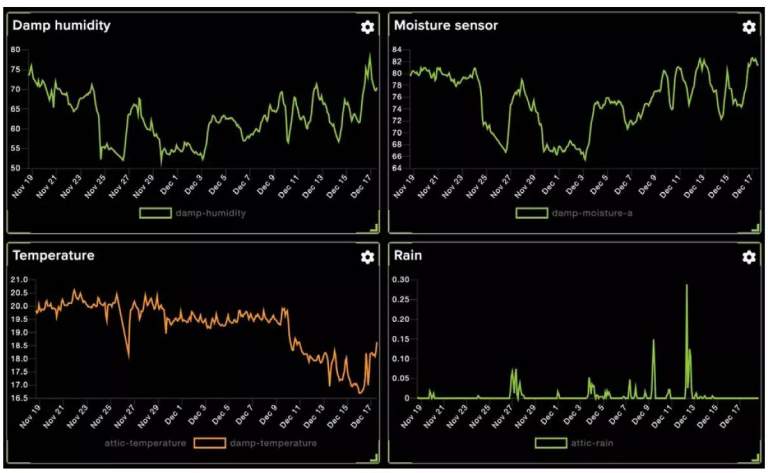
Having nailed high-quality rainfall data, Roberto placed a moisture sensor on to the damp patch. "Initially I tried measuring the resistance but I found when you try to send an electric current through a wet wall, what you're really doing is electrolysis – you're separating the water into hydrogen and oxygen and it doesn't work well," he says.

"So I used a capacitive moisture sensor designed for sticking into plant pots and nailed it to the wall. I also used humidity and temperature sensors hooked up to another Raspberry Pi computer which transmitted data to the internet." Combined, this gave Roberto damp, humidity, moisture, temperature and rain data, but he also needed to actually monitor the growth of the damp patch.

He used a Raspberry Pi Camera Module, built a heavy-duty table to fix it to and ensured the area had consistent, bright lighting. "I used a really nice, bright LED array with mains power," he says. Coding using Python he got the Raspberry Pi to turn the light on, take photos using the libcamera library then turned the light off again. The photos were uploaded to **teleport.io**, a time-lapse hosting service.

"I wrote some code to analyse the damp patch photos with an image-processing algorithm to detect the damp flashes and send an alert when they occurred. I also did a little bit of Micropython, opening a small tidying PR [pull request] on the Enviro MicroPython firmware," Roberto says.

He noticed that the more the wall was wet, the more it glistened. "It would get visibly much wetter then much less wet over the course of maybe half an hour a couple of times a day, or sometimes not at all," Roberto says. "Philippa noticed that one time when the damp patch glistened, our next-door neighbour was hanging out the washing. She started to wonder if it could have something to do with their washing machine. Perhaps it was a leak."



▲ Roberto used an Adafruit IO dashboard to show data from the humidity, moisture, temperature and rain sensors, allowing him to spot any potential trends

Bow Tie Guy

Rather than confront the neighbours, the family decided to isolate the problem by staying with their in-laws for nine days and monitoring the wall while they were away. There was not a single flash of water. Yet within an hour of arriving home, there was another damp flash. "It was being caused by us being in the house, but why?," Roberto pondered.

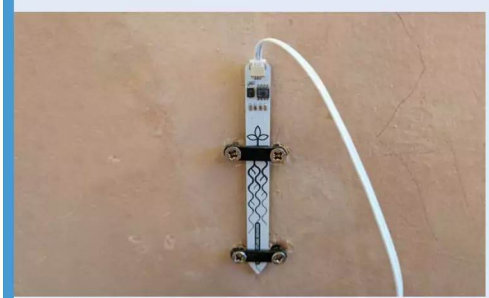
They turned on their own washing machine then later cooked a pan of spaghetti and turned on the extractor fan. Nothing. Then they heard about a mysterious man known only as Bow Tie Guy. "He is the damp detection specialist you go to when all the others have failed. I emailed him, sent him all of our research and he replied, 'sure, I can solve this mystery for you'".

Roberto and Philippa called him. The man had pored over all of the Raspberry Pi-collected data and he said there was no leak in the house. "He explained that our house is 300 years old with a chimney stack nearby that would have been used for hundreds of years to burn coal.

"This gives off particulates, in particular ammonium sulphate, which embeds into the brick wall. After a while it would have been plastered over but if water gets into the wall – and we found out that our neighbour had a little leak in 2018 which they fixed – this hygroscopic salt is carried on to the surface of the plaster. The water evaporates but the salts don't."

It turned out the ammonium sulphate was pulling water out of the air. "So every time we sat in our dining room staring at the damp patch, it was taking our breath," Roberto says. The answer was to strip the plaster away and replace it, solving the problem once and for all. "After all that, we'd been causing the damp patch by obsessing over it," Roberto laughs.

Detecting a damp wall



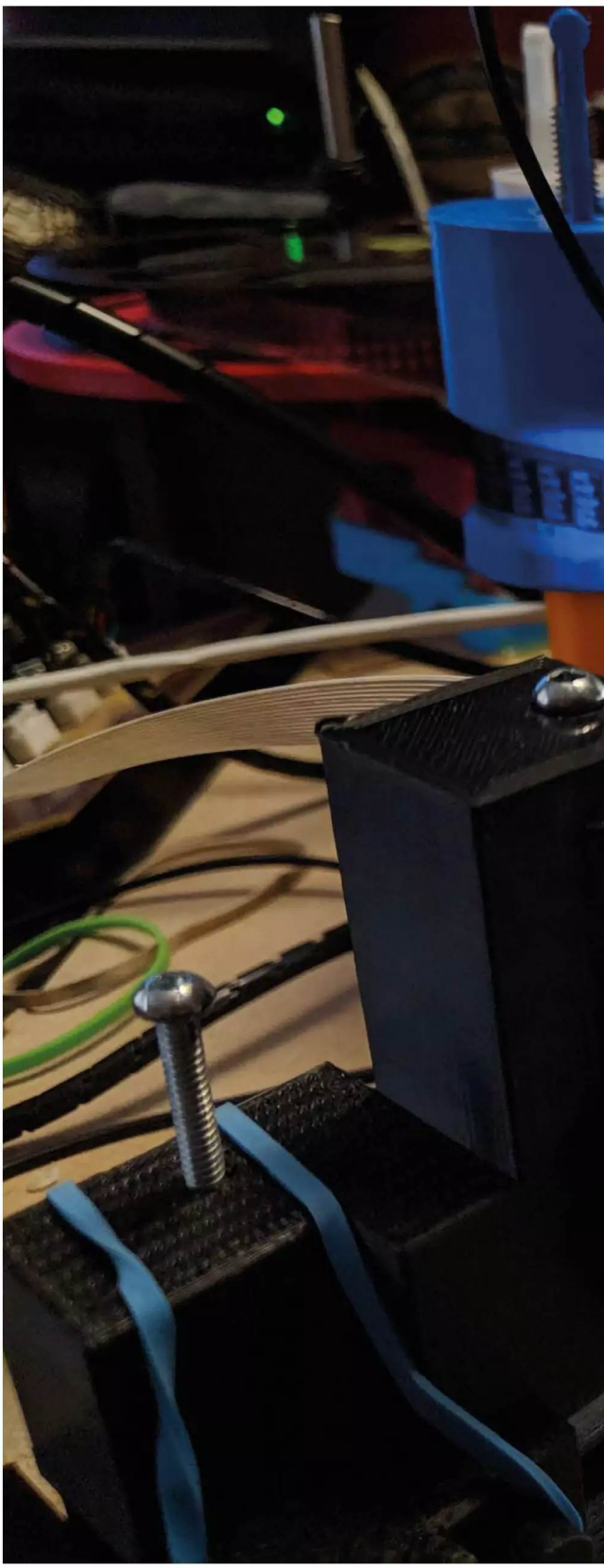
01 A moisture reading in excess of 16% is considered to be damp. Anything over 20% is excessive. Roberto used a Pimoroni Grow HAT Kit for Raspberry Pi and screwed one of the soil moisture sensors to the wall to gather data.



02 With the inexpensive Adafruit BME280 environmental sensor module, Roberto was able to measure the temperature, humidity and barometric pressure with great accuracy via a single unit, placing it behind a transparent acrylic shield to protect it from curious children!



03 Since he was also taking time-lapsed images of the wall at regular intervals, letting him see the damp patch as it spread, Roberto placed a clock on the wall so he could check the time and double-check the room's temperature and humidity.



▶ The Gugusse roller uses Raspberry Pi HQ camera and Pi 4B+ to import and digitise analogue film footage **(Credit: Al Warner)**

Gugusse Roller

This canny way to transfer analogue film to digital was far improved by using Raspberry Pi, discovers **Rosie Hattersley**



MAKER

Denis-Carl Robidoux

French-Canadian Denis-Carl enjoys using Linux and Raspberry Pi in photography and drone projects.

deniscarl.com

Gugusse is a French term meaning something 'quite flimsy,' explains software engineer and photography fan Denis-Carl Robidoux. The word seemed apt to describe the 3D-printed project: a "flimsy and purely mechanical machine to transfer film".

He created Gugusse as a volunteer at the Montreal museum where his girlfriend works. He was "their usual pro bono volunteer guy for anything special with media, [and] they asked me if I could transfer some rolls of 16mm film to digital". Dissatisfied with the resulting Gugusse Roller mechanism, Denis-Carl eventually decided to set about improving upon it with a little help from Raspberry Pi. Results from the Gugusse Roller's digitisation process can be admired on YouTube (**magpi.cc/ytgugusse**).

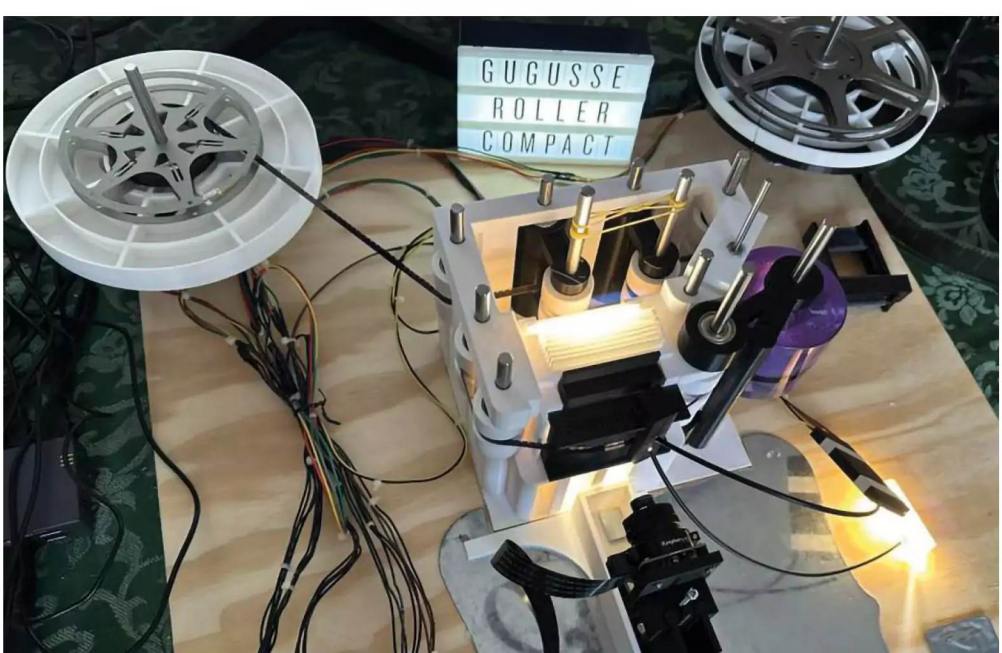
The Gugusse roller uses Raspberry Pi HQ camera and Raspberry Pi 4 to import and digitise analogue film footage

The camera captures a digital 4K image of each frame which is later edited into a continuous reel

The Raspberry Pi HQ camera automatically recognises holes in the film and scrolls it on. Once loaded, a Python script starts up the Raspberry Pi HQ camera

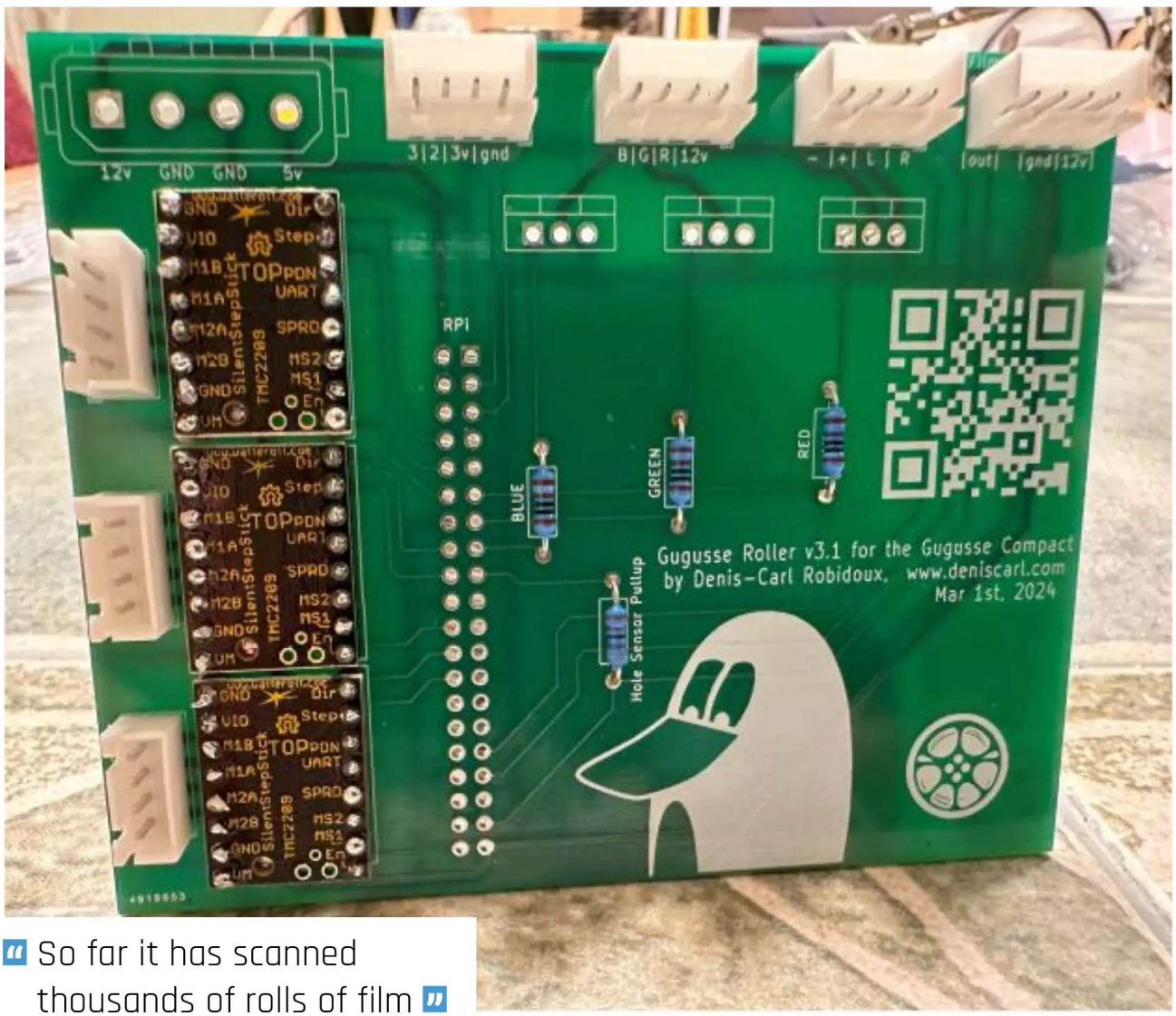
Quick **FACTS**

- The Gugusse can roll film from 8mm to 35mm in size
- The sprocketless design recognises holes in the film…
- …thanks to angled light shining through them
- Raspberry Pi-controlled motors spool the film forwards
- Once captured, images are post-processed in Adobe Fusion



◀ Gugusse Roller fan Al Warner built his own version. **(Credit: Al Warner)**

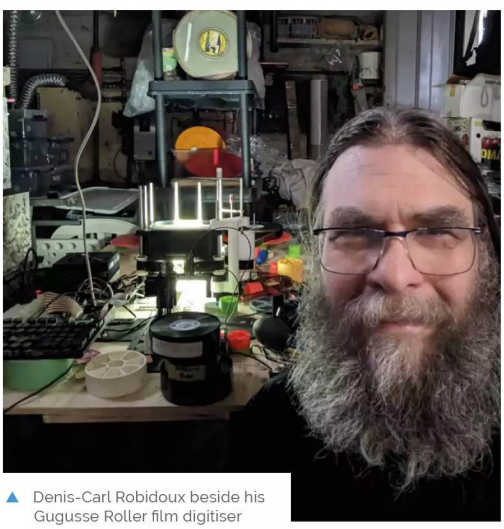
▼ Version 3.1 of Denis-Carl's Gugusse Roller PCB



> So far it has scanned thousands of rolls of film

New and improved

Denis-Carl brought decades of Linux coding ("since the era when you had to write your own device drivers to make your accessories to work with it") and a career making drivers for jukeboxes and high-level automation scripts to the digitisation conundrum. Raspberry Pi clearly offered potential: "Actually, there was no other way to get a picture of this quality at this price level for this DIY project." However, the Raspberry Pi Camera Module v2 Denis-Carl originally used wasn't ideal for the macro photography approach and alternative lenses involved in transferring film. The module design was geared up for a lens in close proximity to the camera sensor and Bayer mosaics aligned for extremities of incoming light were at odds with his needs. "But then came Raspberry Pi HQ camera, which didn't have the Bayer mosaic alignment issue and was a good 12Mp, enough to perform 4K scans."



▲ Denis-Carl Robidoux beside his Gugusse Roller film digitiser

Scene stealer

Denis-Carl always intended the newer Gugusse Roller design to be sprocketless, since this would allow it to scan any film format. This approach meant the device needed to be able to detect the film holes optically. "I managed this with an incoming light at 45 degrees and a light sensitive resistor placed at 45 degrees but in the opposite direction. It was "a Eureka moment" when he finally made it work. Once the tension is set, the film scrolls smoothly past the HQ camera which captures each frame as a DNG file once the system detects the controlling arms are correctly aligned and after an interval for any vibration to dissipate.

The Gugusse Roller uses Raspberry Pi 4 to control the HQ Camera, three stepper motors and three GPIO inputs. So far it has scanned thousands of rolls of film including trailers of classics such as *Jaws* and lesser-known treasures. The idea has also caught the imagination of more than a dozen followers who have gone on to build their own Gugusse Roller following Denis-Carl's instructions: (**magpi.cc/buildgugusse**) and check out other makers' builds on Facebook (**magpi.cc/fbgugusse**).

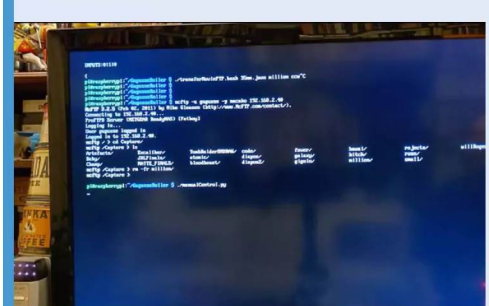
Roll VT



01 The Gugusse Roller uses Raspberry Pi HQ camera and Raspberry Pi 4 to import and digitise analogue film footage. Denis-Carl's custom board sits inside a Canakit case with Raspberry Pi 3B+ and a heatsink.



02 Once assembled, thread a reel of film around each of the Gugusse Rollers until the correct tension is reached. Denis-Carl demonstrates how to achieve this at: **magpi.cc/gugussehow1**.



03 Position the HQ camera ready to capture footage and run **manualControl.py** on your Raspberry Pi. The HQ camera will capture and save each frame to Raspberry Pi's SD card. You can then use video editing software to digitise the shots into a single video clip. See the GitHub for more information: **magpi.cc/gitgugusse**.

RemoteLab

Remote robotics development for university students isn't a pipe dream, it's very real at Wrocław University of Science and Technology. **Rob Zwetsloot** connects with RemoteLab.



MAKER

Wojciech Domski

Wojciech has a PhD in robotics, and builds embedded systems for professional applications for fun. He's also a lecturer at Wrocław University of Science and Technology.

magpi.cc/remotelab

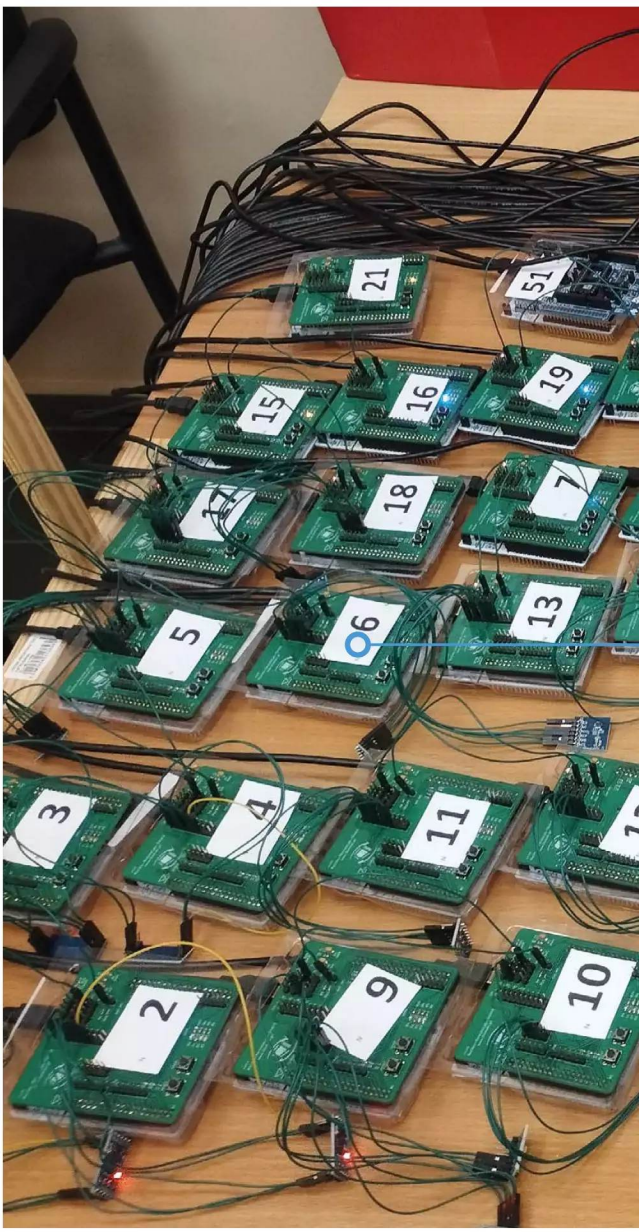
A few issues ago we spoke to Wojciech Domski about his RC plane OSD, a cool little project allowing him to see where his RC plane was flying, along with a little HUD of info. While impressive, he's also been working on a project with Wrocław University for a very long time that he has been very keen to share with us.

"RemoteLab is something known as Hardware-as-a-Service," Wojciech explains. "It offers remote access to resources such as development boards via means of services. It is located at Wrocław University of Science and Technology [WRUST] where it is used for Robot Controller and Advanced Robot Control classes."

RemoteLab came from necessity – in 2020, in-person classes were suspended due to the COVID pandemic at WRUST much like the rest of the world. With students unable to access real development boards (and the labs they were in), Wojciech started building a way to access boards remotely via Raspberry Pi.

"In late 2020 I had a first version up and running at home," Wojciech says. "In 2021 I was able to set up the environment and launch the service. It would not be possible without support from my university and the people from [private company] ST who provided the development boards."

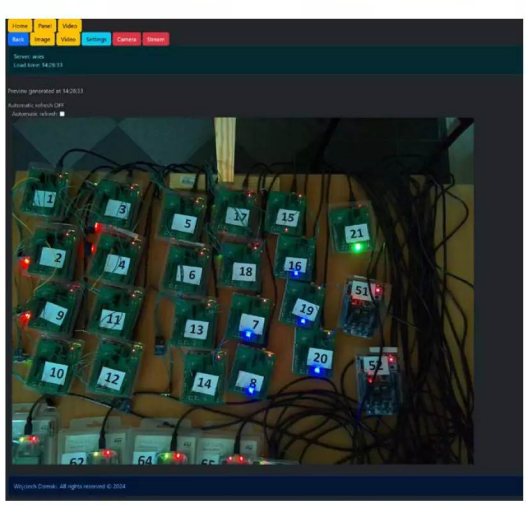
The initial build used a Raspberry Pi 3, with the balance of low-power consumption and hardware performance coupled with a well-supported Linux distro making it the ideal candidate.



"The performance was enough to serve the resources to over a dozen students at the same time," Wojciech tells us. "However, the video streaming offering a view over development boards was not that good. I needed to work around it and decided to use video-like preview based on still images. The next generation included an upgrade to Raspberry Pi 4. Now, it was even possible to work and develop code directly on Raspberry Pi since it offered enough computation power.

Three Raspberry Pi boards act as a server so that students can access these dev boards remotely

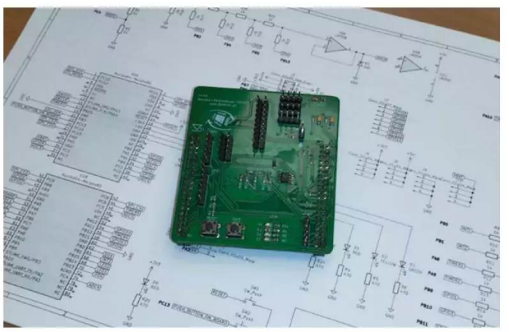
A variety of development boards are accessible via RemoteLab – including Nucleo boards and Discovery boards from ST



The web interface includes a camera so you can monitor the boards

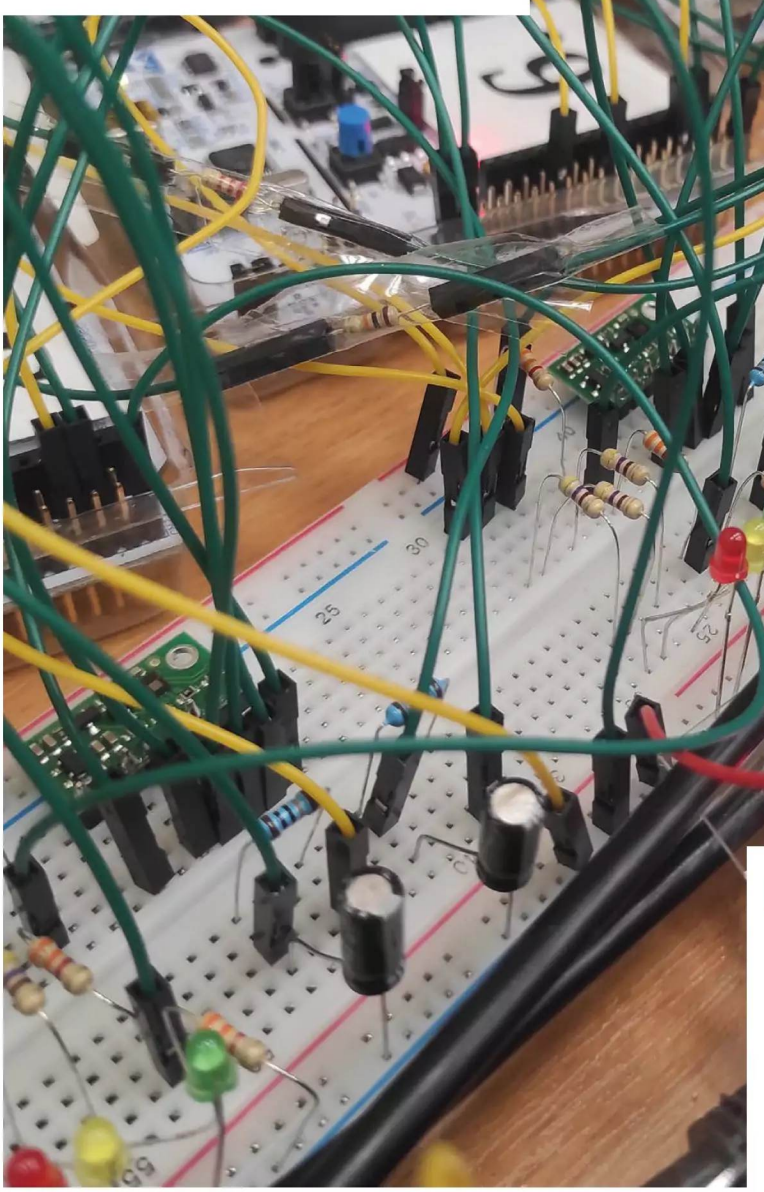
Quick **FACTS**

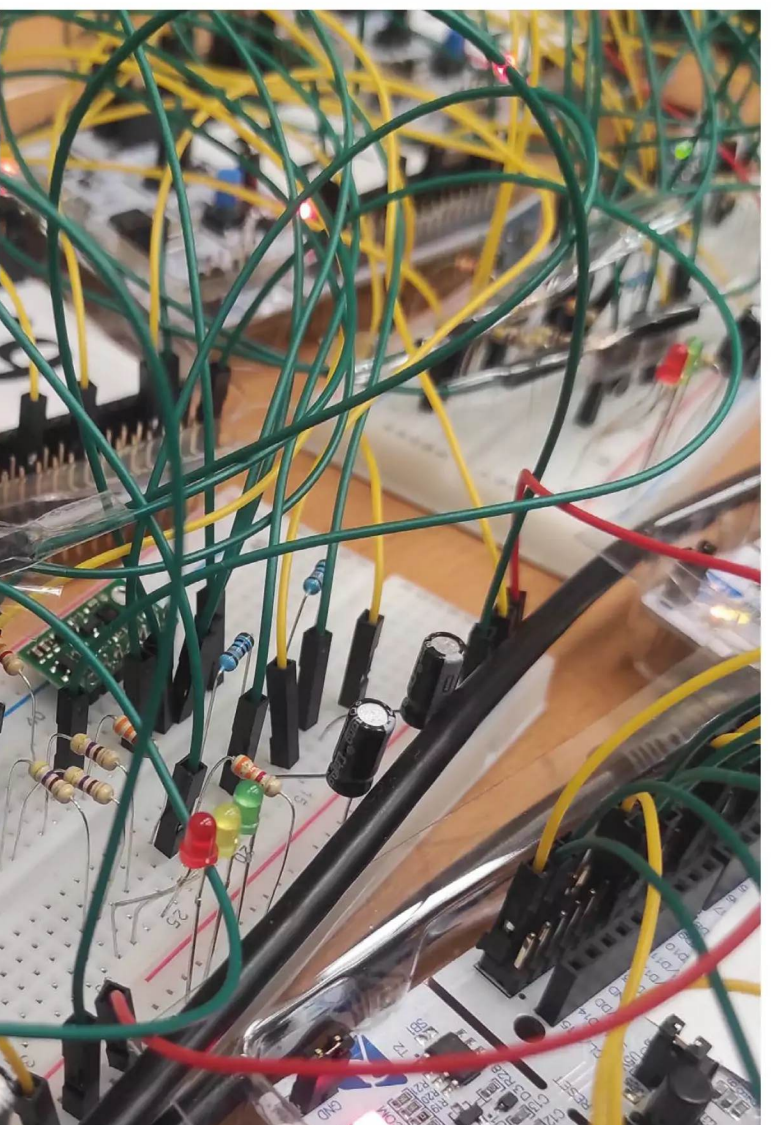
- Dev boards are connected via an active USB hub...
- ...which is crucial to the entire project
- It can work off a single Raspberry Pi 3
- A Raspberry Pi Camera Module provides video feedback
- The whole project is open source and available at **magpi.cc/remotelab**



◀ One of the development boards used in RemoteLab

▼ Prototyping can be a laborious task – this wiring was a tedious and meticulous job





> What was ground-breaking was that the system was available around the clock. I received a lot of feedback that students were able to prepare better for classes

Finally, in 2024 yet another upgrade took place. Three servers were replaced with Raspberry Pi 5s. In addition, a new and refreshed version of the web interface was available. Based on my experiments, Raspberry Pi 5 should be even able to stream real video feedback to an entire class of my students."

Fraught development

We like to ask every maker how the build process was. Wojciech's answer was a blunt "it was horrible :D", with that exact emoticon.

"I do not want to count the amount of time I have spent during evenings to setup the hardware," Wojciech admits. "Preparing software is one thing, you can gradually add new features, revert changes if needed. With hardware you need to have a plan that you carefully follow... What I remember the most was connecting additional hardware, like sensors, to the development boards. It took me something around three days to set it up and test it."

We've all been there with the frustration of a build. In the end, he did manage to get it all working though. Users merely need to connect to the RemoteLab server via SSH, and via the web interface they can see the status of, and control, the development boards in the lab. Oh yes, and now get video feedback as well thanks to the upgrade to Raspberry Pi 5.

Remote learning

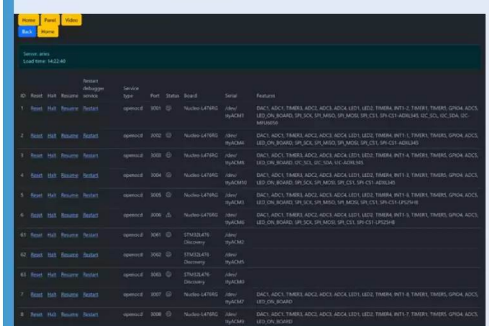
With any project like this, it's important to get feedback from the end user to, and it seems to be a hit with the students.

"Some students really loved the RemoteLab and said that it helped them a lot," Wojciech says. "What was ground-breaking was that the system was available around the clock. I received a lot of feedback that students were able to prepare better for classes and they were not limited by any time constraints."

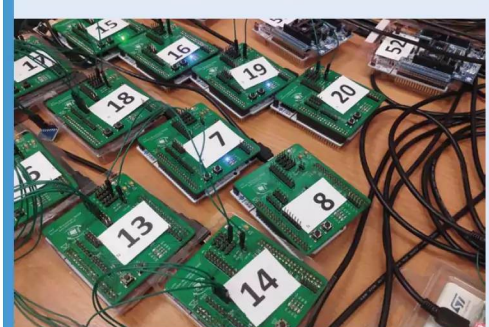
Wojciech is still working on the system, as he has been for the last several years, with improvements in mind – a serial console via the web interface was just added, and he's looking at real-time plotting next. He's also thinking of expanding it a fourth Raspberry Pi server and adding support for Raspberry Pi Pico and Pico 2.

"I think that RemoteLab exactly represents what the Raspberry Pi Foundation is standing for," Wojciech finishes. "It is all about supporting education and encourage people to tinker."

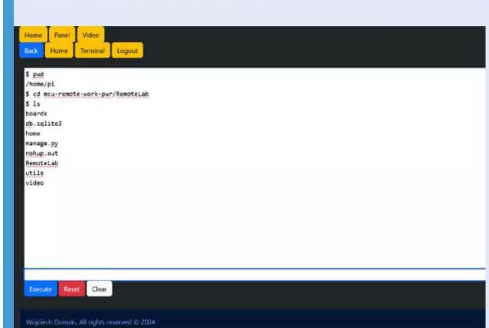
How it works



01 Two ports are tunnelled via SSH from the user to the server, with the web UI on one port. From here you can check the status of a development board, if the debugger is running, and other features.



02 The second port is dedicated to the debugger – openocd or st-link – and is connected via an SWD interface like on Raspberry Pi Pico. Remote debugging allows for new firmware to be uploaded to the development board, or debugging of the source code on the board.



03 The administrator side is a little more complex, with web servers managing the functions described above. A set of Python scripts was created to automate repeating tasks (like updating code) on one or all servers that are a part of any given RemoteLab setup.

Escape room monitoring system

If being locked away in a stinky, possibly damp cell is your idea of a great day, you might just enjoy the Raspberry Pi-enabled creepy check-ins from your captor, shudders **Rosie Hattersley**



MAKER

Caroline Buttet

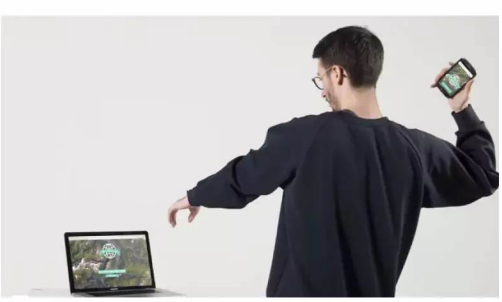
Caroline Buttet is an interaction designer who uses technology and props to dramatic effect.

carolinebuttet.ch

Ferociously cryptic clues, creepy sounds emanating from somewhere you can't quite pinpoint, strange smells and unexplained breezes, locked doors, promising chests and hidden routes that could lead to salvation or certain demise, plus a display steadily and ominously counting down to zero... Some people just can't get enough of the suspense, while hotels, town centres and retail parks up and down the land, along with board games and creators of TV game shows such as *The Traitors*, all play host to the escape room.

As professional Scottish laird-cum-villain Alan Cumming might observe, we all enjoy "a good muurrrder". Messages from a virtual captor make it clear their smartphone screen is showing your every squirm while you try to solve clues and escape before time runs out. This adds to the game's frisson, as interaction designer Caroline Buttet demonstrates in her Raspberry Pi-based high-stakes Escape Room game setup: **magpi.cc/escapeYT**.

Caroline often combines technology with interactivity in quirky (and occasionally risque) art installations. She takes an admirably minimalist approach, focusing on how a particular piece of hardware might be deployed to work with a surprising other element. Examples include a world radio combined with a paper map in which a rotary phone dials up live broadcasts from internet stations selected by plugging a headphone jack into places on the map, and a smartphone paper plane game in which players try to fly their craft to preset cities.



▼ Caroline's previous inventions include a virtual paper plane smartphone game



▲ Caroline also made a Raspberry Pi and retro world phone player

Time-sensitive

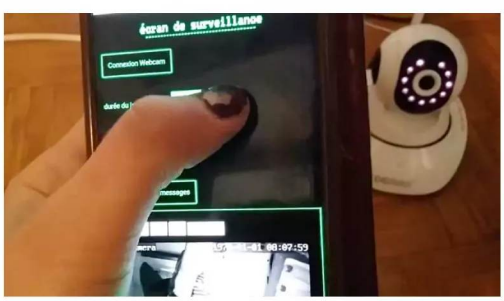
Caroline originally devised her smartphone monitoring system for a client four years ago, but it seems more pertinent now that escape rooms have become so wildly popular: there are more than 50,000 escape room venues worldwide (as well as many, many themed murder mystery nights) of which 1,500 or more are in the UK.

She says the aim was to create a simple, affordable escape room monitoring system. The escape room owner, Mathieu Dorsaz, wanted to be able to see the players enclosed in a room and communicate with them via a chat if necessary. The escape room was located inside a minivan whose location frequently changed (players rented the escape room van, parked up and played wherever they chose). Caroline's first big task was therefore creating an offline communication system using Raspberry Pi to create a local network.

Raspberry Pi provides a countdown for trapped players and connects them to their captor over Wi-Fi

A CCTV surveillance system keeps a watchful guard over escape room participants locked in an isolated vehicle

The escape room owner can watch players squirm and issue terse instructions and clues for them to solve



◀ Raspberry Pi's portable hotspot allows clues to be sent to participants however remote

▼ The hotspot keeps track of his van and checks on players' welfare

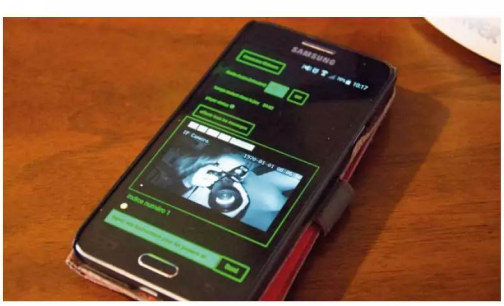
The players would need to see a screen that displayed their remaining time, as well as clues the owner sent them via a closed chat-based messaging system. The escape room owner, meanwhile, would be able to see players via a CCTV surveillance system (smartphone apps for this were less common then). Messages from a virtual captor make it clear their smartphone screen is showing your every squirm while you try to solve clues and escape before time runs out

Somebody's watching me

The monitoring system consists of a smartphone, a Raspberry Pi 3B with a screen attached, and an IP surveillance camera. Caroline chose to use Raspberry Pi because "it is affordable, portable and reliable," and says she could never have created anything similar for a comparable price (less than €200 overall).

Once the Escape Room hardware and code are set up, Raspberry Pi operates autonomously. Power it on and the server automatically starts, the web browser automatically opens to the dedicated page in kiosk mode, and a script checks that the system is always working and restarts it if it isn't. Happily, Caroline reports that there was not a single instance of her setup going down: "I never had to debug the system: it always worked on site." Less happily, the escape room concept for which she created the project is no longer in operation but, having outlined what's needed, she's confident fellow Raspberry Pi creators could easily create their own.

> Messages from a virtual captor make it clear their smartphone screen is showing your every squirm while you try to solve clues and escape before time runs out



Caroline herself has escaped too. She set off from Switzerland on an around-the-world cycle ride and reached Thailand 11 months later, recently checking in from Indonesia after 17 months in the saddle.

Quick FACTS

- There are more than 50,000 escape rooms worldwide
- More than 1,500 of them are in the UK
- Caroline previously invented a smartphone game...
- .. where you try to get a virtual plane to land near a preselected city
- Caroline devised the smartphone version four years ago

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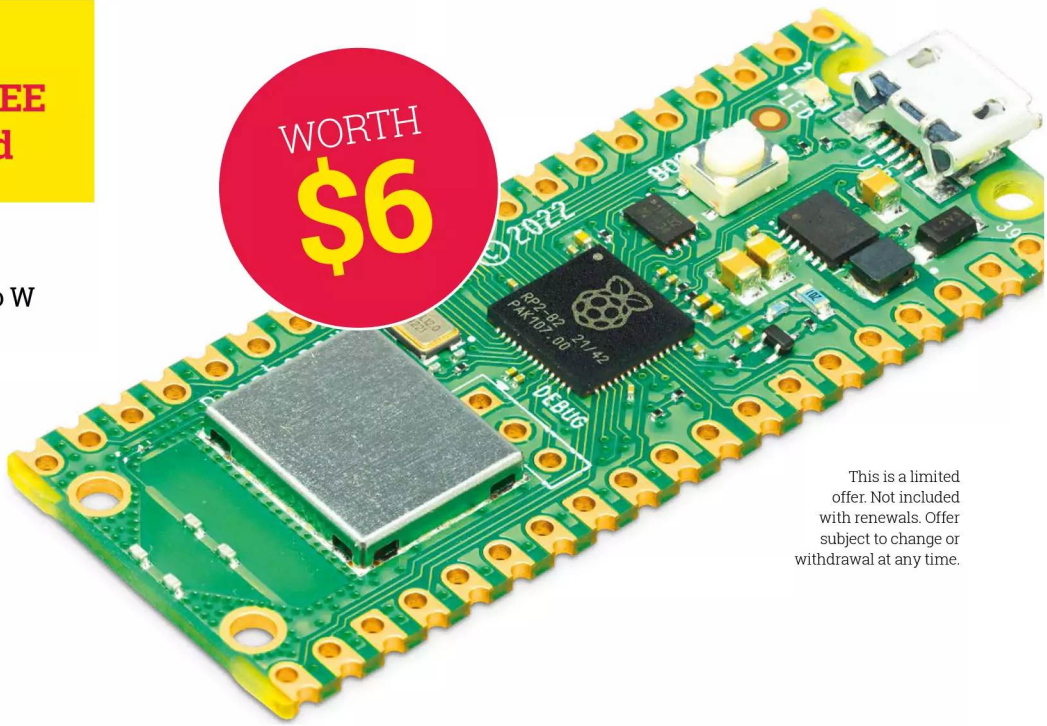
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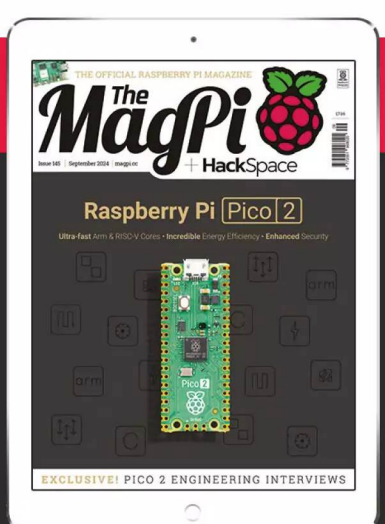
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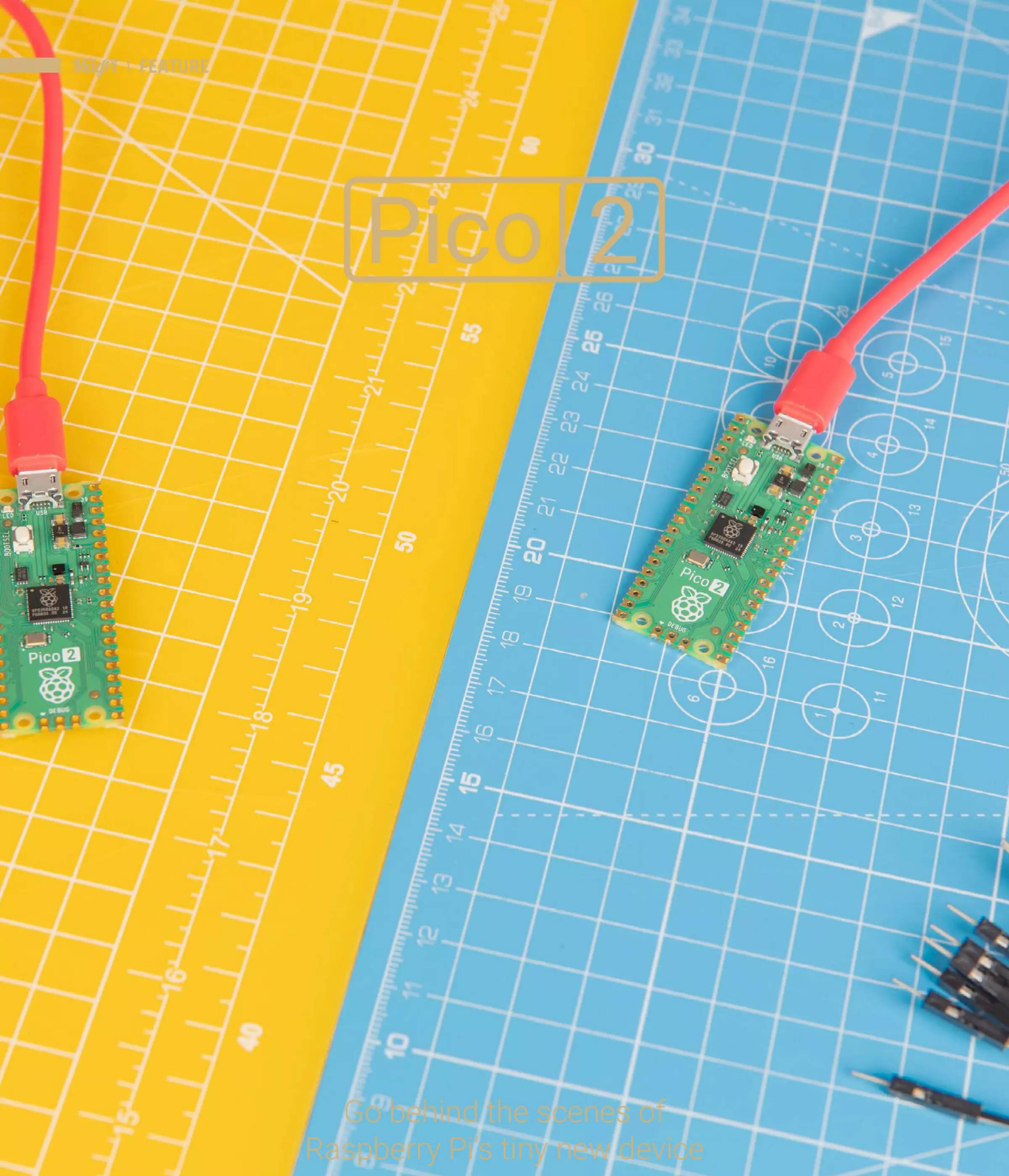
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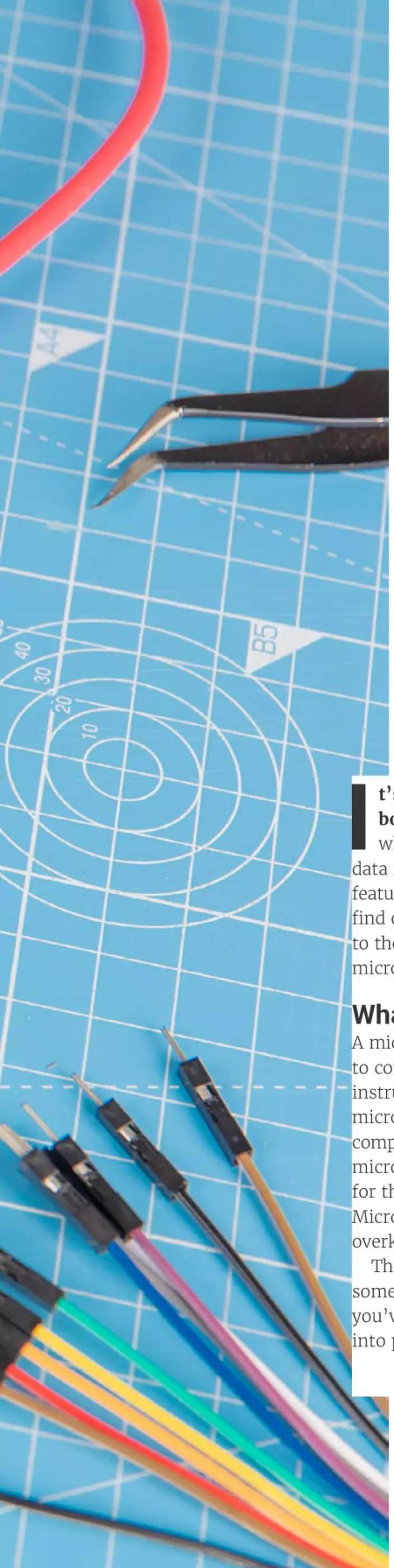
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Pico 2



Go behind the scenes of Raspberry Pi's tiny new device

Andrew Gregory



> Faster processors, more memory, greater power efficiency, and some industry-leading security features

It's here: the second generation of Raspberry Pi's Pico microcontroller board was released to an unsuspecting world on 8 August 2024. And what an upgrade it is: faster processors, more memory, more ways to get data in and out, greater power efficiency, and some industry-leading security features. We've been talking to the engineers behind this miniature marvel to find out how and why they made this device, and we've got a small insight in to the massive amounts of know-how it takes to produce an industry leading microcontroller board. Spoiler alert: it's a load of hard work.

What is a microcontroller board?

A microcontroller is a chip that contains a processor, interfacing options to connect it to other components, and some amount of RAM, to store the instructions that it needs to boot up properly. The difference between a microcontroller and a computer is that you can do multiple things on a computer; send emails, run graphics programs, browse the web, etc. With a microcontroller you program it to do one thing, and it does that one thing for the rest of its life — or until you program it to do something different. Microcontrollers are in every modern appliance, where a computer would be overkill, but there needs to be some form of programmed control.

The RP2350 microcontroller is at the heart of the Pico; take that chip, add some power management, flash memory, GPIO Pins and a USB port, and you've got a microcontroller board: an easy, affordable way to dip your toe into programming devices.

Pico 2: the same, but better



What's new in Pico 2

James Adams, CTO (Hardware), Raspberry Pi

At first glance, not much has changed, according to James Adams, CTO (Hardware) at Raspberry Pi. "It's got the same I/O… it's using the same form factor. It looks almost the same; the biggest visual change is that the silkscreen now says 'Pico 2'. Apart from the new RP2350 chip, we wanted everything to be as similar as possible to provide a drop-in experience for the user.

"Fundamentally, it's going to be a very similar experience to Pico, where developers will download the SDK and it will all look very, very similar in terms of building software, compiling software. Users will still plug the USB in and drag and drop their UF2 files on to it.

"There are two interesting things from the circuit perspective: one is that we've doubled the Flash memory, so you've got 4MB on Pico 2 vs 2MB on the original Pico. The other is to do with the way that power is supplied to the chip.

"RP2040 has an onboard linear regulator that takes 3.3V and regulates it down to 1.1V for the processor core. RP2350 has a switch-mode power supply on board, which does the same thing, but is more efficient.

"One of the highlights of the RP2350 chip are the faster M33 processor cores, as opposed to the M0+. We also have RISC-V cores in there – that's the Hazard 3 as created by Luke Wren, who's one of our employees.

"We've got two M33 processor cores running at 150 megahertz, so they're roughly twice as fast as RP2040, though it will depend on your use case.

"You've got twice as much SRAM, which is going to help with any general stuff, but especially with running things that are quite SRAM heavy, like Micropython. The PIOs have had various improvements based on what we've learned from RP2040, to be more efficient and allow for more use cases. And you've got an extra one of them in RP2350.

"This is the chip we always wanted to build. RP2040 was the pathfinder to this chip. This is what we would have built as RP2040 if we'd had the capability – your second chip is always better, because you learn from the first one, and RP2350 on Pico 2 represents that. It's faster, it's got more peripherals. It's got the improved power states and security that were lacking in RP2040 and the original Pico. And so we're super pleased that we've now put together the chip that we always wanted to build in RP2040, but we had to cut a lot of features out because they take a long time to develop. It's the chip we always wanted, in the Pico we always wanted."

Pico 2 hardware specification

Form factor
21 mm × 51 mm

CPU
Dual Arm Cortex-M33 or dual RISC-V Hazard3 processors @ 150MHz

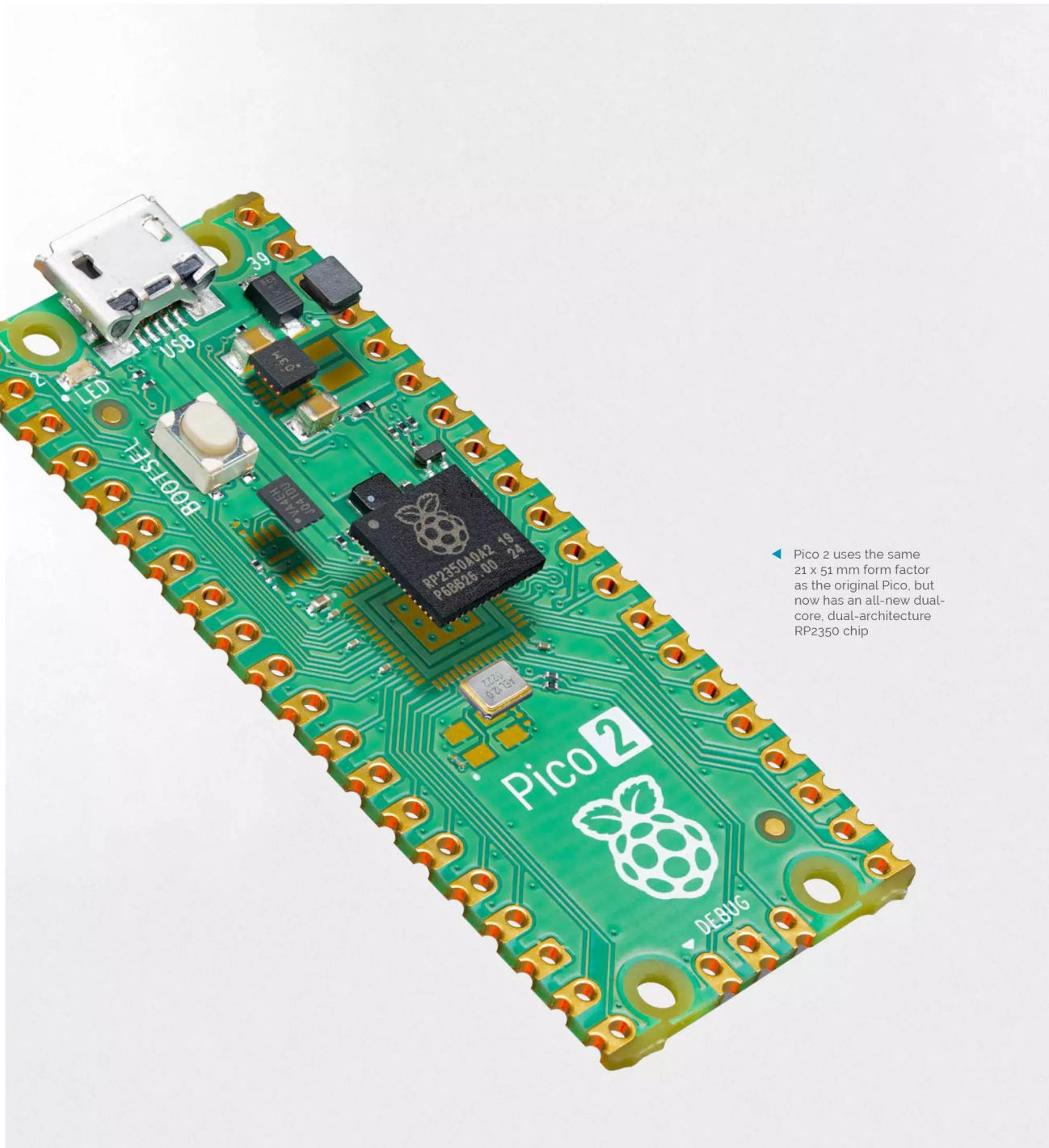
Memory
520 KB on-chip SRAM;
4 MB on-board QSPI flash

Interfacing
26 multi-purpose GPIO pins, including four that can be used for ADC

Peripherals
- 2 × UART
- 2 × SPI controllers
- 2 × I2C controllers
- 24 × PWM channels
- 1 × USB 1.1 controller and PHY, with host and device support
- 12 × PIO state machines

Input power
1.8–5.5V DC

Operating temperature
-20°C to +85°C



Pico 2 uses the same 21 x 51 mm form factor as the original Pico, but now has an all-new dual-core, dual-architecture RP2350 chip



RP2350

As we've heard from James Adams, the Pico 2 is physically virtually indistinguishable from the original Pico. What makes the difference is the brains of the board: the RP2350 chip.

> We can get down to less than a tenth of the power used by RP2040 in its low power state



RP2350 changes

Nick Francis,
ASIC Technical Director

"There are quite a few changes from RP2040 to RP2350. The main ones are security, higher performance through dual Cortex-M33 processors running at 150MHz, more memory and new OTP, and lower power modes.

On RP2040, in our low-power state, we'd get down to about 180 microamps in our dormant state with all clocks off. On RP2350 we can switch off power to a lot of the chip and get down to less than a tenth of that, which is going to be more useful for low-power applications, for example, where a device might spend a long time just waiting for input from a sensor.

"We've gone from a regulator to a switcher. Regulators are inherently not as efficient under load. So we've changed our core supply regulator – it's actually a combination device, so it has a small regulator for low-power modes up to 1 milliamp, when most of the chip is powered down and we're waiting to wake up. And then when we turn the core on we flip to a switch mode power supply which can provide up to 200 milliamps – more than RP2040, as the chip is bigger so has a higher peak current. The switcher is more efficient than the regulator used on RP2040.

"The PIO is still there; with some enhancements to that. We now have a third PIO block in there, so another four state machines. And we're still using the TSMC 40nm process. Re-using a process that you know saves a lot of time. When you're going to a new process node, you have to go and get a load of new IP and have to learn how to use it all.

So sticking to the same process meant that we can reuse some of this IP and knowledge from what we did on RP2040 and also RP1 [Raspberry Pi's first in-house chip, which was used on the Raspberry Pi 5]. So we've reused cell libraries, memories, ADC, PLL and USB PHY from RP2040.

So there's quite a lot that is the same, and we can just drop it in fairly easily and can then focus on changing the other logic and adding any new IP like the OTP or core supply regulator. We did review and update parts of the existing design, but there's an awful lot of new design in RP2350, and some higher level features like power changes or security touched a lot of the chip and has a wide impact on design and verification."



Software

Graham Sanderson,
Principal Software Engineer

"When you power up the chip, you have to run some software, but the program that the user installs, their firmware is stored in flash, so you have to run some code to be able to read flash before you can do anything else. That code is part of the boot ROM, named because it runs at boot, and it's stored in ROM.

"On RP2040 the boot path is fairly simple – there is a program in flash, you go look for it, and then you run it. The rest of the boot ROM space is taken up by things like floating point math support, a variety of other useful runtime APIs, and of course the UF2 bootloader that enables the user to drag and drop programs onto the Pico, mounted as a USB drive, and make them run.

"The RP2350 boot path supports a bunch of new functionality, support for RISC-V as well as Arm processors, and particularly completely new support for secure boot on Arm. This requires us to verify that the program stored in flash is trusted to run on the RP2350, by verifying a cryptographic signature. Additionally, we have hardened the boot code with the goal of making it impossible to run any user code that is not correctly signed, even in the hands of an attacker.

"The RP2350 boot ROM also supports dividing the flash into multiple partitions so that you can keep multiple copies of a binary, or keep shared data or resources separate from the main program. Our focus, as ever, has to make things powerful yet simple; therefore you can set up secure boot and have two (A/B) partitions, but still just drag and drop a UF2 to update your software. Dropping the UF2 will automatically target the partition that isn't currently in use, before switching at the next boot, thus avoiding situations where you have only half written the program. If your new program version is not correctly signed, the old version will continue to boot. Support for A/B partitions makes it much easier for user code to over-the-air updates, for example, reading a new version of itself from a web server, but now it can write that new copy to an unused area of flash, rather than worrying about updating the part of flash it itself is running from!

"Let's not forget about the Raspberry Pi Pico SDK either. This has had a lot of enhancements, bug fixes and new features, and of course, now supports both RP2040 and RP2350, and both Arm and RISC-V. Nonetheless, most people should just only need to recompile their RP2040 program for RP2350 with minor, if any, changes. I can't wait to see what people do with the new chip."

Where does the name come from?

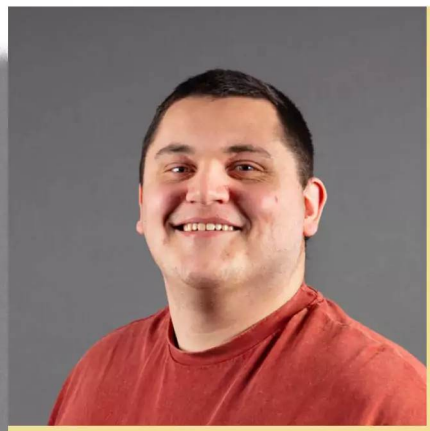
RP2350

- **RP** stands for Raspberry Pi – obviously!
- **2** The first number, 2, is the number of cores.
- **3** The second number, 3, is loosely the type of processor – on RP2040 it was an M0+; on RP2350 it's an ARM Cortex-M33.
- **5** The 5 is the log to base 2 of the RAM divided by 16 kilobytes. RP2350 has 520kb of memory, essentially double what we had on 2040, so that goes from 4 to 5.
- **0** The last zero is the size of the on-chip non-volatile storage. On the RP2350 there isn't any – however, in the near future there will be variants on the market with on-board storage, and you'll see that reflected in the chip names.

RISC-V

RISC-V is an open-source chip instruction set. The first RISC-V chips were released in 2014, and since then it's been steadily growing in popularity, particularly in academic circles – the open source nature of RISC-V makes it a perfect place to start if you want to study how processors work.

The Hazard 3 RISC-V cores on the RP2350 were designed by Raspberry Pi's own Luke Wren in his spare time – and as they're open source, you can download the design files yourself and start poking around in the very same chip that will eventually be in use on millions of units out in the wild. As Eben Upton puts it: "In adding Hazard3 to RP2350, we're aiming to give software developers a chance to experiment with the RISC-V architecture in a stable, well-supported environment, and to popularise Hazard3 as a clean, open core, suitable for verbatim use in other devices, or as a basis for further development."



Luke Wren

Principal Engineer, Chip Team

"I've been doing logic design in my spare time since I was a student. It's highly addictive, and I think it's more accurate to say I'm a hobbyist who works in chip design than a chip designer with a hobby! It's an open-source processor design that anyone can put in their chip and use to run RISC-V code anywhere. You can also run it on an FPGA board, or run the simulator on your own machine. It's all built using open-source tools like yosys, nextpnr and gtkwave.

"The best way to get started is to get an FPGA board and just get hacking. Writing RTL [register transfer level] is a bit mind-bending at first – you can think of it like a C program where all of the statements execute at once, rather than sequentially – but that kick of seeing your own hardware come to life keeps you going. Start by blinking an LED, and keep going.

"Hazard3 is 100% my own design. It's a fork of Hazard5, the processor I designed for RISCBoy, my open-source competitor to the Game Boy Advance. Hazard5 is a five-stage pipeline – therefore having many hazards: data flow, control flow and structural – and a hazard is also a kind of 'risk', like the instruction set.

"Hazard5 was meant to run at the highest possible frequency on an iCE40 FPGA, so I could run the RISCBoy graphics core at a higher frequency too. Hazard3 on the other hand is a production-grade processor which delivers as much performance as possible in its small area envelope and within the range of frequencies I expect to see on microcontroller designs. It's a productionised version of Hazard5 with a shorter pipeline, hardware debug, and some security and memory protection features that people expect in real systems.

"From forking Hazard5 to having Hazard3 running CoreMark took less than a week. From that point until the first RP2350 tapeout was around two years, working on it on-and-off throughout. There is still ongoing maintenance work, and plans for future expansion – it will never be 'finished', just transition from development to stable releases.

"Before I started working on RISCBoy I had a project called Tarantula which was an eight-thread barrel processor implementing the Armv6-M instruction set, because that was the ISA I was most familiar with at the time, having written some Assembly during a summer internship. I abandoned the project because I realised I would never be able to share it with anybody, and I don't think I even have that source code any more.

"That experience changed how I looked at things from that point forward. When I decided I wanted to build a games console from scratch, including the processor, I looked around the instruction sets available at this point, this was around 2018, and there were a few interesting ones – Hitachi SuperH had just become much less legally restrictive – but RISC-V stood out as an instruction set where I could implement it fairly easily.

"The base instruction set is quite clean and simple, and you can add more complexity from a menu of extensions. I could share that with other people, and they could actually use it, and I could program using a real production-grade compiler like GCC or LLVM

"That was a long time ago, and RISC-V has come a long way since, both technically and as a community. There are other instruction sets that have become more open in the wake of RISC-V but I think it's clear where the momentum is. It's easy to criticise some of the technical decisions made in the base ISA – did we really need 31 link registers? – but the community is the most important thing in my eyes.

"I am excited about RISC-V because it lets you perform your mad-scientist architecture experiments on top of a clean and standard architecture. If you look at something like CHERI, which is a super-exciting development in the embedded security space, those folks have just gone and written a spec, and you can just go and implement it – no need to wait for it to be served on a plate.



The RP2350 has been designed to make it easy for third-party manufacturers to incorporate it into their products – such as the RP2350 Stamp by Solder Party

Security

James Adams, CTO (Hardware), Raspberry Pi

"What was missing from RP2040? Any kind of security, right? If you were building a product on top of RP2040, and you programmed your flash, there was no encryption in there – anyone could go and steal your firmware. If you build something on RP2040 there was no security whatsoever. And that was by design, because security is hard – we wanted to get a product out and see what people did with it.

"At the high level, you can do encrypted boot. You put encrypted firmware in the flash. It's got mitigations against the usual chip sort of fuzzing and glitching.

"It runs Arm's Trust Zone for microcontrollers. That's an interesting distinction – Arm always refers to Trust Zone, singular, but actually, there are two trust zones: there's the micro world trust zone, and then there's the big A-class Linux, Raspberry Pi stuff, and they're, both a little bit different.

"We run the microcontroller trust zone. You can hive off peripherals to be secure or insecure. So you basically have these two modes, you know, secure mode and insecure mode. And you have lots of different switches to allow you to partition the device into the secure bits and the non-secure bits. And that, along with, encryption, enables you to build a secure product.

"At a high level, you're kind of partitioning the chip into secure bits and insecure bits. And you can run secure bits of code and insecure bits of code, and they can talk to each other in prescribed ways that keep the whole thing secure. Just like any other microcontroller chip from STMicroelectronics and all these guys who have this security, the RP2350 does the same stuff, but we've also put quite a lot of effort into making it secure, right?

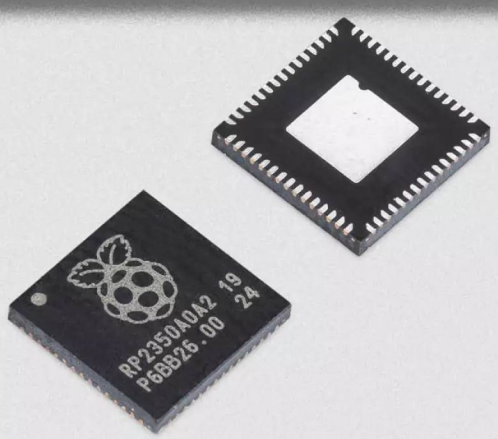
"[We've also been thinking] about how people could try and crack it, and putting mitigations in there. We have a special peripheral that means when the thing's actually booting from its boot code, it has to feed this peripheral with state [information] continuously. So as you're booting, you kind of capture the state, and you have to feed the peripheral with the right state, otherwise it resets the entire chip.

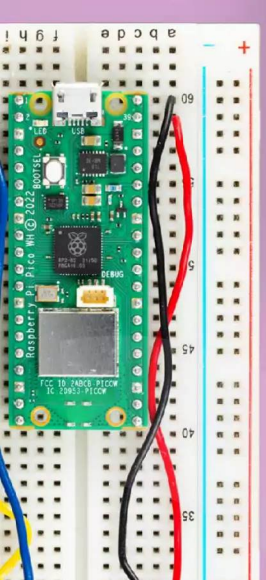
"What that means is, if someone's trying to glitch the chip, glitch the boot ROM to go and jump to a different set of instructions, that state becomes discontinuous, and the peripheral will immediately see that. Effectively, if you don't execute the instructions in the right way, it will immediately detect it and shut the chip down.

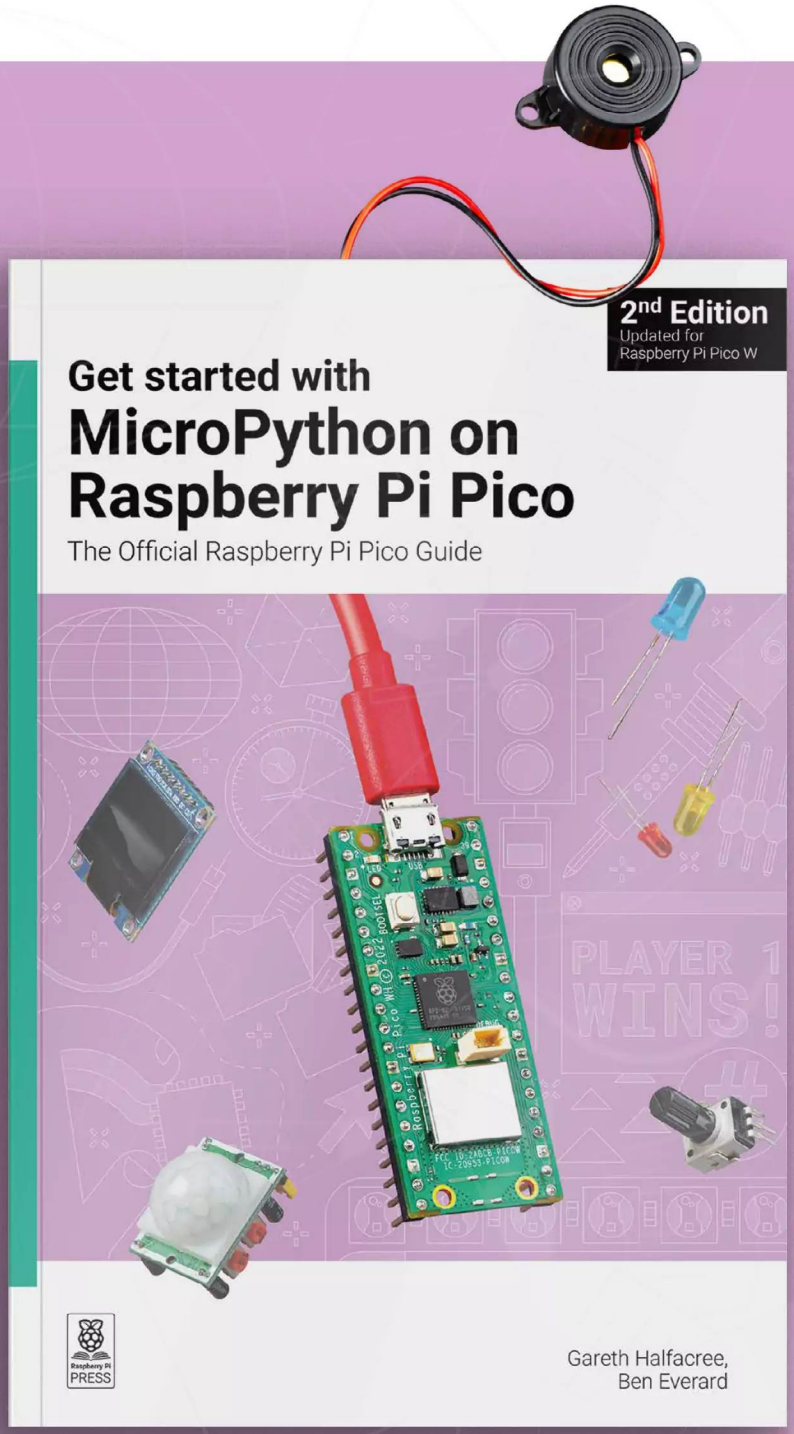
"And we've actually had a couple of consultants take a look at the chip and try and do all the standard glitching and resetting and fuzzing, and so far they've been unable to break this stuff.

"So that's one layer of mitigation; another one is glitch detection in the chip. So again, if it detects the voltage glitching, it will reset; we have a filter on the reset pin to try and stop people glitching it in the first place.

"There are several layers of mitigation for the security. And actually, it does seem, at least for the moment, that this is proving very difficult for the guys who tend to be able to crack these things to actually do it."






2nd Edition
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Get started with
MicroPython on
Raspberry Pi Pico
The Official Raspberry Pi Pico Guide
Raspberry Pi
PRESS
Gareth Halfacree,
Ben Everard



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Part 02

Build a private cloud server

This month we take our private cloud server online, and get secure access to our files from anywhere in the world, no third party required



MAKER

PJ Evans

PJ is a writer who has had a home server for years. He's a bit worried that it keeps changing its hostname to HAL.

@mrpjevans

You'll Need

- Your OpenMediaVault server **magpi.cc/144**
- Access to your internet router

Top Tip

Changing port numbers

If you're concerned about the bad people finding an open Wireguard port, you can always reconfigure your router to forward a different port to 51820 locally. It's not perfect, but it helps.

Last time we built a local network-attached storage system (NAS) using a Raspberry Pi and some large hard drives. But wait, you say, isn't this a cloud server tutorial? Well yes, you're right. Now we've laid the foundations, we can start the process of getting things online. We'll start with access to the OpenMediaVault (OMV) file store we created last time. Exposing the files to the rest of the Internet is straightforward, but doing it securely requires a little more work. We need a virtual private network (VPN) that we can use to access files and all the other services we will be adding in the future.

01 Get a domain name

Most people have a dynamic IP address at home. That means that the address that identifies your home router on the internet will change from time-to-time (when and how often depends on many things). So the first problem we have is how to find our private cloud server when we're away from home. We have a solution! Start by registering yourself a domain name. This step is optional (you'll see why shortly) but it does mean you have control of your internet address going forward, you'll also need one if you want to do more with your server such as host email. Register a domain name of your choice with a registrar such as GoDaddy or Fasthosts.

02 Set up a dynamic DNS account

Dynamic DNS is a 'fix' to the changing IP address problem. A dynamic DNS service runs a small script on your server that 'pings' your current address to a DNS system every few minutes, keeping everything up-to-date. If a static IP address isn't an option (ask your ISP) create an account at a service like DuckDNS (**duckdns.org**). You'll get another domain name and instructions to implement the script on your server. This is normally just a few lines of code, DuckDNS provides full instructions on how to set it up (others will vary). You should now be able to ping your home router from that domain name.

03 Create an alias

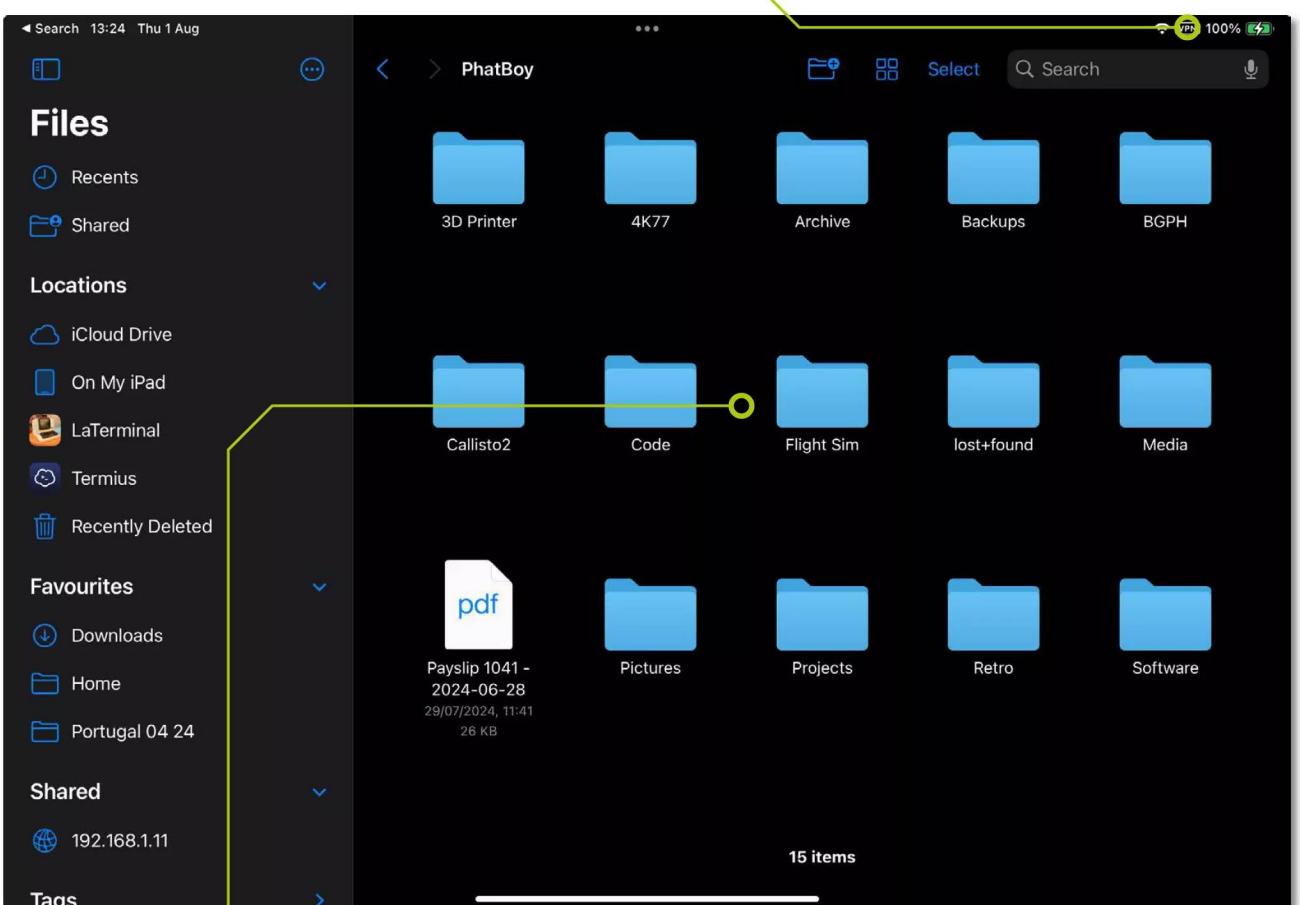
The domain supplied by a service such as DuckDNS will probably not be ideal and cannot be used for creating sub-domains or hosting things like email servers. This is why we recommend registering your own domain name. We can then map a domain to your dynamic DNS provider, which is known as aliasing. In your domain name control panel, create a new CNAME (alias) record and choose a subdomain for your server (we used 'cloud'). Add this as an alias to the domain given to you by the dynamic DNS provider. You should shortly be able to ping your home router using your new domain.

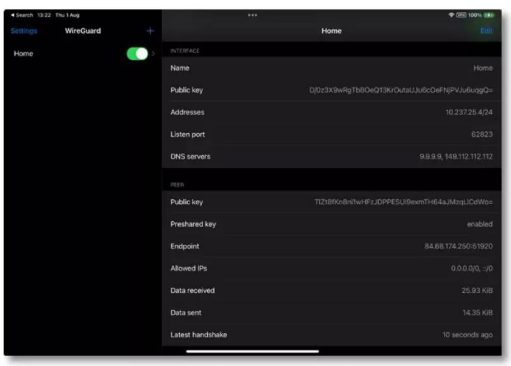
04 Install PiVPN

Now you can reach your home router from anywhere in the world using your shiny new domain name, but what we really want is to be able to reach your private cloud server and to make sure only you and those you permit can get that access. We also need to ensure that no one can listen in on your traffic. We need a VPN and PiVPN (pivpn.io) is the free tool that provides just that. To install, get to the command line and run:

```
curl -L https://install.pivpn.io | bash
```

> The first problem we have is how to find our private cloud server when we're away from home





▲ The Wireguard app runs in the background, but you can check your configuration and see that traffic is passing to and from your home network

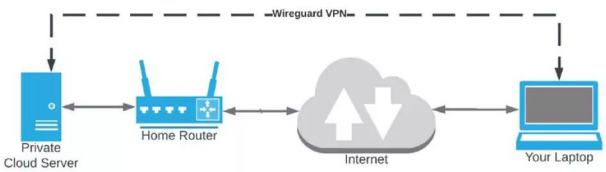
05 Configuring PiVPN

Time to configure PiVPN. The first section will ask about your static IP address. Your server should be configured to have the same IP address on your home network at all times. Check with your home router instructions on how to reserve a DHCP lease or follow the instructions to set a static IP address. When asked to choose the installation mode, choose 'Wireguard'. Leave the port at 51820 and reply 'yes' to everything until you get to 'Public IP or DNS'. Select DNS Entry then enter your own domain name (the full one from the CNAME record). We recommend, when prompted, you allow unattended upgrades or security patches. Reboot when prompted.

06 Configure your home router

Your private cloud server is now ready to receive connections via the Wireguard VPN, but the outside world cannot yet see the server, only your router. The next step will vary depending on which router you are using, but what you need to do is set up port forwarding. Your router needs to allow port 51820 inbound and forward all that traffic to port 51820 on your server (using its internal IP address). If prompted for the type of traffic, select UDP or 'All/Both'. Some routers may need to reboot. Now any traffic arriving from the outside world on the Wireguard port will be forwarded to your server.

▼ A virtual private network sends encrypted data through the internet between your devices, giving the impression they are on the same local network



07 Install Wireguard clients and create profiles

To use your new VPN, you need the Wireguard software on every device you want to use to access our network. Luckily, the Wireguard software is free and available for a wide range of platforms, see **wireguard.com/install**. Once installed, each needs its own individual profile. To generate the profiles, go to the command line on your server and enter:

```
pivpn add
```

Enter the name of the profile (e.g. 'My laptop'). A profile will be generated and stored in the 'configs' directory of your home folder.

08 Install profiles

Repeat Step 7 for every device you want to use. Now, for any computer or laptop, transfer the matching file in **~/configs** to that computer. You can use `scp` from the command line or use a USB key. Open Wireguard and select 'Import tunnel(s) from file'. Choose the profile and your VPN access will be configured. For mobile devices it's even easier. From your server's command line run:

```
pivpn qrcode
```

Now choose the profile you want and a QR code will be displayed that can be read by the phone or tablet. Your tunnel is ready to go.

09 Connect!

The easiest way to test whether everything is working is on a smartphone. When you're ready, disable Wi-Fi so the phone is using cellular data (this assumes you can get a decent connection). Open up Wireguard and set the profile to 'Active' (e.g. slide the switch on iOS). Using a network utility like Fing, try and ping the internal IP address of your private server. If you get a response, all is working as expected. You can try opening the OpenMediaVault web page and logging in. Don't forget to deactivate the Wireguard VPN when you are finished.

10 File access

We can now take our first real steps into running a private cloud server. Thanks to OpenMediaVault, we can now access our files from anywhere in the world. How you do this all depends on what platform you are using, but it'll basically work the same way as if you are on the local network. For now, use the IP address of the server, not its hostname – we'll sort that another time. For example, on macOS, select 'Finder' > Go > Connect to Server and enter **smb://ip-address/sharename** (replacing those values as needed). iPhone users can use the Files app and a range of SMB clients are available for Android.

11 Further configuration

By default, Wireguard will tunnel all of your traffic through the VPN. That means if you are accessing a web site, when Wireguard is enabled everything is going though your home server, which may have an affect on performance. To rectify this, edit your profile in the Wireguard client. Make a note of the IP address of 'Addresses' and change 'Allowed IPs' to the same value, replacing the last section of the IP address with 0. So, **10.237.25.4/24** would become **10.237.25.0/24**. Once saved this will only route your cloud server traffic through the VPN.

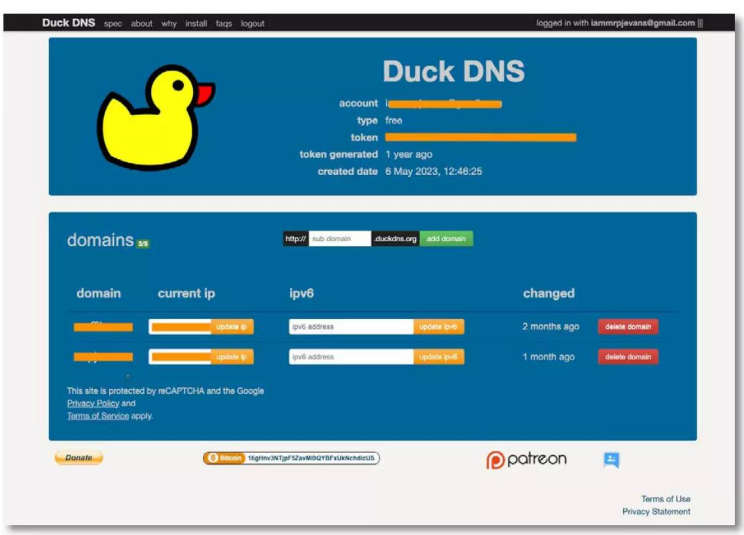
12 Next steps

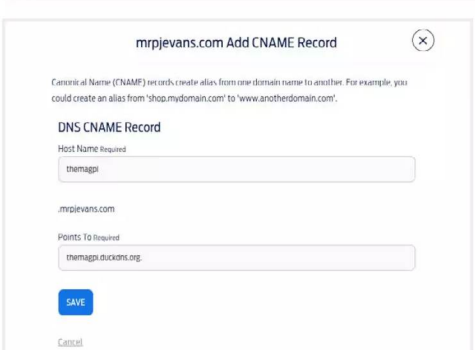
This was a complicated part of the process, but it enables all kinds of possibilities for secure access to your precious data. You can now get access to your home network from anywhere in the world and not just your cloud server, you can also reach other devices on your internal network too. However, you don't want to go through the process of creating VPN profiles every time you want to share a file with someone and next month we'll be looking at how to add easy and secure open file sharing.

Top Tip

Paying the (duck) bills

A lot of dynamic DNS services are expensive, but DuckDNS is free of charge and run by a single person. Consider saying thank you with a donation.





- DuckDNS is one of many dynamic DNS providers that can give you a reliable domain name even if your public address changes
- Adding a new DNS CNAME record is an essential step in accessing your NAS from over the internet

Part 01

M.A.R.S. Rover: Build a robot and remote-control it

Explore Mars, or your backyard, with an all-terrain Raspberry Pi rover



MAKER

Phil King

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

@philkingeditor

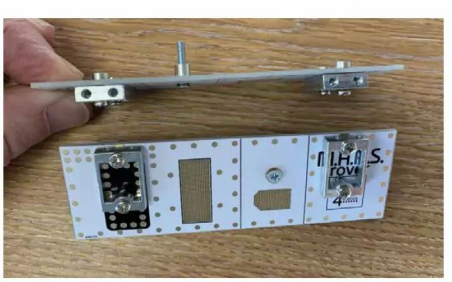
The M.A.R.S. Rover from 4tronix is one of the best robotics kits around. Loosely based on NASA's Curiosity rover on Mars, this six-wheeled robot features a similar rocker-bogie suspension system that enables it to crawl over rocks and navigate tough terrain. Another unusual feature is the ability to steer four of the wheels using servos.

In this first instalment of our guide, we'll be covering how to build the M.A.R.S. Rover, set up the software, calibrate the servos, and then control it manually from a remote computer. Even if you don't yet have a M.A.R.S. Rover kit, you can pick up a few general tips along the way for your own robotics projects.

01 Build the chassis

Every robot needs a chassis to house the electronics and fix the motors to. In the case of the CamJam EduKit #3 (**magpi.cc/edukit3**) beginner's kit, you can even use the box it comes in! For building a custom wheeled robot, there are numerous chassis available, in a variety of shapes and sizes. Or you could even 3D-print one.

This isn't required for the M.A.R.S. Rover, however: its chassis is formed by three rectangular PCB pieces connected with metal brackets and screws. The top PCB integrates all the electronics, including the all-important drivers to operate the servos and motors. A dual H-bridge enables two sets of motors to be driven forward or back by reversing the polarity. Pulse-width modulation (PWM) of the electrical signal is used to adjust the speed.



▲ Make sure the metal brackets are fitted flush to the edge of each side piece, to attach the top PCB

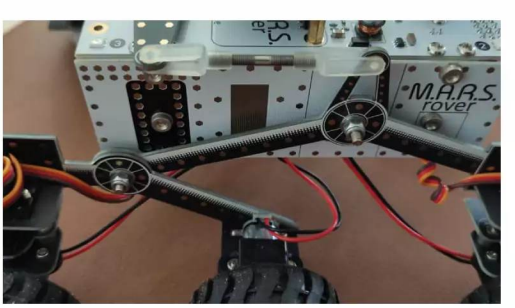
02 Add arms and bogies

With the main chassis built, it's time to fit the rocker arms and bogies for the Rover's suspension system. Each arm is fixed to a chassis side using a screw, washers, and a nyloc nut. This is a key part of the build. Holding the screw steady with the screwdriver, use the supplied multi-wrench tool to tighten the nut. It needs to be tight enough to stop the arm wobbling around too much, but not so tight that it can't rotate freely. So tighten it fully, then ease it off slightly. The same principle applies to fitting the bogie to the rocker arm. Make sure not to tighten it so much that the bogie can't rotate freely.

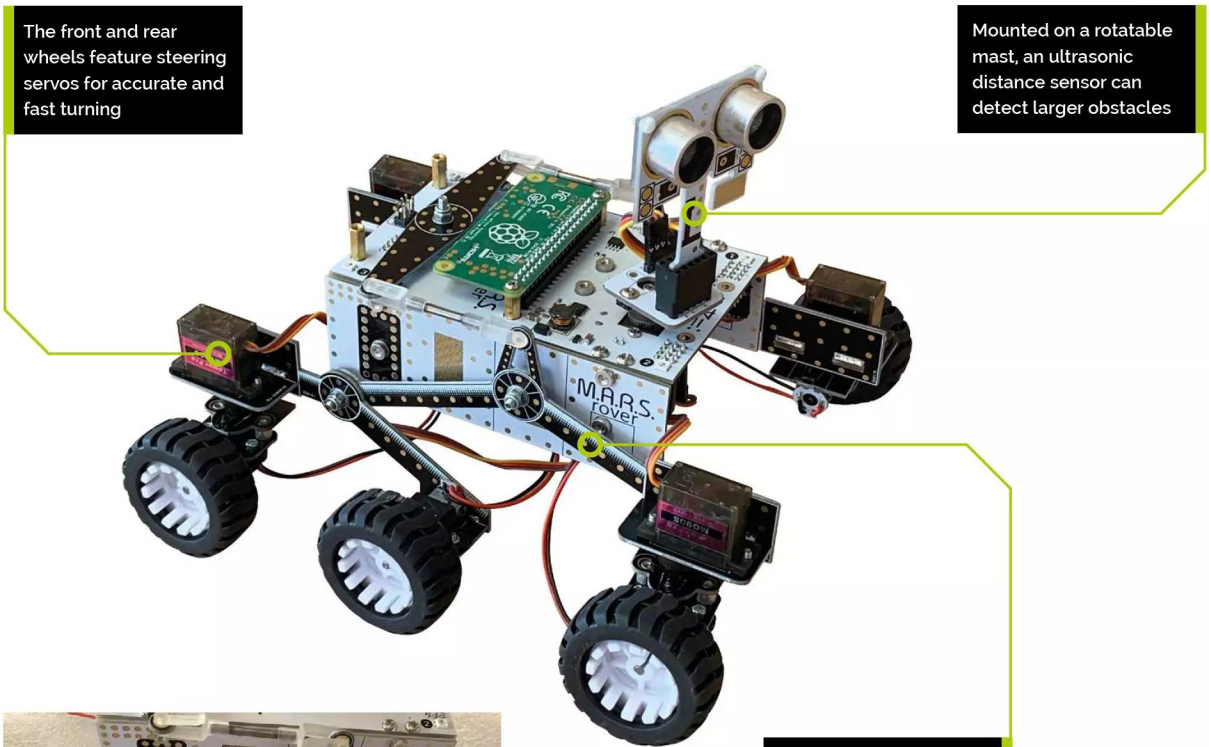
03 Fit servos and differential

Each rocker arm and bogie has a mount for a servo that enables the four corner wheels to be steered independently. Screw each servo to its mount from below, with the servo's label side on the exterior. Leave the cables unconnected for now.

A connecting differential arm is used to coordinate the rocker arms on each side of the rover. Screw the arm to the top PCB from beneath, tightening the nyloc nut without preventing the arm moving freely.



▲ Push rods connect the rocker arms to each other via a differential arm on top of the rover





▲ When attaching the rocker arms and bogies, make sure not to overtighten the nuts so they can move freely

For each push rod, screw a plastic snap link on either end and carefully measure the distance between the two clip points – it should be around 53mm. Then clip one end to the differential arm and the other to the top of the rocker arm. Check it works by moving a rocker arm up and down: the opposite arm should move the opposite way.

04 Fit corner mountings

While the two middle motors are attached directly to a mount on each bogie, the others are fixed to separate brackets that are connected to each steering servo via a corner mount. In turn, these are connected to the shafts of the servos using cross-shaped servo arms, attaching them with 6mm screws.

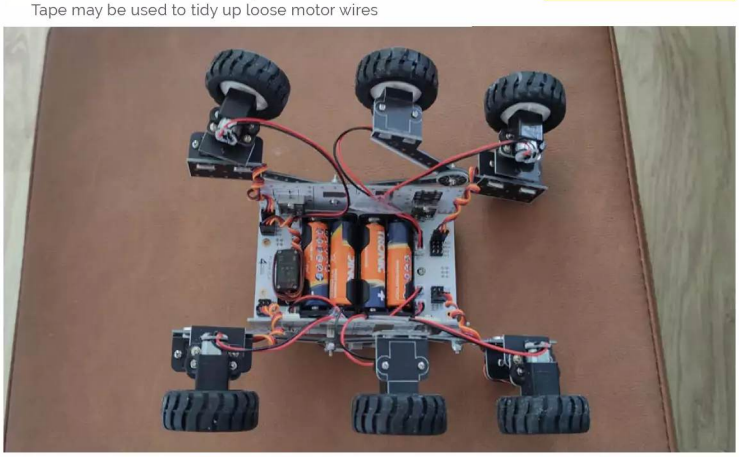
At this point, you can calibrate the servos with the little ZeroServo board supplied in the kit. For each servo, make sure the corner mount has its protrusion facing away from the chassis, at 90°, then plug its leads into the USB-powered ZeroServo to set the zero position.

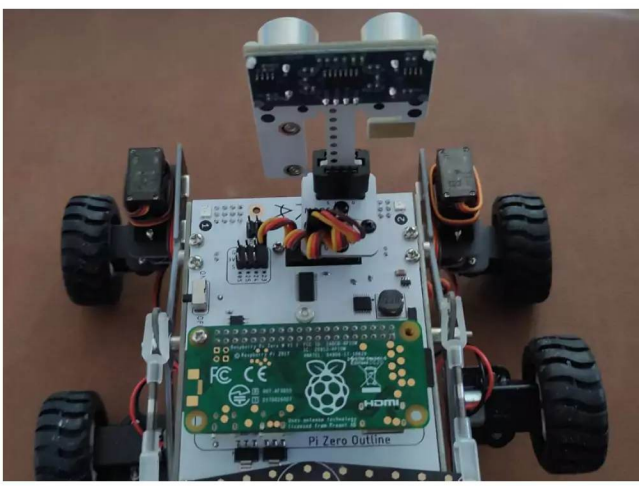
> For a custom wheeled robot, there are numerous chassis available

You'll Need

- M.A.R.S. Rover for Raspberry Pi Zero kit **magpi.cc/marsrover**
- Raspberry Pi Zero W or 2 W
- microSD card
- 4 × AA batteries

▼ Four AA batteries provide the power. Tape may be used to tidy up loose motor wires





▶ Raspberry Pi Zero is mounted on top, along with an ultrasonic sensor / camera mast

05 Add the motors

With the servos zeroed, it's time to fit the motor brackets and motors. Start with the corner ones, screwing to their mounts, then the latter to the corner mounts. As mentioned, the two middle motors are fitted directly to the bogie mounts.

With all motors attached, connect their JST leads to the J1–J6 sockets on the underside of the main PCB. It doesn't matter which ones you use, as long as they're on the correct left and right sides, since all the wheels on each side are driven simultaneously. For tidiness, you could tape loose wires to the interior of the chassis sides, so long as it doesn't impede the movements of the rockers and bogies.

It is important to connect the servo cables to the correct pins on the PCB underside, however. Each one should be plugged into the pins nearest it, so SV15, SV9, SV13, and SV11. Make sure the brown wire is connected to G (ground) in each case. To keep the cables tidy, wrap them around the servos; or you could stick them down each side of the battery holder.

06 Fit wheels and mast

A wheeled robot needs wheels. Generally, these come in a wide range of types and sizes. There are even special mecanum wheels with 45°-mounted rollers that enable a robot to spin on the spot. The wheels on the M.A.R.S. Rover are standard ones with grippy tyres. While holding the motor, push each one onto the motor's shaft, lining up the D-shaped hole and axle.

To help sense its surroundings, the rover has a mast with an ultrasonic distance sensor, plus a camera mount. The mast is plugged into a socket on its mount, which is turned by a servo fixed to the underside of the rectangular hole at the front of the main PCB. The servo cable needs to be plugged into the SV0 pins on the underside, while the mast mount board is connected to the #23 pins on the top.

07 Zero and power

Finally, you can add the brains of the operation: your Raspberry Pi Zero W or 2 W, with soldered GPIO pins. Using standoffs and a booster header, mount it upside down on top of the rover, with its power/USB ports pointing backwards – the PCB has an outline to help you.

When it comes to power, you need four good-quality AA batteries. Since Raspberry Pi Zero requires extra current when booting up, we found that some rechargeable batteries didn't supply enough, so you may need to use standard alkaline batteries or better rechargeables (4tronix recommends Eneloop or Energizer Extreme ones).

08 Prepare Raspberry Pi

A special Python module is used to control the FireLEDs (akin to NeoPixels) on the M.A.R.S. Rover. Since the Bookworm version of Raspberry Pi OS requires Python packages to be installed within a virtual environment, it's easier to use the older Bullseye version – in Raspberry Pi Imager, select Raspberry Pi OS (Legacy 32-bit). In the Raspberry Pi Imager settings, you should also ensure that the newly installed Raspberry Pi OS connects to your Wi-Fi router and has SSH enabled.

Top Tip

Assembly guide

We've covered the build basics here. You can find a more detailed step-by-step assembly guide on the 4tronix blog: **magpi.cc/marsroverguide**.

Powering up the rover, wait a little while for Raspberry Pi Zero to connect to the Wi-Fi before SSHing in from another computer with:

```
ssh [username]@IP address]
```

You can then install the necessary module with:

```
sudo pip install rpi_ws281x
```

For the rover to communicate with Raspberry Pi, you'll need to enable SPI and I2C. Enter:

```
sudo raspi-config
```

...then select '3 Interface Options' > I4 SPI > Yes. Repeat this for I5 I2C before rebooting with:

```
sudo reboot
```

09 Install software

Next, install the M.A.R.S. Rover software with:

```
wget https://4tronix.co.uk/rover.sh -O rover.
sh
bash rover.sh
```

This creates a **marsrover** directory. Change into it and list its contents.

```
cd marsrover
ls
```

Along with the main **rover.py** library, there are several example programs, including one to fine-tune the calibration of the servos:

```
sudo python calibrateServos.py
```

There are also scripts to test the motors, servos, LEDs, and 'sonar' ultrasonic sensor.

10 Drive the rover

To control the rover manually from your keyboard, enter:

```
sudo python driveRover.py
```

Arrow keys can then be used to drive the rover forward and in reverse, as well as steering the servos to turn it left and right. To stop, press **SPACE** to coast to a halt, or **B** to brake quickly. In addition, you can alter the motor speed with the **<** and **>** keys – note that this doesn't take effect until you press an arrow key.

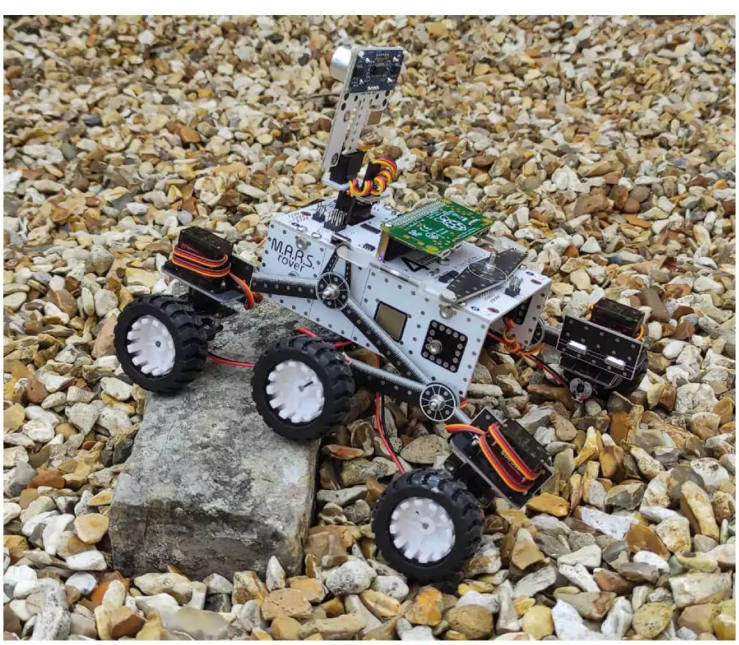
Try driving your rover over a small rock – or the end of your foot – to see that clever rocker-bogie suspension system in action.

Next time we'll look at programming the rover to drive itself autonomously, avoiding larger obstacles by detecting them with its mast's ultrasonic sensor.

Top Tip

In a spin

The rover.py library includes spinLeft and spinRight functions that you can easily add to the driving script, assigning keys to trigger them.



▼ Try driving the M.A.R.S. Rover over tough terrain and obstacles such as small rocks

HackSpace

TECHNOLOGY IN YOUR HANDS

HACK | MAKE | BUILD | CREATE

TOP PROJECTS



PG 60

FAUXTRS

The quasi-replica of a TRS-80 will stimulate your nostalgia glands

PG 62

FLOPPY DISK CLEANER

This 3D-printed machine takes care of your retro removable storage media

PG 64

LENTICULAR CLOCK

This complicated clock slices up images of seven-segment numbers under a lenticular lens

PG 66



TINY PC

The retro recreation emulates an early 2000s Dell running Windows XP

OBJET 3D'ART



PG 68

HYDROPONIC TOWER

Control nutrient levels, light, temperature and water flow. It's gardening, for geeks

FORGE

PG 70

TESSELATIONS IN FABRIC

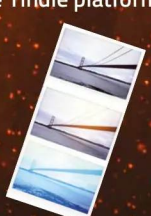
Discover the geometry behind tessellation patterns

PG 74

BUILDING YOUR SIDE HUSTLE

Set up a small maker business using the Tindie platform

PG 80



RETRO INSTANT CAMERA

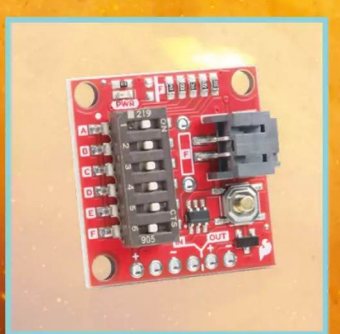
Upcycle a 1950s instant camera to use modern film

PG 86

POWERING YOUR PROJECT

A collection of useful components for electronics that need electricity

Best of Breed

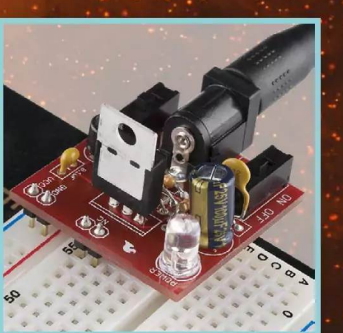












FauxTRS

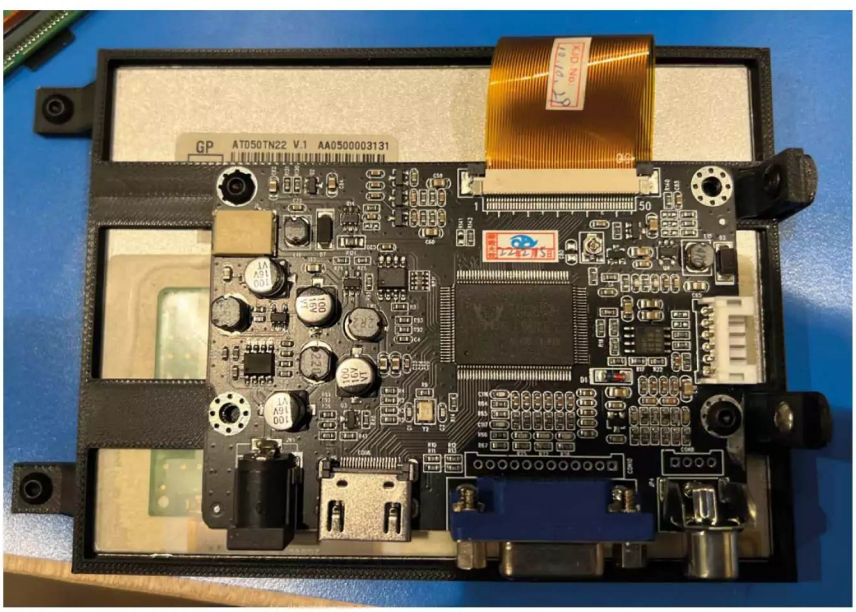
By Joe Pasqua

hsmag.cc/FauxTRS



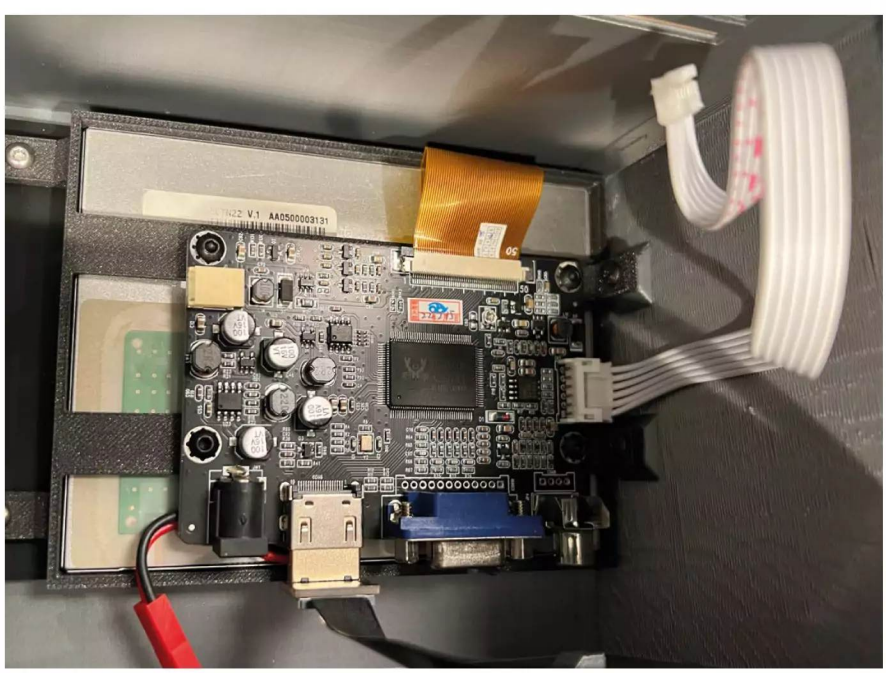
Few people in the UK will recognise this quasi-replica of a TRS-80 model 3/4, but for North Americans of a certain age, it's possible that this was the first home computer they ever used. It was sold in the Radio Shack chain of shops owned by the Tandy company (hence TRS), and while there were various models, this one emulates the top-of-the-range version, which had 48K of RAM and two floppy disk drives, all for the bargain price of $2,495. That's $2,495 in 1980 money. This is not an exact replica of a TRS: instead, it's meant to evoke the feeling of using one. The two disk drives that came at such a high price back in 1980 don't work in this model, but they do have LEDs that flash randomly, again adding to the feel of using a real TRS-80.The trs80gp emulator that Joe used in this build has been around for donkey's years (it's so old that it runs on Windows XP, itself old enough to be considered a retro operating system). The special thing about this project is that it demonstrates the power of building something. Running software on a emulator is one thing, but running it on a 3D printed almost-replica of the original hardware is far more engaging. At heart, this is a Raspberry Pi 4 in a 3D-printed enclosure, and we absolutely love that sort of thing.





Left
Joe's model is 40% the size of the original TRS-80, and packs a 5-inch 640x480p screen



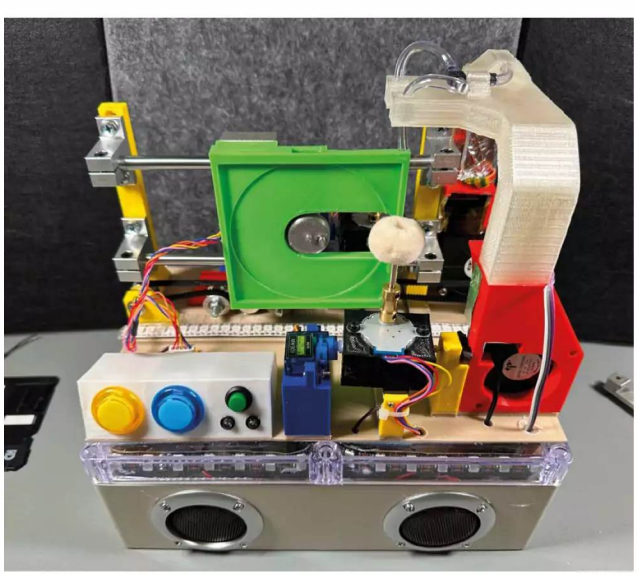


Floppy disk cleaner

By Rob Smith

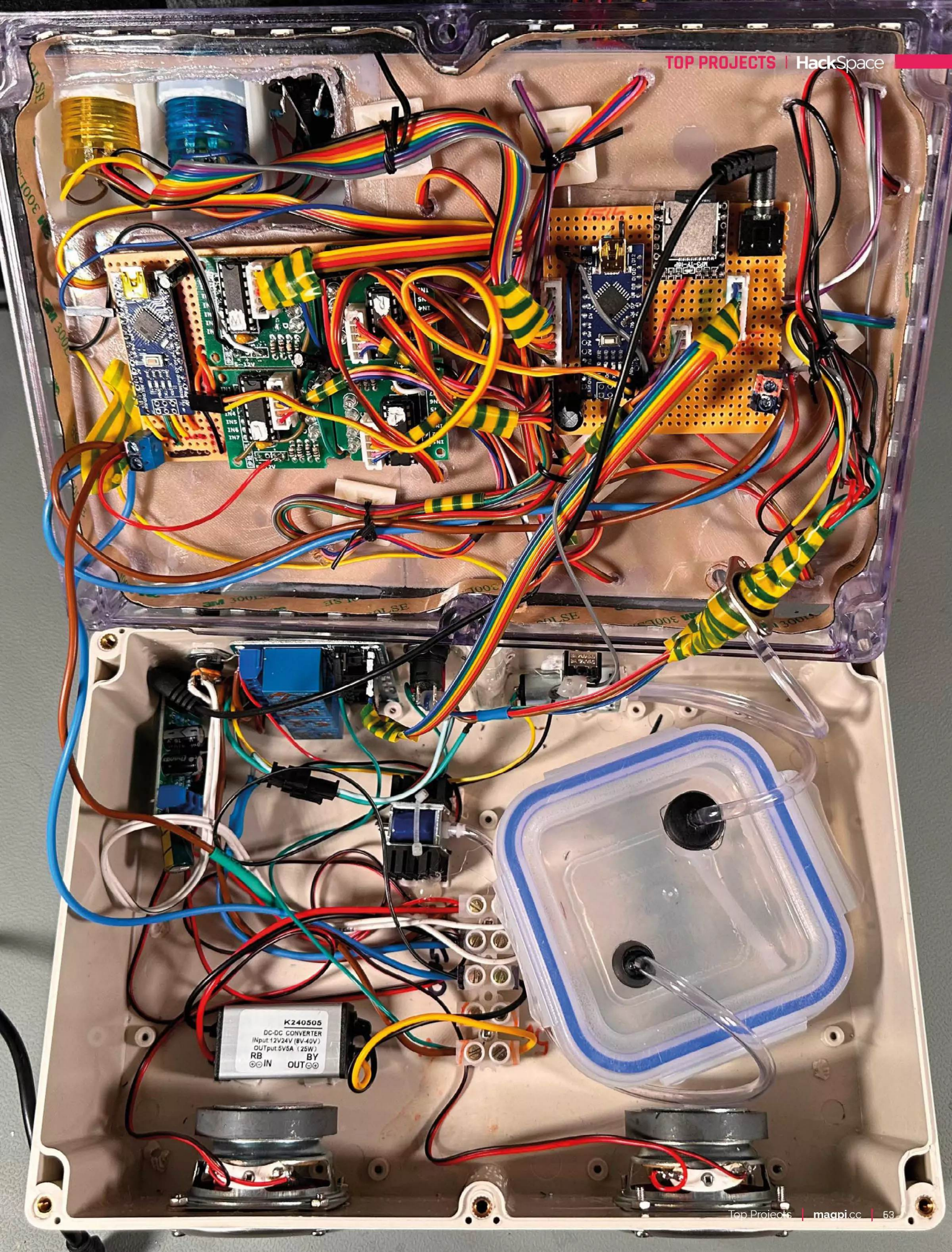
hsmag.cc/FloppyCleaner

Right Rob proudly displayed his disk cleaning machine at Kickstart, the event for Amiga lovers



Floppy disks (the 3.5-inch version) have a problem. When they're not being wiped by magnets, degrading through physical wear, or being accidentally recorded over, they are prone to going mouldy. This isn't a problem that afflicts many of us, having long ago moved into the 21st century. But if you're one of those people who still prefers the superior graphics and sound provided by the Amiga, you'll need a way to keep your disks clean.

You could spend a few minutes wiping them with a cloth, and perhaps a little isopropyl alcohol. Or you could spend weeks designing a building an Arduino-powered, 3D-printed machine that not only takes care of your removable storage media, but looks amazing at the same time. The latter is the approach taken by Rob Smith with this beautiful machine. He describes it as a Rube Goldberg machine, which would suggest to us that it works in a convoluted way; this machine, despite its fancy LEDs, large arcade-style buttons and speakers (that play the music of Bonnie Tyler) is all business. And as a side note, we love it that 3D printing has moved on from its previous default of beige filament and now looks like this.


K240505
DC-DC CONVERTER
INput:12V24V (8V-40V)
OUTput:5V5A (25W)
RB
IN
OUT
BY

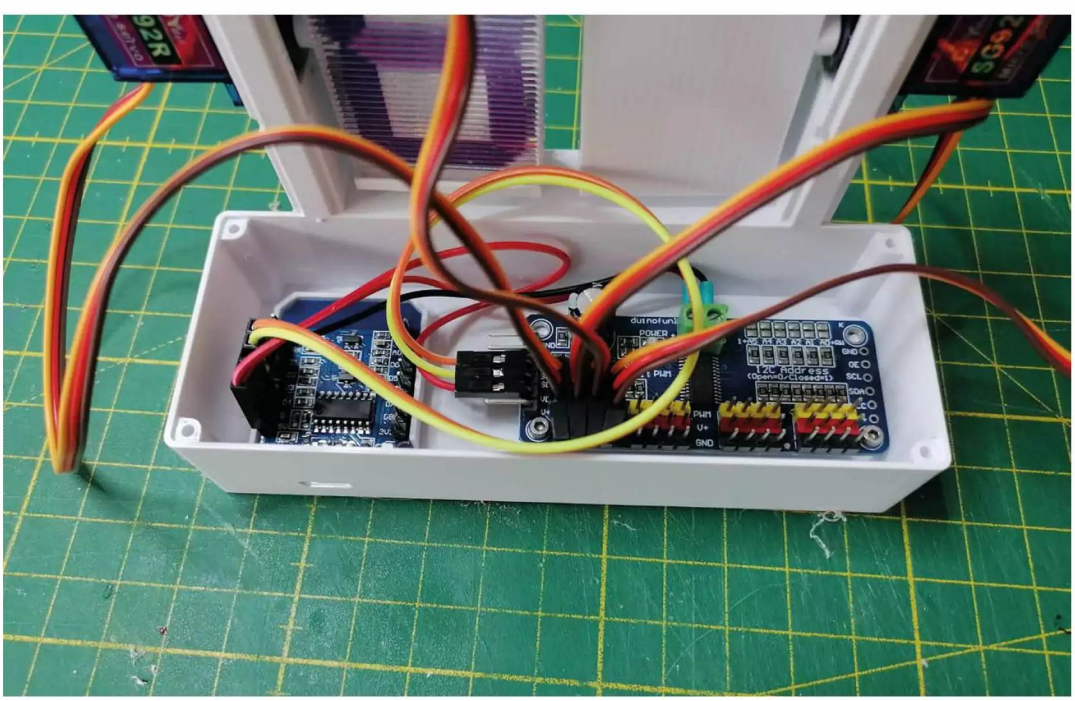
Lenticular clock

By **Moritz Sivers**

hsmag.cc/LenticularClock

You might have seen the work of Moritz Sivers before; you've probably scrolled past on Instagram or the platform formerly known as Twitter and thought "that's amazing". This latest build of his, a lenticular clock, performs exactly the same function that any other clock does, but it uses a method that we've never seen in any other clock, made by anybody. Lenticular images are sliced up, so that when an array of lenses is placed over them, the image appears to move when you change the angle you look at it. The best example we've seen is an old magazine cover that was on sale at around the time one of the Star Wars films came out: look at it one way, you're looking at an image of Anakin Skywalker; look at it from another angle, you're looking at Darth Vader. With Moritz's lenticular clock, you keep your head still, and the digits change angle relative to your eyes, revealing the different numbers in the lenticular. It's one of those builds that's hard to explain, but really easy to understand once you see the video, so check it out, then marvel at the work it took to put this together.

Slicing up images of seven-segment numbers to align under a lenticular lens sounds complicated: Moritz used software to slice up the digits and create the animation. Lenticular lens sheets are available in different resolutions; he went for 20lpi (lines per inch), which offers a lower resolution compared with 40- or 60lpi. Finally, the digits are tilted by four servos, controlled by a Wemos D1 mini ESP8266 via a PCA9685 PWM driver board.





Right
You've seen this effect on childhood toys; now use it to measure the hours you work



Tiny PC (nostalgia edition)

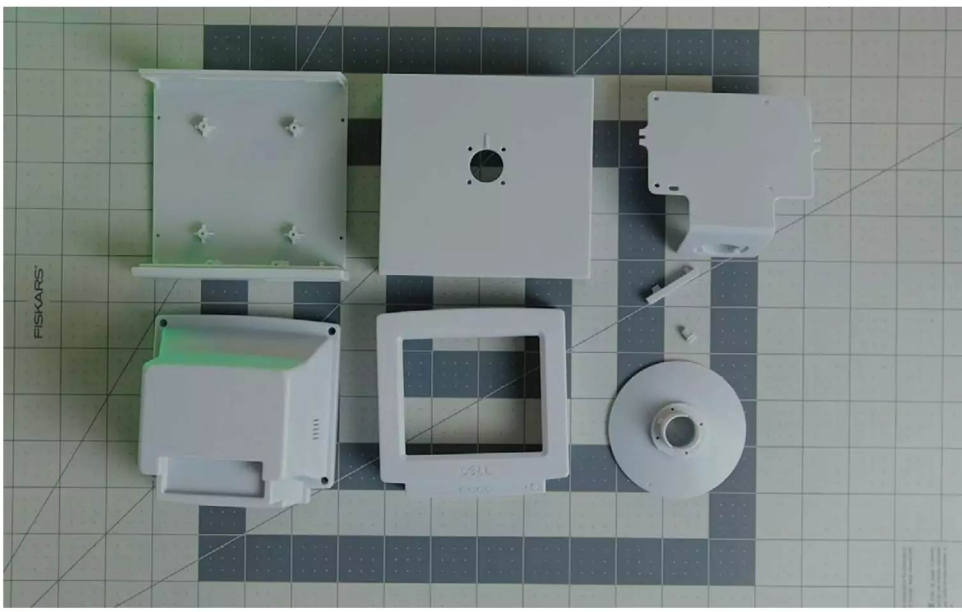
By Salim Benbouziyane

hsmag.cc/UselessRobot

There's a bit of the theme in this month's Top Projects: retro computing. The storage media were unreliable, the machines were incredibly expensive, and performance was, by today's standards, limited. For whatever reason, however, vintage computers retain their fascination, leading to some brilliant reimplementation with modern hardware. One such is this tiny PC by Salim Benbouziyane. Like many makers, he's taken a Raspberry Pi 4 and put it in a 3D-printed shell; unlike many other makers, he's made it look like an early 2000s Dell running Windows XP (we understand the love for Amigas, but beige Dell boxes? Seriously?).

What elevates this project isn't the four-inch Waveshare screen, or even the meticulously detailed 3D-printed case (printed at an accuracy of 50 microns, by the way – it's not just in the choice of colours that 3D printing has advanced in recent years); it's the bespoke PCB, which connects the Raspberry Pi with the peripherals that Salim has packed into this tiny PC.





Left
Just as we were singing the praises of Rob Smith for using colourful 3D-printed parts, here comes Salim Benbouziyane, who's intentionally spray painted this build beige. The horror!



Objet 3d'art

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

Hydroponic setups are often used for tomatoes and other water-intensive plants, giving the grower a clean, pest-free way of growing fresh produce without taking up too much space.

Hydroponic setups are also used in restaurants to ensure a steady supply of fresh greens, and as they're ripe for computerisation there's a large community of enthusiasts using Raspberry Pi, Arduino and ESP32 to control nutrient levels, light, temperature and water flow. It's gardening, for geeks.

This modular hydroponic tower by 3D printing enthusiast ekoscape builds on a previous design, and brings a neat, efficient and dare we say space-age look to indoor agriculture. According to the maker it's suitable for growing a variety of plants, from leafy greens to small herbs. We like this because hydroponics can often look chaotic; this setup, with the water pump hidden in the base of the tower and LED strips built into the rings around the central tube, is efficient and aesthetic.

hsmag.cc/HydroponicTower











Tessellations in fabric

Another handicrafts and maths crossover... this time using fabric



Nicola King

Nicola King is a freelance writer and sub-editor. It may be summertime, but she's already preparing for those holidays that begin with 'C'... knitting gifts for the knit-worthy takes a while!

QUICK TIP

Most sewing machines have a needle plate on which are etched lines and numbers. These etchings are intended to be used as seam allowance guides, so you can use those when sewing your fabric tiles together.

The word 'tessellation' comes from the Latin word 'tessera' meaning a small square, and references the small clay, stone, or glass tiles used in ancient Roman mosaics. Tessellations have a very, very long history, having been used as far back as 4000 BC by the Sumerians in Mesopotamia to make wall decorations. After that, tessellations were used in the art of the Egyptians, Greeks, and Byzantines, to name but a few ancient civilisations.

Tessellating patterns are something we encounter on a regular, if not daily, basis – just think about the way tiles are arranged on a bathroom wall, patterns on wallpapers, how bricks or slabs are arranged to make a path. An official definition is that a tessellation is a covering of a surface, often a plane, using one or more geometric shapes with no overlaps or gaps, and a 'regular' tessellation is a pattern made by repeating a regular polygon, such as a triangle, a square or a rectangle (basically a flat 2D shape with straight sides). Tessellations can also be made from semi-regular geometric shapes and non-regular or non-geometric shapes. Over the next few pages, we'll be exploring how to tessellate some simple shapes using fabric – many quilters will be aware of the concept of tessellation, as it's often a key feature of quilted designs.

A MATHEMATICAL MINDSET

Mathematics and problem-solving arguably come into play in the creation of any sewn fabric item – sewing is an everyday kind of activity for a lot of people, and they are very often using maths, perhaps without even realising it. Let's look, for example, at handmade quilts, which can also be thought of as assortments of fabric tiles that fit together. The image of a quilter sat in a rocking chair sewing away by hand needs an overhaul!

First, the quilt maker needs accurate measurements of the size of the item they are making, and this includes thinking about how much seam allowance will be needed when sewing the individual and separate pieces of fabric together. They then need to calculate the amount of fabric that will be required to make the item from each colourway that they want to use, and include things like the front or top of the quilt, but also the backings, and any borders. If they under-estimate, they'll need to go and purchase more, and if they overestimate by too much, they will spend too much money on fabric.

Geometry also comes into play when planning how the shapes the maker wants to use will be laid out – are they working, for example, with squares, rectangles, diamonds, or maybe triangles? Quilters focus on the properties of the specific polygons they are using, how the polygons will fit together, and if the sewn together pieces will tessellate the plane involved. →



YOU'LL NEED

- Contrasting pieces of fabric
- A sewing machine and thread
- Fabric scissors or a rotary cutter
- A mat to cut on (with ruler guides)
- Templates to cut around
- An iron and ironing board

MC ESCHER – BLENDING ART WITH MATHEMATICS

Maurits Cornelius Escher (1898-1972) was a Dutch graphic artist. He illustrated books, designed tapestries, and was a muralist and printmaker. He is best known for the mind-bending optical illusions and geometric patterns that he created in his work. He created the idea of 'impossible spaces' in his pieces, interplaying reality with illusion, and he enjoyed distorting perspective in his hundreds of woodcuts and lithographs, and in his over 2000 drawings and sketches. In fact, you may be more familiar with his art than you think you are – it was used on numerous album covers in the 1960s and 1970s, and his distinctive tessellations have been used in the world of fashion, architecture, and interior design.

In the 1920s and early 1930s Escher travelled a great deal, particularly through Italy and Spain, and visits to such places as the Alhambra in Granada were to have a huge influence on his work. The lavish tile work, motifs, and geometric, symmetrical patterns of Moorish architecture that he saw set him on a path of experimenting with symmetry, tessellations, infinity, and impossible constructions. 'Ascending and Descending', for example, is one of his lithographs that includes a 'never ending' staircase (**hsmag.cc/EscherStairs**). Escher also liked to use a technique called recursion, where objects nested in each other make it look as though they go on forever.

One thing that Escher noticed on his travels was that, in Moorish decoration, he could not see any human or animal forms depicted. If you take a look at some of his work, you'll notice they include images of birds, fish, flowers interspersed with leaves, and butterflies to name a few. So, he took the Moorish inspiration and built his own interpretations, keen to include recognisable forms.

Escher's legacy is enduring and far-reaching, having captivated the imagination of architects, filmmakers, and mathematicians among others. His very distinctive designs have arguably shaped how contemporary designers approach themes such as perspective and infinity.

Read more about this very intriguing and interesting artist, who became something of a cultural phenomenon and challenged our perceptions of space and reality, here: **mcescher.com**.

Above
This is our simple pattern of shapes that fit together on our plane, without gaps or overlaps, and which can be repeated in all directions infinitely, as a tessellation should be able to do

Below
Some tessellated fabric examples, including hexagons and diamonds. You can see how you can effectively just keep on going, adding more and more of these basic shapes until the fabric piece is as big as you want it to be



The patterns in a quilt are by no means random, they are calculated. In thinking about the pattern, the maker also might consider the mathematical function of symmetry too – quilts are often made up of components called 'blocks', and the maker can create a myriad of patterns just by changing how blocks are positioned against each other. Playing with symmetry helps them achieve their required, and maybe unique, design. And, in order to get to their final goal, a quilter will use rulers, templates, often a state-of-the-art sewing machine, and perhaps some software designed specifically for quilt makers – technology can definitely help those who tessellate textiles!

LET'S MAKE A SIMPLE TESSELLATED PIECE OF FABRIC

First of all, you'll need a template. We used a 2.5" 'tumbler' template (quilting tends to be measured in inches, even in countries that use the metric system). You can easily download a template from online, or make your own using paper, pencil, and ruler.

Next, you need to use the template to cut out a number of shapes; let's call them 'tiles' here, and the number you cut out will depend on how big you want your tessellated piece of fabric to be. We cut out nine tiles of fabric in two colours, so that we could create a reasonable-sized tessellation. We used a rotary cutter as it's quick and easy, but be aware of the sharp edges of the blade.

The next step is to start sewing. Take two tiles and place them right sides together, then sew down one side. The standard seam allowance is usually a quarter of an inch, but whatever you use, make sure you are consistent with every seam. Take the next tile and add it to the strip, again sewing with right sides together. Have an iron handy so that you can press the seams open, as this gives a nice neat finish. Keep going until you have the number in a strip that you want. Make another strip the same size and then sew the two strips' right sides together, along their long edges. Try and ensure that the seams match as you sew along. As before, use an iron to press open the long seam too, so that your piece of work is nice and flat.

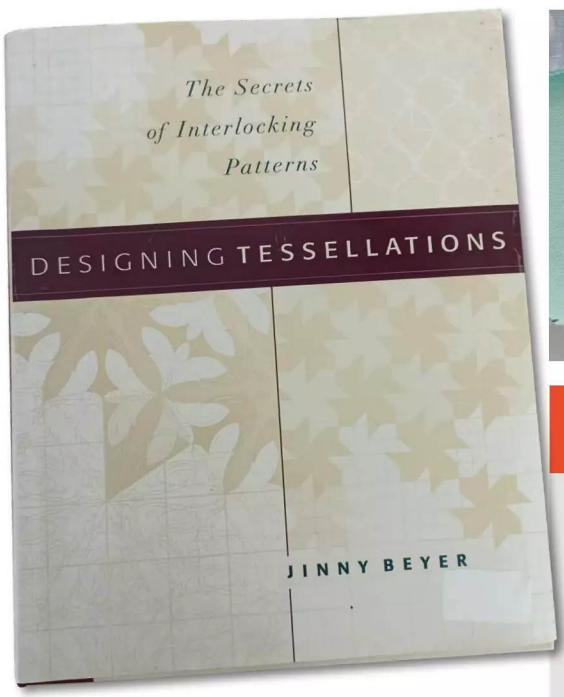
You can make your tessellated piece of fabric as big or small as you want. You can even turn it into something useful if you back it with some wadding and backing fabric – perhaps a place mat or coaster for the table. We're going to make ours bigger and make a cot-sized quilt. The choice is yours...

TESSELLATIONS IN THE NATURAL WORLD

It's fair to say that we are surrounded by tessellated patterns. Perhaps one of the most recognisable is the array of hexagonal cells in a honeycomb, a naturally tessellated structure. If bees created a structure with circles, that would leave clear gaps in the honeycomb, since circles or ovals can't tessellate. Squares and triangles would not leave gaps, but the tightly packed wax hexagons work best within the structure. The hexagon is a useful shape to a bee for storage purposes while also using the least amount of wax, which takes bees some degree of effort to produce, to hold the most weight. Fish scales and snakeskin are other great examples of tessellation.

Some rock formations are examples of semi-regular tessellations, ie a mixture of shapes that have formed a pattern. For example, the Giant's Causeway in Northern Ireland is a mixture of hexagonal-shaped stone plinths, but also those shaped liked pentagons, heptagons, and even octagons.

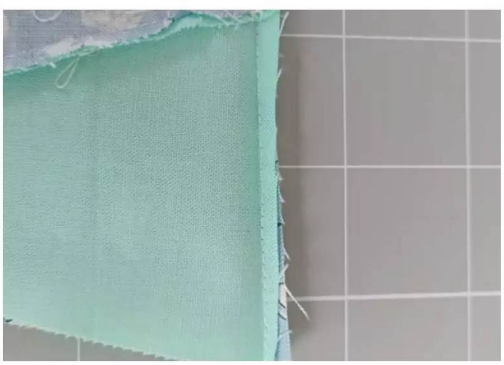
When it comes to common foods, the outside of a pineapple shows a symmetrical, repeating pattern of hexagonal shapes that fit together. Basically, If you start to look for tessellations in your day-to-day world, you begin noticing them everywhere...



> **The patterns in a quilt are by no means** random – they are calculated

IN CONCLUSION

There are so many shapes that can be tessellated, that some quilters are forever designing new and interesting quilt patterns to see how far they can push the boundaries. It's an interesting area to delve into, and involves more mathematics than you may have thought. We've literally just skimmed the surface of the subject here. In *Designing Tessellations*, Jinny Beyer suggests that the easiest way to create tessellating designs is just to use your imagination and just let it happen – maybe doodle some ideas on some graph paper and see where it takes you.



ELABORATE... I WANT TO TESSELLATE

The subject area of tessellations is another rabbit hole you can easily fall into. Here are a few pointers if you would like to delve a little deeper down that hole, or even try and make your own tessellations:

- *Designing Tessellations (The Secrets of Interlocking Patterns)* by Jinny Beyer is a fabulous book this author picked up for £1 (!) in a second-hand book store. It's a treasure trove of information and covers such subject areas as experimenting with symmetry, forming geometric tessellations, and creating representational tessellations (as Escher attempted to do in his numerous artworks). There's also a myriad of books available on quilting if you want to learn the nuts and bolts of the craft and take your tessellating to a higher level.
- YouTube has some useful videos on the subject, so try these for size: **hsmag.cc/OtterArt** and also **hsmag.cc/StudioJocelyn**.
- If you want to teach younger people about tessellations, this BBC Bitesize page is a useful resource – **hsmag.cc/BitesizeTess**. Or, how about using Scratch to create some code to build them?: **hsmag.cc/ScratchTess**.
- Finally, if you'd like to try making some fabric patchwork tessellations using English paper-piecing (in the shape of cats, birds, chickens, and even elephants), you can buy downloadable tessellated patterns here to begin your fabric tessellation journey: **hsmag.cc/Tessepatch**.

Far Left
A must-have tessellation tome that takes a very detailed look at the subject, while guiding you on how to create your very own. It's arguably not just aimed at quilters either, as the concepts arguably apply much more widely than just to the arena of fabric bed coverings

Left
The sewn seam of two tiles of fabric. Keep your seam allowance the same throughout. Trim off any excess pieces of thread with scissors



Do the hustle!

Figure 1 As well as building your side hustle maker business online, you might consider finding real-world events to sell at

Building your side hustle as a maker



Jo Hinchliffe

With a house and shed full of lathes, milling machines, 3D printers and more, Jo Hinchliffe (AKA Concretedog) 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.

Making things is, we imagine for most readers, primarily a fun activity. For some it might be part of their work, but there is a third option where making is still fun but others might be interested in buying the things we make.

In this article we'll look at approaches to building a small side hustle maker business using the Tindie platform and we'll look at some things you might need to consider. My own Tindie shop, or 'store' in its native US parlance, has numerous products and has slowly built up to become a small part of my regular income. Most of my products link to rocketry or robotics and are pretty niche so it definitely sits under the heading 'side hustle' rather than a huge money-making enterprise. While this article has a focus on Tindie as a platform, much of what we'll look at could apply to other online platforms too.

Signing up for Tindie is pretty trivial. You need a basic account to be able to buy from Tindie, and every account has all the options to start selling. Your need to give your store a name, then set up a verified PayPal account, and then you are ready to list your first product. A couple of things to note about Tindie is that you must have an image of your actual product on the product page, you can't have a render of a product that you will make if you get an order. Neither can you list a product that you plan to make, so you can't use Tindie to act as a pre-order system.

Listing a product is pretty straightforward: you fill in some details about the product, then supply links to any documentation and any source files you are sharing. Brilliantly, Tindie is also set up to promote open-source hardware projects well, so there are dialogue options to add OSHWA certification numbers, see **Figure 3**. You can add multiple images

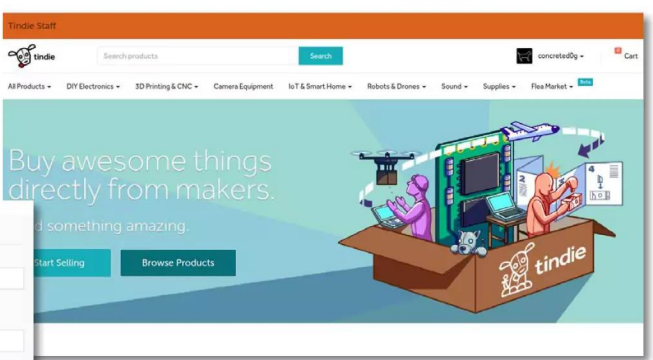


Figure 2
Tindie is a great online market place for side hustles, as it's focused on maker products and technology

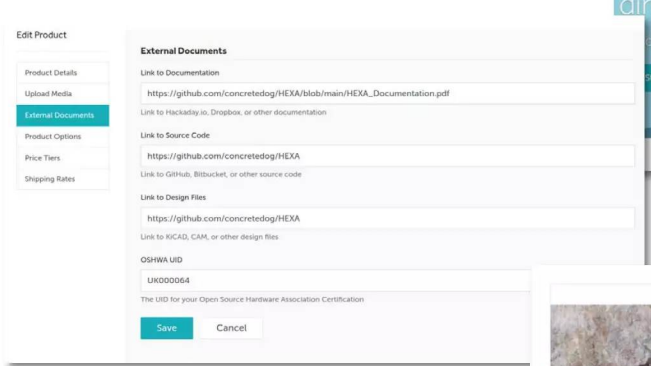


Figure 3
Among the details you can add to a Tindie product description you can add links to design files and show your OSHWA certification number if you have one

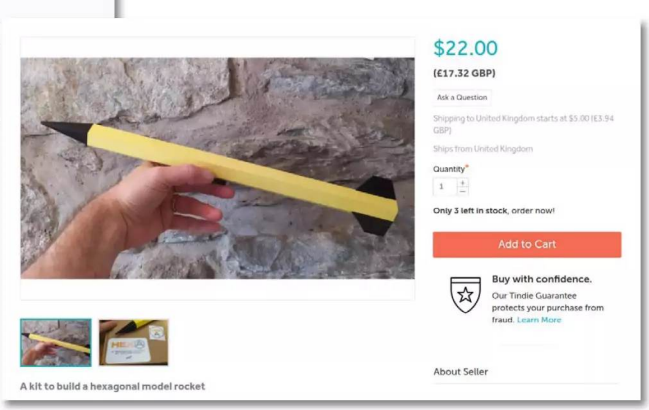


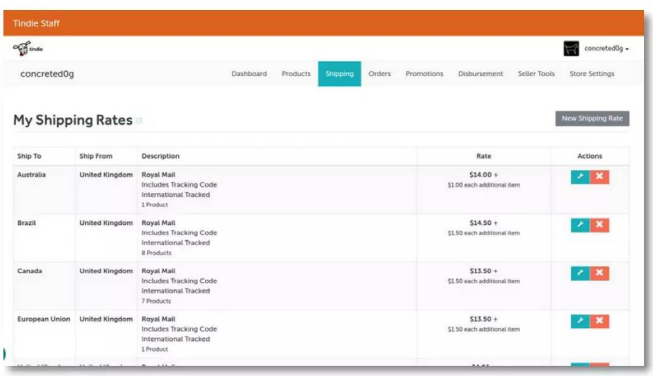
Figure 4
An approved product page for the HEXA rocket kit set up and ready to receive orders

and also links to videos which automatically embed in the bottom of the project page. Save your product listing as a draft, and you can preview the page and check your work; it's very similar to creating a blog post. When you are ready to launch the product you submit the product for approval and the Tindie team will take a look before setting it live on the site.

When someone orders your product you get a notification in your store menu and an email to your registered email address. You have two weeks from the time of order to ship the item and mark it as such. If you don't ship it in that time then Tindie will refund the buyer and cancel the order. On Tindie you can add shipping options for different regions and services and then assign them to different products. This makes for a very flexible system. For example, many of my products can ship within the UK as a large letter weighing under 100 grams →

> **You must have an image of your actual product on the page, you can't have a render**

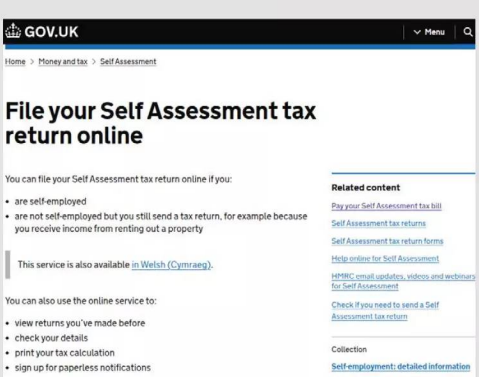
Figure 5
Setting up a variety of shipping options on Tindie is straightforward, and you can apply a shipping option to one or more products



TAXING TIMES

In the UK you need to declare and pay tax on any earnings, and this may include money from your side hustle. We aren't experts in this field, but in the UK you can earn an extra £1,000 per financial year from the selling of items without paying any additional tax, and this is referred to as the trading allowance. This is on top of the £12,570 income tax threshold, under which you don't pay tax. So if you pay some tax on your earnings through employment or self employment and your side hustle stays below £1,000 then you don't need to do anything.

If you earn over £1,000 from your side hustle then you need to declare this to HMRC in the form of a tax return. You can file a tax return using the HMRC website and it's pretty straightforward. As a freelancer, all my earnings and work are submitted in my tax return, but its also possible to be employed by an employer (referred to as pay as you earn or PAYE) and also submit an additional tax return. You simply use your end of year paperwork or P60 to first input the details of your PAYE earnings and tax payments and then you fill in a section about your additional earnings. As such it's important to keep good records and receipts of what you spend on your side hustle and keep track of what you receive via your online store.



To make this pretty straightforward Tindie allows you to download .CSV files, which can be opened by any common spreadsheet application with all details of orders and transactions. Whilst all this section might sound a little off putting it really is straightforward and the HMRC website and helplines work really well.

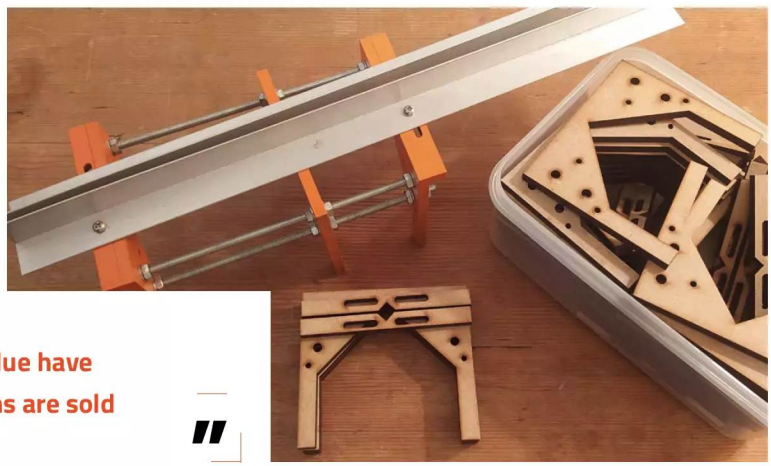
Figure 6
It's definitely worth considering how much space both your stock and your packaging options will take up

so can set up that postal option and then assign it to numerous products as in **Figure 5**.

Each shipping option has an "additional item cost," so you can add an extra charge for additional packaging. You can use this functionality to push a postage option into a different service, so for example if someone buys one item they pay for a 100g large letter, but the additional item costs mean that if they buy three items which would weigh over 100g then the additional item cost has raised the postage price so that it covers the 250g large letter option. It takes a little thinking about, and trial and error, but it becomes pretty straightforward after a few sales. I tend to use tracked services so that items are insured and that delivery to the person is somewhat guaranteed; this perhaps loses me some sales as my shipping rates are higher, but keeps the stress levels lower! The majority of my sales are to the UK or the US but occasionally I will get a notification that someone has requested a shipping option for a product to a new region. This doesn't guarantee a sale, but you can research shipping options to the destination and set up an option in response and the potential customer will be notified.



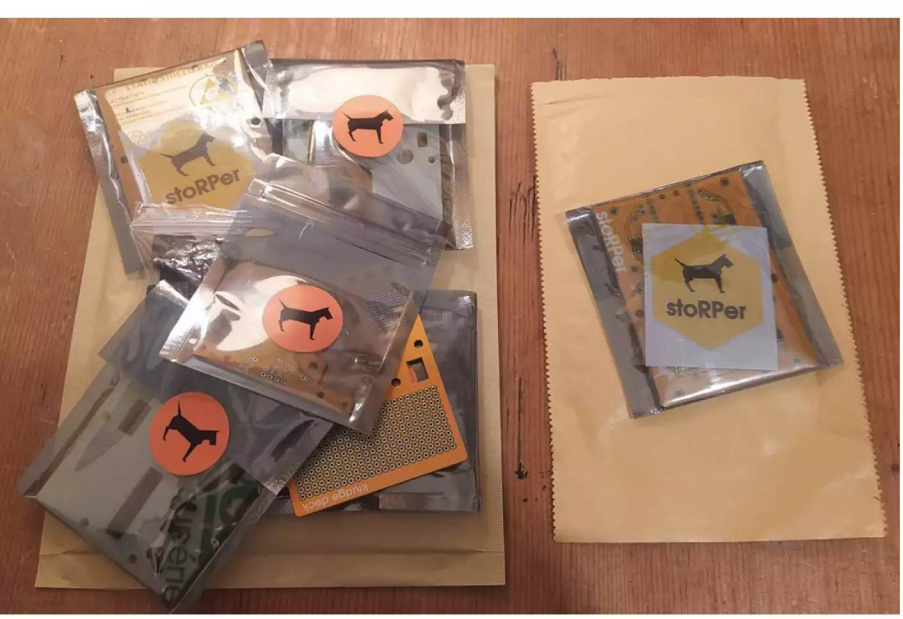
Yet another consideration around postage, which may be a little less obvious, is packaging and the storage of packaging. Often this can be tricky and you may well need to allocate more space than you need to store your product packaging. Many of the products I sell are small electronics, and as such the actual kit is packed into small anti-static packaging which can be shipped in a very small padded envelope. Some of the larger products require a bigger envelope, and sometimes products require a range of padded mailer envelopes to accommodate the range of options.



> "Stock storage and also stock value have affected how products and designs are sold"

As an example I can send a basic PCB and header kit of the StoRPer robot PCB in a size 000 small padded mailer, but if I need to add 3D-printed motor mounts and a laser cut 'deck' as add-on options then I often need to jump to a larger envelope. If I packed the items in the smaller mailer it becomes too wide for the 'large letter' service, see **Figure 7**. It also makes sense to bulk buy your shipping packaging, and for my range of products this means the shipping packaging takes up at least as much storage space as the actual stock items, as in **Figure 6**.

Figure 7
The StoRPer robot product has lots of options and add-ons, so needs a variety of packaging sizes



STORPER: GENESIS

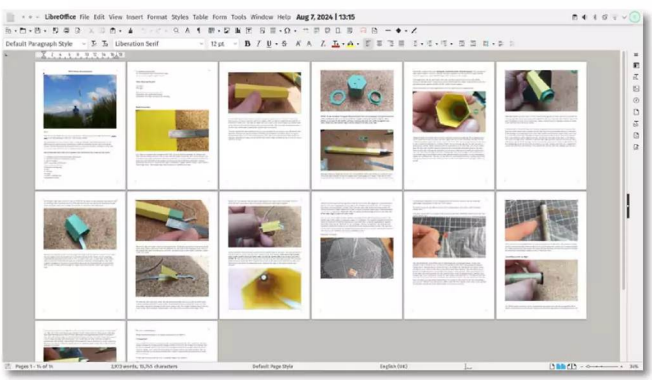
Within the stock subject there are a couple of things worth considering. The first is how much stock are you capable of making and storing. I live in a pretty small and packed old Welsh mining cottage and I have physical limitations on how much space I can give to stock. When I first started and just had some of the early products like my rocketry screw switches and centre of pressure and gravity stickers, everything could fit in a shoe box. As I added products and product options this has grown somewhat. Stock storage and also stock value have affected how products and designs are sold. An example of mine is the Laser Cut Fin Jig Short Kit. The Fin Jig product is a tool that once assembled allows rocket builders to position fins onto rocket body tubes incredibly accurately. Getting fins on straight and vertical and well aligned is a key concept in getting a rocket to perform well. The jig has numerous laser cut parts and also quite a bit of metalwork in the form of longish 90° angle aluminium sections and 5mm threaded rod sections plus lots of nuts and bolts. A full kit with all the metalwork included would be heavy and costly to post, and would require me to stock and warehouse lots of long metal sections. The threaded rods and angle →

Figure 8
The complete Fin Jig tool product on the left, was too complex, heavy and bulky to create stock for, so the short kit (middle) featuring just the laser-cut parts has been a good option, selling well

QUICK TIP

I tend to put a slightly lower numbers of stock items that I actually have, as this covers accidental loss, damage or replacements being requested.

Figure 9
Product documentation is important for customers to feel confident they understand a project or a kit before purchase



sections are the type of thing that can be found in most parts of the world but perhaps not everyone has access to a laser cutter. The solution therefore was the 'short kit' in **Figure 8**, which just offers the laser-cut MDF parts from which you can build the whole tool. I am sure this approach has lost me some customers, but it means that I can at least do something with the design and it has become a reasonably well sold item. I can keep around a year's worth of stock in a shoe box and the postage is pretty affordable.

Aside from developing an item to the point you feel confident it is a quality product, documentation is a key bit of work that you need to do. Documentation has a couple of roles in a maker business. First and foremost it needs to explain the product and give the technical information that a customer might need. It also though is crucial in terms of making a sale. If there are parts of a product that seem unclear and unexplained and the potential customer can't find an answer quickly then it is much less likely they will purchase the product. The level of documentation a product needs is hugely variable. For example I haven't felt the need to document things like my centre of pressure and centre of gravity stickers, but the recently launched HEXA model rocket kit has a 14-page PDF about the assembly of the kit and usage, as in **Figure 9**.

One thing I have noticed is that you need to repeatedly make content about items that you sell to keep bringing them to the attention of potential

WORLD TRADE

Although I'm based in the UK, around half of the orders I see on my Tindie store are international orders, mainly to the USA but also other parts of the world. When shipping goods internationally from the UK using the Royal Mail you will need to fill out a CN22 form, commonly called a 'customs form,' which will contain information about your product. If you are using a Royal Mail service via the Click and Drop online process, the online service automatically asks for the details it needs and creates a CN22 form as part of your printable documents.

Other courier services don't require a CN22 specifically, but you will need to include a commercial invoice with similar details on it, and whichever you use you will need to add a commodity code. A commodity code is a long number that assigns your goods into a certain category. This is because other countries may levy different import duties on certain goods. It can be a little challenging to find a UK commodity code for your particular item. To identify your item's most suitable code you can search on the Trade Tariff Tool website using simple terms describing your product. For example my recent HEXA model rocket kit is mostly 3D-printed plastic parts with a small number of cardboard components. It feels reasonable to describe this as a "plastic model kit," and this leads me to the commodity code 9503003500 which seems the closest match. While this process can take some time and research once you have a suitable commodity code number make sure you note it down clearly somewhere and then, for that product, you won't have to search for it again!

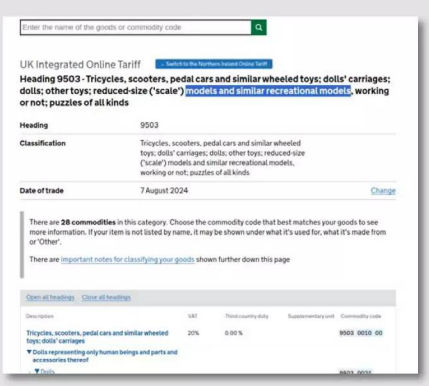




Figure 10
A combination of a phone, a Bluetooth card reader, and a power bank makes it easy to take payments in most situations

customers. I am not particularly good at this, as I tend to really immerse myself in creating projects and products and then move on to the next idea. The people who excel at building business in this sector are those who can create content that regularly shows new features or applications of products. Wonderfully, sometimes people talk about their build of your product online, and this can serve to generate interest in your designs. This is one reason why considering open-source approaches may help, as others may be more inclined to use your project and share it.

IN THE NIGHT MARKET

While this article has predominantly looked at Tindie and online sales, you can of course find places and events where you can sell directly to customers. If your products are less specific than mine and appeal to a general population then, of course, craft fairs and markets are a great potential source of sales. I recently applied for and was allocated space at EMF Camp's excellent solar-punk themed night market in the Null Sector area of the festival. Even at a festival full of hacker types it's unlikely I would do that well selling niche high-power rocketry parts, so I opted to just take StoRPer, my modular, open-source, Raspberry Pi Pico-powered robot platform. Getting into the theme, I even modified a vintage travel case to contain stock, be branded and lit: it's in **Figure 1**.

I felt it was important to have a few examples of the robot built up, and you have to be prepared to talk a lot about your product and the design choices you have made. You also need to work out how you can receive money from sales – a small amount of customers will carry and use cash, but it's far more common for people to use contactless payment. There are a few contactless reader options available for small businesses and it's worth looking around them all. You may even find that you can manage contactless payments using a smartphone. I opted for a common solution from Sumup, where I bought a Sumup Air card reader for £40 as a one-off expense.

Sumup, and other similar services, set you up with an account and charge a small transaction fee. Contactless payments are first transferred into the Sumup account and you can then transfer the money out to whatever bank account you prefer. The card reader device connects to the Sumup application on my phone via Bluetooth, and you can quickly set up a charge/transaction in-app. This works excellently. As a side note, if you have less than perfect data coverage or Wi-Fi at an event it isn't totally critical, so long as the contactless transaction has completed it will be logged in the application and everything will pass through when connectivity is re-established. Similarly, this means that, perhaps with the help of a USB powerbank, you can be totally off-grid!

I hope this article has inspired you to have a go at selling some of your creations. It can be challenging but also rewarding, sometimes financially, but often it's the fact that people enjoy using your designs and product that really motivates you to make and sell more. It's also a great way to connect and communicate with like-minded makers who are interested in similar projects to yourself.

QUICK TIP

When you have a wider range of items in an online store you'll notice that customers are more likely to add in the odd smaller item with their main purchase.

Use a Pico to add light leaks to a retro instant camera

Upcycle a 1950s instant camera to use modern film and add a Raspberry Pi Pico to provide computer-controlled light leaks



Rob Miles

Rob has been playing with hardware and software since almost before there was hardware and software. Find out more at **robmiles.com**.

QUICK TIP

Contrary to the popular song, you should never shake an instant picture while it is developing. The phrase "Shake it like a Polaroid" in *Hey Ya!* from Outkast makes for a great refrain and dance move (and turns out to have sold a lot of instant cameras), but it doesn't improve the quality of the image.

Instant photography, where the physical picture is produced just after being taken, has been popular for many years. Over 60 years ago photographers were using beautifully made instant cameras to produce high quality results. But as technology moved forwards, these splendid examples of engineering were overtaken by the plastic lensed, computer-controlled cameras that we use today. In this article you'll find out how to bring these magnificent devices back to life and use modern LED technology to add artistic effects to shots taken with them.

If you were a thrusting executive in America in the 1950s and 1960s you would have had a Polaroid Land Camera to record family trips and important moments. The cameras were loaded with film packs comprised of spools of film, print paper and pods containing chemical gels. After you had taken a picture, you'd pull the film and paper through rollers in the camera to burst the pods, spread the gel over the film and start the development process. After development the negative and the print paper were peeled apart to reveal a high-quality image.

These cameras were popular for a long time, but film technology moved on to create single part instant photographs like the ones we use today, where the film, print and chemical pods are all in one sealed enclosure.

By 1980 Polaroid had stopped making the peel-apart film packs and the lovely old cameras became useless, which was a pity because they were extremely well engineered devices with very good lenses. It would be great if we could find a way to use them again, and it turns out that with a bit of effort we can do just that. You can find links to the conversion sites, the software and designs for the Pico case on the GitHub site for this project: **hsmag.cc/picopolaroid**.

> **The good news is that we can 3D print an** adapter to convert a Polaroid Land camera

3D PRINTING TO THE RESCUE

The first piece of good news is that we can 3D print an adapter to convert a Polaroid Land camera to use different media. A Polaroid Land camera can be adapted to use 4x5-inch sheet film. The second piece of good news is that the Lomography company makes a LomoGraflok back that fits in place of a 4x5 sheet film holder and can be loaded with instant film cartridges. Adapt a camera to take 4x5 pictures and clip on a LomoGraflok back, and you have a powerful picture taking machine producing Fujifilm Instax Wide 10cm x 6cm colour prints. The LomoGraflok back is not cheap, but it works well, and it can be attached to lots of different cameras. →

WHY DO I WANT TO USE A CONVERTED INSTANT CAMERA?

Fujifilm, which makes Instax film, sells a range of cameras to go with it. These are carefully calibrated for Instax film and generally produce well exposed and good-looking results. However, their plastic lenses are less sharp than the glass ones in the Polaroid cameras and their fixed exposure settings make it much harder to get photographic effects such as long exposure and shallow depth of field. An adapted camera provides a lot more flexibility, although it will be slightly harder to use. It also lends a lot more of a sense of occasion to any photograph.



Figure 1
This process will work on Polaroid Land 110, 150 and 800 cameras. The author has successfully converted cameras of each type

YOU'LL NEED

- **An old Polaroid Land 110, 150 or 800 camera**
  Search your favourite auction site for "Polaroid Land 150". You can usually find quite a few for sale
- **A LomoGraflok 4×5 Instant Back**
  This holds Fujifilm Instax Wide instant film cassettes. You can find details here: hsmag.cc/LomoGraflok4x5
- **A set of 3D printed parts to make the adapter and the PICO holder**
  See the text for sources
- **Some m3 6mm and 8mm countersunk bolts and some M3 × 3mm(Length) × 5mm(Outer diameter) brass knurled insets**
- **A metre of "bungie" cord and fittings**
  (you can get these from any decent haberdashery)
- **A Raspberry Pi Pico & Pimoroni Pico Display Pack**
- **Some wire wrap wire**
- **A strip of Neopixels**
- **A switched battery holder**
  for 3×AA batteries
- **Lots of packs of Fujifilm Instax Wide film**

Figure 4
The focus must be adjusted until the duck only has one eye facing the camera

Figure 2
The camera has two viewfinders. One is used to focus the shot and the other is used to aim the camera and frame the picture

CONVERTING A CAMERA

The conversion process involves removing the back of the camera and replacing it with a 3D printed one. The author used a design from Morten Kolve (**hsmag.cc/DarkroomDIY**) which involves drilling holes in the camera and is not reversable.

If you want to be able to return your camera to its original state after conversion, you can follow this process from Albert Cornelissen (**hsmag.cc/110Conversion**). In both cases the conversion process is not too difficult. You'll need a hand drill and some pliers. **Figure 2** shows the back of a camera after conversion. This camera is also fitted with the Pico-controlled light leaker.



TO INFINITY AND BEYOND

Once you have adapted the camera you need to make sure that the camera rangefinder is properly adjusted and then replace the "infinity stop" on the camera to make sure that the camera can focus properly. The infinity stop is the lens position when it is focused on a distant horizon.

Figure 3 shows how a camera focuses light onto the film. The light from the scene comes into the camera from the right-hand side of the picture. The camera lens focuses light onto the film surface.

You can use small piece of semi-transparent plastic (for example the lid of an old sandwich box) to check the focus and adjust the position of the camera infinity stop. You put the plastic on top of a spacer provided with the LomoGraflok back, use the B setting to open the camera shutter and then you can view the image produced by the lens on the plastic. Then you point the camera at something a long way away and adjust the infinity stop until the image is sharp. There are instructions on how to do this on the web site for each of the conversion descriptions.

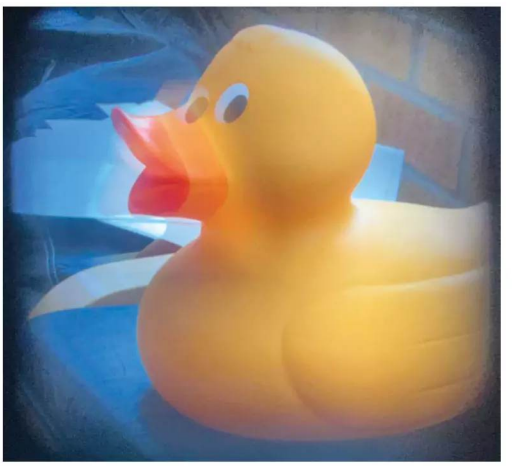
QUICK TIP

The Polaroid Land 110 was an instant camera made for press photographers. The 110 cameras have a more complex lens and shutter providing more creative options, although the cameras are sought after and therefore a bit more expensive. They can be converted to Instax film in the same way as the others.

Figure 3
The cassette in the LomoGraflok back holds 10 sheets of film

QUICK TIP

A good way to make sure that the camera is light tight is to put a light inside the camera and then take the camera into a darkened room. Cover any leaks with thick black tape.



TAKING PICTURES

Taking a picture with a Polaroid camera is a bit more complicated than using a modern camera or phone. You start by opening the front of the camera and pulling the lens assembly out from the camera until it reaches the infinity stop. The camera is now ready for use and is focused on distant objects. To focus on closer subjects the lens must be moved away from the camera. The bellows on the front of the camera allow the lens to move backwards and forwards. The front of the camera contains a dial which is turned move the lens.

You set the focus on the Polaroid camera using a rangefinder which provides a view of the scene containing two versions of the image, one offset from the other. You adjust the focus using until the two versions coincide. Alternatively, you can measure the distance and then set the value on a scale on the camera. Once you have set the focus you need to set the exposure.

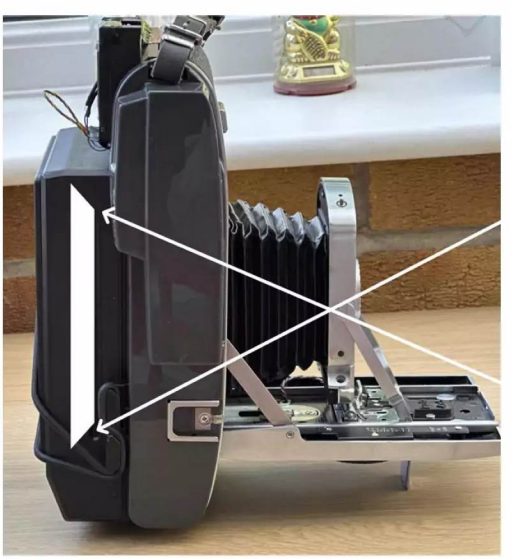




Figure 8
The bright sky was not affected by the red light leak as much as the darker trees and buildings

Figure 7
This is the second test picture. The first test came out completely white because the LEDs were lit for too long



If you have used manual exposure cameras before you might be thinking that you need to set the shutter speed (how long the film is exposed to light) and aperture (the size of the hole that lets the light through). However, on Polaroid cameras the exposure is selected using an "exposure value" which represents a particular shutter speed and aperture combination. The bigger the number the more light there is. You use a light meter (or a metering application on your phone) to get the exposure value and then rotate a dial on the front of the camera to set that value. Before you take a reading from a meter or meter application you need to set the speed of the film, which in this case is 800 ISO.

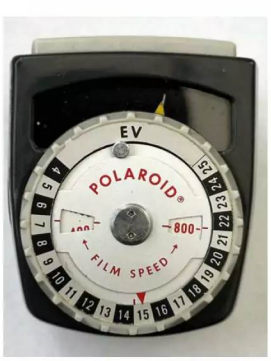


Figure 5 shows a light meter that was sold specifically for use with Polaroid cameras. You turn the outer dial to move the triangular indicator until it matches the needle position. Then you read the exposure value from the arrow along the bottom.

The converted camera takes very good pictures. It takes a bit of patience to use and, because the Instax film it uses is slightly smaller than the original Polaroid film, you need to be careful to make sure that you get your subject in the right place inside the frame. One of the reasons that the author likes analogue photography so much is that it makes you 'earn' your pictures. In this respect the camera is very good exercise.

ADDING LOCAL COLOUR

Cameras are supposed to be light-tight, but sometimes they aren't. When light gets inside the camera and onto the film it can cause flares and other effects on the pictures. These sometimes make images more attractive and atmospheric. You can buy film which already has light leaks added and there is even an instant camera which contains LEDs to add light effects. The author thought it might be fun to have a go at this and so he fitted a strip of NeoPixels inside the camera. The LEDs are triggered for a very short time before or after taking the picture.

Figure 6 shows the pixels added to the camera. The back of the camera is fitted with a Pico and a battery holder. The LED cables are wire wrapped onto the pins of the Pico, which are then pushed into the socket on the Pimoroni PicoDisplay which provides an LCD panel with four buttons and a coloured LED.

Figure 7 shows the first successful test photograph. It turns out that just putting LEDs along the bottom leads to a fairly even background. It is not quite perfect, but it is good enough to make photographs more interesting.

Figure 8 shows the first test shot of an outdoor scene. The picture was taken first and then the red leak was added afterwards. This gives a uniform-looking red cast to the entire image. It was decided that for now the simple LED placement is plenty to be going on with. This illustrates an important engineering principle. It is easy to think of complicated things you might need to do to solve a problem, but it is best to start with some tests of simple solutions before you add too much complication. →



QUICK TIP

The focus process inverts the image, with light from the top of the scene being directed onto the bottom of the film. It also transposes the image from left to right. Because we are using a LomoGraflok back the Instax film is held some distance behind the original Polaroid film position, so the camera lens must be moved back too, otherwise our pictures will not be sharp.

Figure 5
The meter is reading a light level of Exposure Value 15

Figure 6
The wires from the LEDs are connected to the Pico on the outside of the camera. The wires go out through a hole in the camera back

QUICK TIP

Use a vacuum cleaner to get rid of the metal fragments produced as you drill the holes in the body.

QUICK TIP

The process of taking a picture using a focusing lens creates an image which is inverted and transposed from left to right. The peel-apart process creates a mirror image of the taken picture which is the right way round. Later Polaroid cameras used a complex system of mirrors to create a correctly oriented print. Instax film inverts the image by exposing the black back of the picture to light and using a chemical process which creates the image on the white front of the print.

LEAKY PYTHON

The test code for the light leaker just turned the LEDs on at a particular brightness for a particular duration. This was used to prove that light leaking works. But once it was decided that the idea was worth bothering with, it was time to make a 'proper' user interface based on the Pimoroni PICO display

Figure 9 shows the user interface. The coloured LED indicates the current leak colour, and the four buttons allow the user to select the pattern for the light display (Patt) the exposure of the light (Exp), and the colour (Col). If one of the menu buttons is pressed the appropriate method will then update the display for that function. When you are ready to add a light leak you press the GO button and the LEDs inside the camera are illuminated for a few milliseconds. The battery box has a power switch.

The software which controls the light leaker is written in MicroPython. The light is controlled by a Python object of type **LightLeaker** which is created when the program starts and then repeatedly updated and drawn when the program is active.

```
display = PicoGraphics(display=DISPLAY_PICO_
DISPLAY, rotate=0)
lightLeaker = LightLeaker(display, pixel_pin=10,
no_of_pixels=15)

while True:
   lightLeaker.update()
   lightLeaker.draw()
```



Figure 9
You select a particular function by pressing the name next to it. The middle of the display is used for messages

The code above shows how this is done. It creates a variable called display which refers to the PicoGraphics display device. The **PicoGraphics** class is part of the custom MicroPython implementation provided by Pimoroni. A **LightLeaker** instance is then created. The constructor for the **LightLeaker** is passed a reference to the display to use and told the pin number and the number of pixels for the pixel string inside the camera. This version of the camera has a 15-pixel strand connected to GPIO pin 10. The **LightLeaker** object implements a menu system which binds function calls to buttons on the display. When the **LightLeaker** is created the **__init__** method in the **LightLeaker** class sets up the page of buttons provided by the display.

```
def __init__(self,display, pixel_pin,no_of_
pixels):
    self.display = Display(self, display)
    self.buttons = PageOfButtons({
        "a":PageButton(12,self.display.button_a),
        "b":PageButton(13,self.display.button_b),
        "x":PageButton(14,self.display.button_x),
        "y":PageButton(15,self.display.button_y)
        })

    self.do_display_main_menu()
```

The code above initializes a **Lightleaker** object. The PicoGraphics display has buttons labelled "a", "b", "x" and "y" which are connected to General Purpose Input/Output (GPIO) pins on the Pico. The constructor creates a **PageOfButtons** object which contains descriptions of each of the buttons on the page. The **PageOfButtons** object is given a dictionary of buttons which are used to build the page. The constructor also creates a **Display** instance which defines where on the page the legend for each button is displayed. This probably looks like a very complicated way to set things up, but it does gives us a lot of flexibility. It is now very easy to create pages of commands and behaviours. The **do_display_main_menu** function maps particular keys on the page to commands and specifies the methods to be called when the button is pressed and released.

```
def do_display_main_menu(self):

    self.display.do_status("LightLeaker")

    main_page = [ ("a","Patt",self.do_pattern,
self.released),
                  ("b","Col",self.do_col, self.
released),
                  ("x","Exp",self.do_exp, self.
released),
                  ("y","GO",self.do_go, self.
released)]

    self.buttons.setup_buttons(main_page)
```

The code above displays the main menu. The **do_status** method is used to display a status string in the middle of the display. The **main_page** object specifies the button to be used, the string for the button legend and functions to be called when the button is pressed and released. This version of the software doesn't do anything when buttons are released.

The **do_pattern** method is one of the methods that can be selected from the main menu. It lets the user select between two different patterns. The "fill" pattern lights up all the LEDs, whereas the "leak" pattern only lights up one. The user can select between the two patterns by pressing the Up and Down buttons. The code below shows how **do_pattern** builds a command page that allows pattern selection.

```
patterns = ["fill","leak"]
def do_pattern(self):
    self.do_show_pattern()
    pattern_page = [ ("a","Up",self.do_pattern_up,
self.released),
                     ("b","Down",self.do_pattern_
down, self.released),
                     ("x","",self.do_nothing, self.
do_nothing),
                     ("y","Done",self.do_pattern_
done, self.released)]

    self.buttons.setup_buttons(pattern_page)
```

The **do_pattern** method first calls **do_show_pattern** to display the current pattern. Then it configures the "a" and "b" buttons to act as up and down, and the "y" button to act as "Done". The "x" button is not needed for this page, so its legend is left blank. It is easy to add extra patterns, we just have to add them to the list.

"TO THE BRIDGE!"

Figure 10 shows some test shots taken at the Humber Bridge in the UK. The top shot is a standard picture with no light leaks. The second shot has had a leak added in the form of a single yellow LED. The third shot has a blue fill for which all the LEDs were lit.

It turns out that different coloured LEDs have significantly different brightness as far as the film is concerned. It may be necessary to add compensation factors to allow for this. Having said that, the author is very pleased with the way that the test shots came out and he is looking forward to trying more experiments using different coloured LEDs. He is also interested in seeing what effect the leaks have on pictures of people; assuming he can find any volunteers to stand in front of his camera.

LIGHT ARRANGEMENTS

The author wasn't sure of the best way to arrange the lights inside the camera to get the best-looking light leaks. He had all kinds of ideas for 3D-printed baffles and filters to spread the light in different directions. However, he started with something simple (just sticking the LEDs along the inside of the back of the camera) on the basis that he could make things more complicated later if he needed to.



Figure 10 You can see how the framing improves with each successive shot

ONLY THE BEST

Powering your project

A collection of useful components for electronics that need electricity

By **Marc de Vinck**

Power: it's one of the most basic requirements of your DIY electronics project. It's also at times one of the most difficult things to master as a beginner or even advanced electronics enthusiast. Anyone who's been in the DIY electronics hobby arena has blown out an LED, popped a capacitor, or otherwise let out the "little blue smoke" inadvertently due to overpowering your circuit. At least I know I have – multiple times!

And besides overpowering your circuit, there's always underpowering. I remember many years back, working on a project and just couldn't figure out why it wasn't running properly. The code looked great, the circuit was all perfect, and then I finally figured out that running multiple servos was eating up too much of the power, wreaking havoc with the entire circuit.

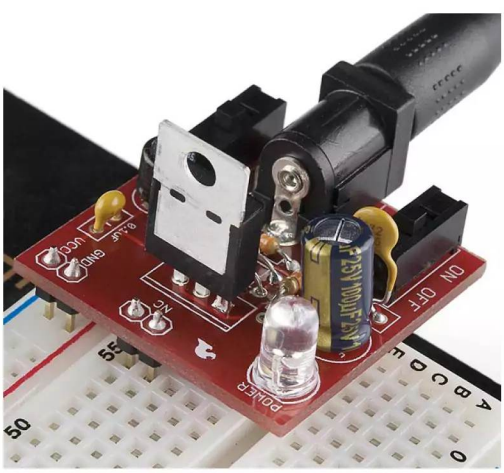
In this Best of Breed I'm going to look at a few things that should be helpful for the beginner electronics enthusiast, and maybe even for more advanced users too. Hopefully some of these products can help save you a little bit of frustration, maybe a little bit of money too. So, let's jump in and take a look!

Multifunctional USB Digital Tester - USB A and C vs SparkFun Breadboard Power Supply

ADAFRUIT $24.95 | adafruit.com **SPARKFUN** $11.95 | sparkfun.com

This multifunctional USB digital tester by Adafruit is a really handy tool that everyone should consider having for their workbench. You can easily measure voltage, current, power, charge time, and more. You can even gather data for coulomb-counting, or total power consumption over time. It's capable of working with USB Type-A, Micro-B, and USB Type-C. It has a full-colour display and can even do total power consumption. If you need a way to measure USB power, this is a great little tool to have.





This is a very simple breadboard power supply designed by Sparkfun electronics. I have personally built a couple of these over the years, because they are so handy to have on your workbench. You typically power this with a wall wart type power supply, like most of us have stashed in a box somewhere. The power supplies can range from six to 12 volts, and what you get out of this little DIY breadboard power supply is fully regulated five volt or 3.3 volt power.

This kit does not come assembled, so you'll need to solder it together. And speaking of soldering, this also makes for a great first time learn to solder kit. And when you're all done, you've got a great new and useful tool.

VERDICT

Multifunctional USB Digital Tester - USB A and C

A great tester for a specific task.

9/10

VERDICT

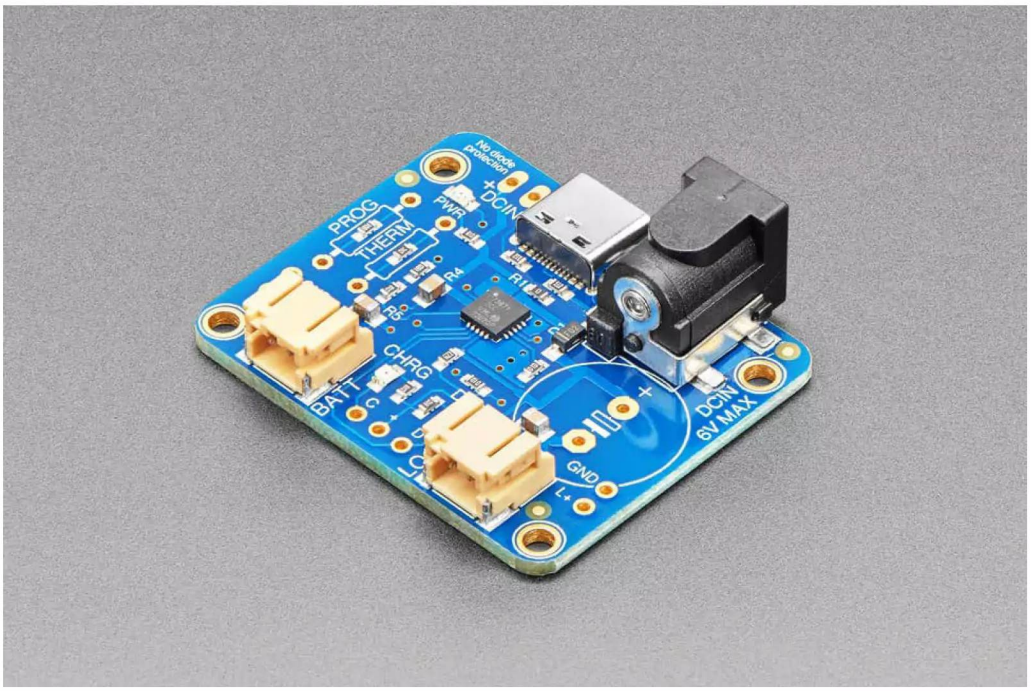
SparkFun Breadboard Power Supply

A great kit for a beginner.

10/10

Adafruit Universal USB / DC / Solar Lithium Ion/ Polymer charger

ADAFRUIT $17.50 | adafruit.com



Charging Lithium Ion batteries via a solar panel can be very difficult, and in some cases dangerous. That's where this universal solar charger designed by Adafruit comes into play. So, what does it do? It handles all the tricky circuitry required for safely charging Lithium Polymer (LiPoly) or Lithium Ion (LiIon) rechargeable batteries via a solar panel. Not an easy task!

Making the connections is easy. You have a convenient barrel jack connector for a solar panel, also available at Adafruit. And you have a standard connector for your battery on the other side of the board. At the heart of the board is the bq24074 IC which handles all the complexities and automatically draws the most current available from the solar panel. Charging these types of batteries can be complicated, so make sure to head over to the website to learn more about this handy little charger.

VERDICT

Adafruit Universal USB / DC / Solar Lithium Ion/ Polymer charger

A great solution for solar power management.

10 /10

Mini Power Meter vs Adjustable Power Supply with 2.1mm / 5.5mm DC - 3V to 12V at 5A

ADAFRUIT $24.95 | adafruit.com

ADAFRUIT $17.50 | adafruit.com

The Mini Power Meter available at Adafruit is a convenient way to easily display the voltage, current, Watts, mAh and mWh in a circuit. The meter has a built-in LCD display to show all the information it's capable of gathering. And besides the typical voltage and watts and amps it will also calculate cumulative Watt hours and milliamp hours over time and display the ambient temperature. You don't need any code, no calculations, or any data logging: it does it all for you!





Adjustable power supplies can be expensive, especially ones with extra features that you sometimes just don't need. This power supply, available at Adafruit, is simple and affordable. It allows you to adjust the voltage range from 3 to 12 volts DC and 5 amps. It's also very small, allowing you to take it with you as needed. I can see a lot of very practical uses for this simple power supply, especially if you are working with LED strips.

VERDICT

Mini Power Meter

A nice addition to understand your circuit's power levels.

8/10

VERDICT

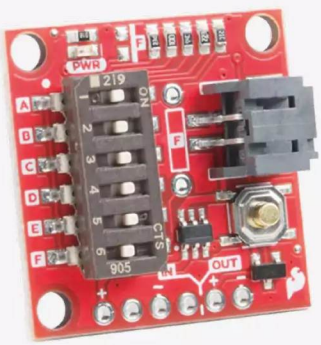
Adjustable Power Supply with 2.1mm / 5.5mm DC - 3V to 12V at 5A

Affordable for the power it can output.

9/10

SparkFun Nano Power Timer – TPL5110

SPARKFUN $7.30 | sparkfun.com



As Sparkfun rightfully declares, "Sometimes we want our projects on, but sometimes we want to turn them off for a while to save power". And this is where the Nano Power Timer comes into play. Consuming a minimal amount of power, approximately 35nA, you can easily add a simple timer to your project.

The board features a TPL5110 delay IC which is configured based on the input resistance. Sparkfun has added a series of switches to the board, and depending on how you turn them on and off is how you set the delay. This board can handle voltages from 1.8 to 5.4 and can set an on off delay between 100ms to two hours. If you're designing a circuit that needs intermittent power, this is definitely a board you should check out.

VERDICT

SparkFun Nano Power Timer – TPL5110

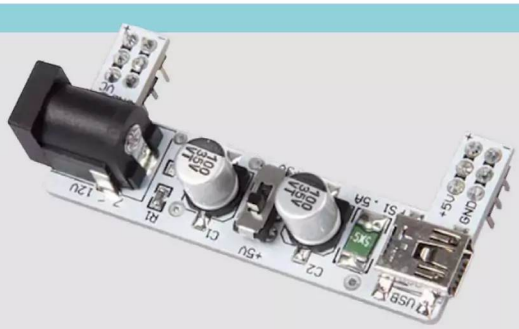
An affordable and simple timer board.

9 /10

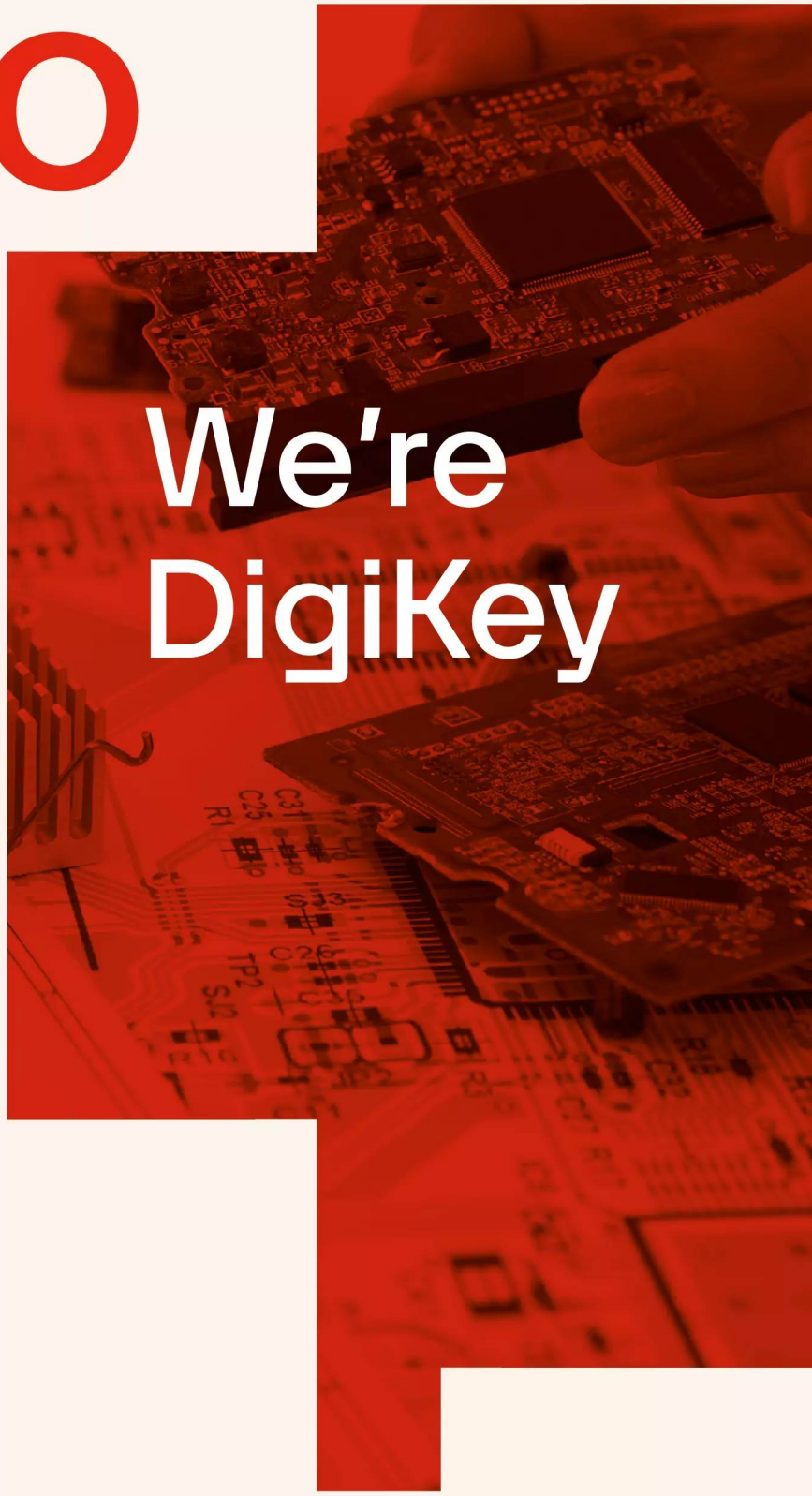
TWO-CHANNEL POWER MODULE FOR BREADBOARDS 3.3V/5V

PIMORONI $4.13 | pimoroni.com

Breadboarding your circuit is one of the first things most everyone does when developing a new piece of hardware. This breadboard power supply fits perfectly in the power rails of most breadboards. It features 3.3 volt or 5 volt and makes adding power simple and is surprisingly affordable. Your input voltage can be between 7-12 volts, or five volts via USB plug. This is a handy little power supply that everyone should have on their bench especially considering its price.



Hello



Whether you're an

- **engineer**
- **designer**
- **purchaser**
- **maker**

we've got the products, services, and business solutions to help move you forward.

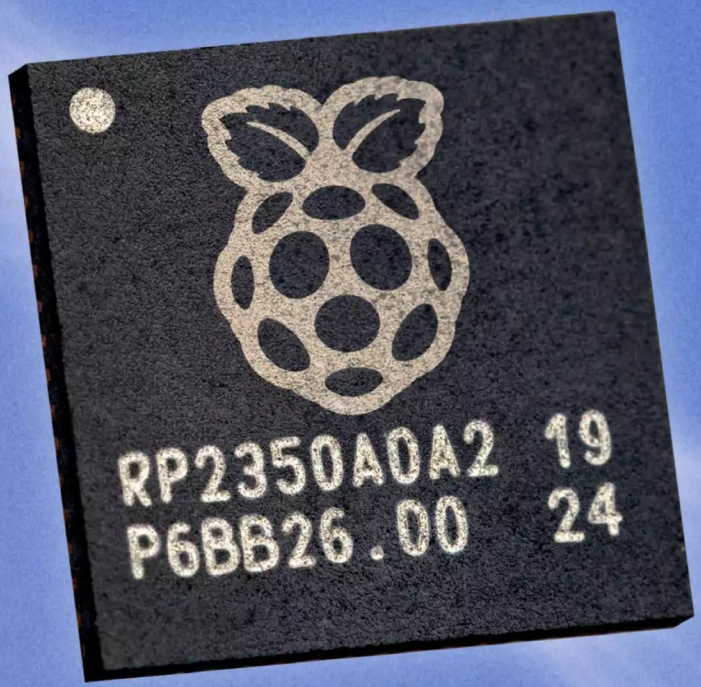
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RP2350 products OUT NOW!

Excited by RP2350 and all it can do? Here are some things that already use it...

By Rob Zwetsloot

Raspberry Pi Pico 2 is here! We expect you've read all about it in our big feature earlier in the issue, and you may be wondering how the new chip that powers Pico 2 – RP2350 – will be used elsewhere. You won't have to wait long as plenty of companies are already using RP2350 in their products, and we've got the scoop on just about all of them.

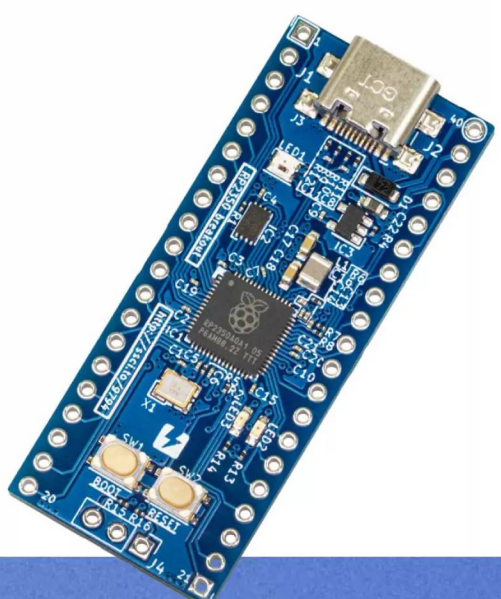
Development boards

> Plenty of companies are already using RP2350 in their products, and we've got the scoop on just about all of them

Picossci 2 Breakout with Type-C

Switch Science
magpi.cc/picossci2

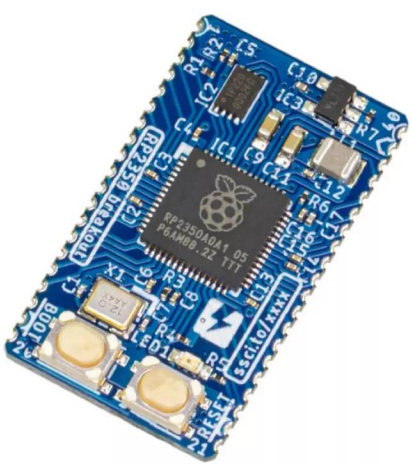
This board has the same shape and pin assignments as Raspberry Pi Pico 2, meaning it can be used right away as a replacement for Pico 2 – and it has USB Type-C.



Picossci 2 Breakout Module

Switch Science
magpi.cc/picossci2bo

A board specifically designed to open up lots of functions of RP2350 on a small board, including exposed USB terminals in lieu of a USB port. The exterior is finished with 1.27mm pitch edge through-holes so it can be mounted onto a PCB directly.



Picossci 2 Breakout Tiny

Switch Science
magpi.cc/picossci2tiny

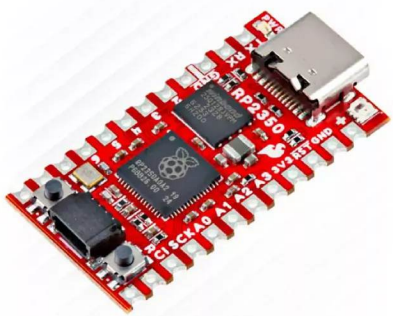
An RP2350 microcontroller board. Miniaturisation was achieved by minimising peripheral components.



SparkFun Pro Micro - RP2350

SparkFun
magpi.cc/promicro2350

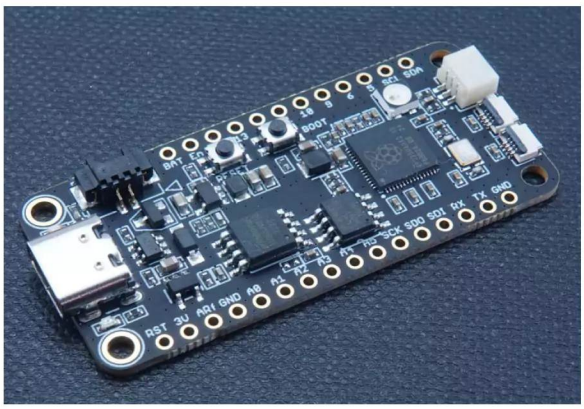
A powerful and compact development board designed around the RP2350. This updated Pro Micro form factor board includes a USB-C connector, Qwiic connector, WS2812B addressable RGB LED, and memory enhancements over the standard Pico 2.



Challenger+ RP2350 BConnect

Invector
magpi.cc/challenger2350bc

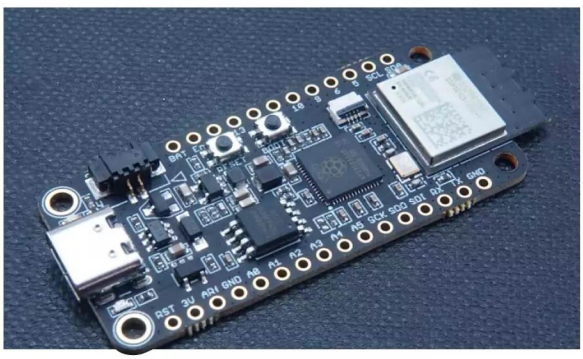
A versatile and powerful platform designed for advanced interfacing and connectivity. A standout feature of the Challenger+ Rp2350 BConnect is the integration of dual iLabs BConnect channels. BConnect is a great interface concept designed to unify various electrical connections such as I2C, serial, and SPI through a flexible flat cable (FFC) system.



Challenger+ RP2350 WiFi6/BLE5

Invector
magpi.cc/challenger2350wb

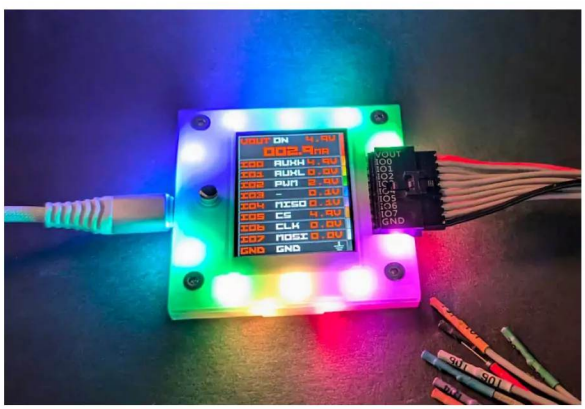
An advanced development platform featuring the Raspberry Pi RP2350 MCU and the ESP32-C6 Wi-Fi/BLE subsystem. The on-board pre-certified ESP32-C6 system provides robust wireless connectivity, seamlessly interfaced with the RP2350 via a high-speed SPI interface, enabling ultra-fast data transfer rates. From the start it provides both Wi-Fi 6 (2.4GHz) and BLE5, but support for various 802.15.4 stacks such as Thread, Zigbee and Matter are in the works.



Bus Pirate 5XL and Bus Pirate 6

Bus Pirate
magpi.cc/buspirate

An open-source hardware debugging tool that converts simple commands into common bus protocols such as 1-Wire, I2C, SPI, UART, several LEDs and more. Send commands to a chip or sensor and get a response, without writing a line of code.



RP2350 Stamp

Solder Party
magpi.cc/2350stamp

This versatile modules comes with 16MB of flash, a 3.3V LDO, Reset and Boot buttons, a LiPo battery management chip, a charge state LED, and the brand-new Raspberry Pi RP2350. Thanks to the Stamp's castellated edges, you can create an RP2350-based project without the need for soldering fine-pitch QFN chips or worrying about lots of external circuitry.



XIAO RP2350

Seeed Studio
magpi.cc/xiao2350

The Seeed Studio XIAO RP2350 packs the power of the Raspberry Pi RP2350 into a compact, thumb-sized form factor. Measuring just 21x17.5mm, it features 19 multifunction GPIOs, an RGB LED, and a battery management system. Thanks to the Seeed Studio XIAO ecosystem, the XIAO RP2350 is compatible with a wide range of add-ons.



Feather RP2350

Adafruit
magpi.cc/feather2350

RP2350 flies high with the Feather format - now you can use any FeatherWings with this battery-powered dev board. It comes with 8MB of flash, a 22pin HSTX output port, Stemma QT, debug SWD, and optional PSRAM spot.

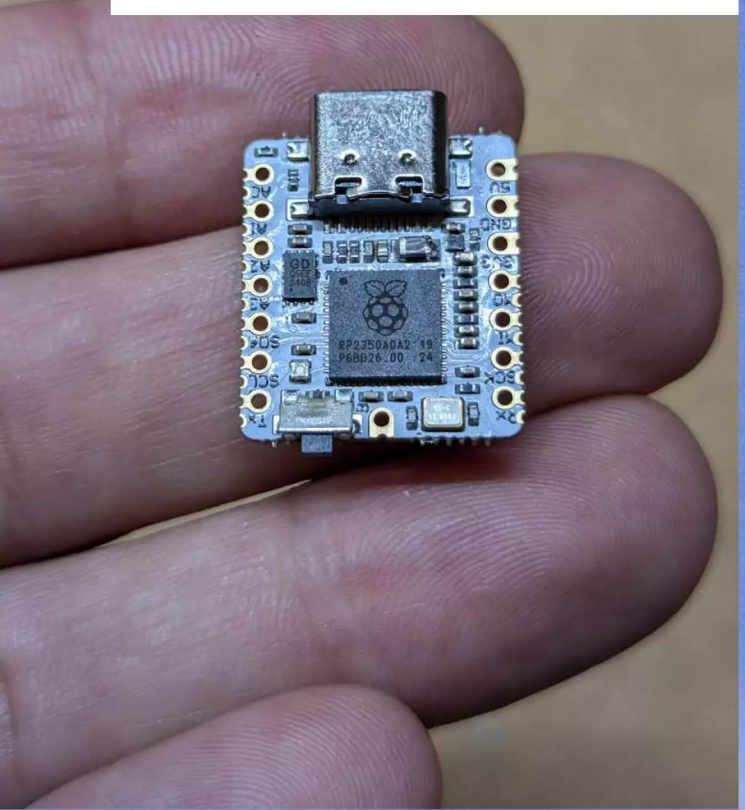


> The maximum number of exposed pins crammed into the smallest possible space

RICK TNY

Phyx
magpi.cc/ricktny

TNY is Phyx's take on the Adafruit QT Py and Seeed studio XIAO board specifications but with added SMD pins for optional extra IO capabilities and a built in WS2811 compatible LED output. This miniature board has 16Mb of flash and a built-in Neopixel making the RICK TNY an interesting upgrade for current and future projects.



RP2350 Stamp XL

Solder Party
magpi.cc/2350stampxl

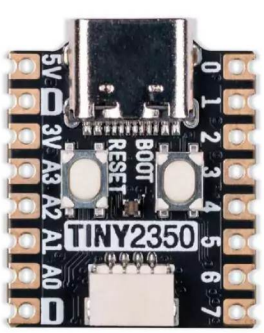
A larger version of the RP2350 Stamp, its increase in size is to incorporate additional GPIOs and an optional second QSPI chip for either flash or PSRAM.



Tiny 2350

Pimoroni
magpi.cc/tiny2350

A postage stamp sized RP2350 development board with a USB-C connection and 4MB of flash storage, perfect for portable projects, wearables, and embedding into stuff.



Breakout boards

Metro RP2350

Adafruit
magpi.cc/metro2350

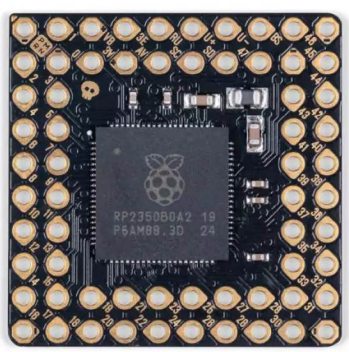
The Metro has an Arduino-shield compatible RP2350 layout and now it sports the RP2350. It comes with 8MB of flash and an optional PSRAM spot. To round it out, there's a microSD port, debug and STEMMA QT connectors, 22-pin HSTX output port and the classic header layout you know and love.



PGA2350

Pimoroni
magpi.cc/pga2350

A minimal but powerful RP2350 breakout board modelled on a pin grid array, with the maximum number of exposed pins crammed into the smallest possible space. It has 8MB of PSRAM and 16MB of flash storage.



Plasma 2350

Pimoroni
magpi.cc/plasma2350

An all-in-one, USB-C powered controller for WS2812/Neopixel and APA102/Dotstar addressable LED strips. A QW/ST connector has been popped on there too, to make it super easy to plug in Qwiic or STEMMA QT breakouts.



Hellbender RP2350 development board

Hellbender
magpi.cc/hellbender2350

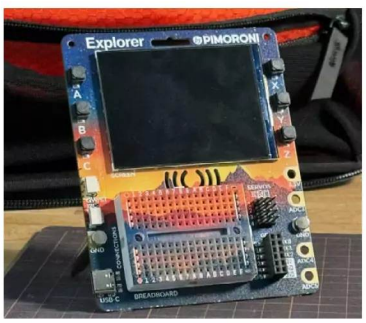
Designed to be a general purpose microcontroller and sensor board ready to be integrated into any project. Key features include a flat back, 46-pin castellated IO headers, USB-C and SWD programming, a microSD card, LiPo battery power and charging, integrated RTC, IMU, temperature, pressure and relative humidity sensors, plus QWIIC connector support.



Explorer

Pimoroni
magpi.cc/pimexplorer

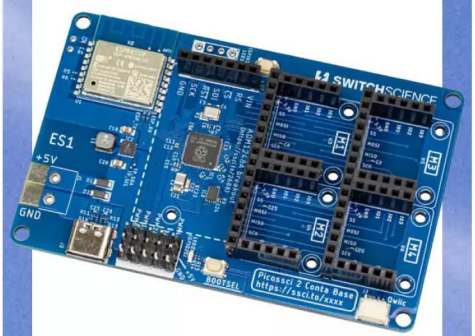
An electronic adventure playground for physical computing, built around the RP2350 chip. Includes a 2.8" LCD screen, a speaker, a mini breadboard, servo headers, analogue inputs, a speaker, plenty of GPIO, and more.



Picossci 2 Conta Base

Switch Science
magpi.cc/picossci2conta

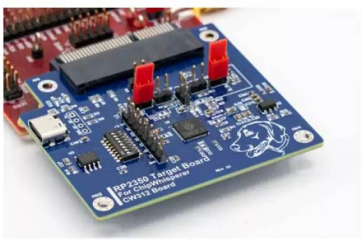
An RP2350 microcontroller board which allows you to connect small boards, sensors, etc, from the Conta range that can be connected without soldering.



RP2350 Target Board

NewAE
magpi.cc/2350target

Explore the advanced security features of the RP2350 including validating your usage of the glitch protection mechanisms. It can also be used for performing side-channel analysis of libraries or frameworks you are using, and for performing research on new security algorithms and their secure implementation.

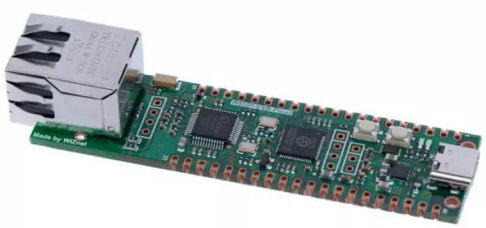


Internet of Things, motors, and more

EVB-Pico2

WIZnet
magpi.cc/evbpico2

Designed to enhance connectivity performance for a wide range of applications. Three versions are available with different WIZnet TCP/IP controller chips, and it has power-over-Ethernet with an additional module.

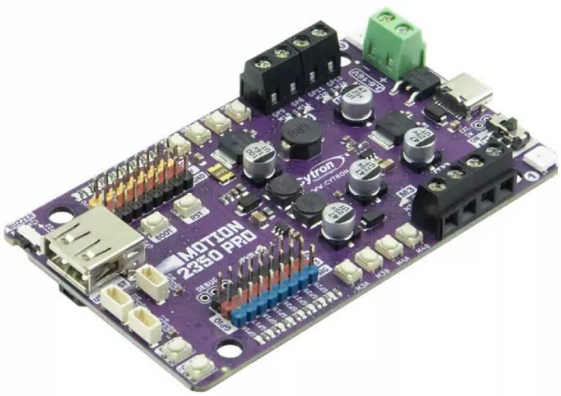


> Run indefinitely on solar power and a compact battery, perfect for off-grid projects

Motion 2350 Pro

Cytron
magpi.cc/motion2350

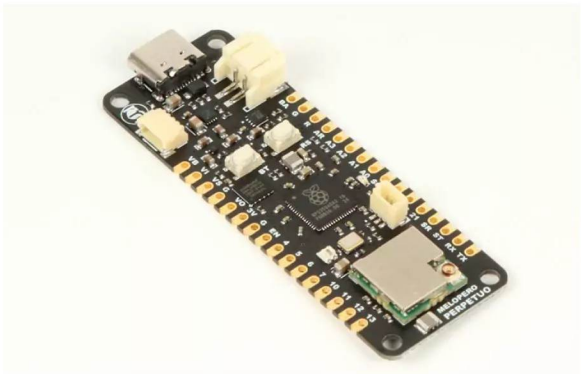
This board comes with a four-channel DC motor driver that can control up to four DC brushed motors, handling voltages from 3.6V to 16VDC. With the built-in Quick Test buttons and motor output LEDs, you can test your setup without a single line of code.



Perpetuo LoRa

Melopero
magpi.cc/perpetuolora

This integrates a LoRa radio module (the EMB-LR1276S from Embit), enabling robust wireless communication capabilities. Designed with sustainability in mind, the board includes a sophisticated LiPo battery charger that can be seamlessly connected to a small solar panel. This feature allows it to run indefinitely on solar power and a compact battery, making it perfect for off-grid projects.



DEF CON badge

Entropic Engineering
magpi.cc/defcon24badge

A handheld game system featuring the RP2350, a touchscreen display, speaker, rechargeable battery, infrared communication, motion sensor, real-time clock, buttons, and of course lots of RGB LEDs. The hardware was developed on an in-house assembly line, while Dmitry Grinberg wrote Game Boy and Palm OS emulators.



Thumby Color

TinyCircuits
tinycircuits.com

Measuring just 51.6 x 30.0 x 11.6mm, Thumby Color has a 0.85in 128 × 128 pixel 16-bit colour screen, eight buttons, and an internal speaker as well as programmable rumble! While the Thumby Color comes preloaded with new games, users can load games as they become available from the community, or code/create their own. See p102 for more.



Coming attractions

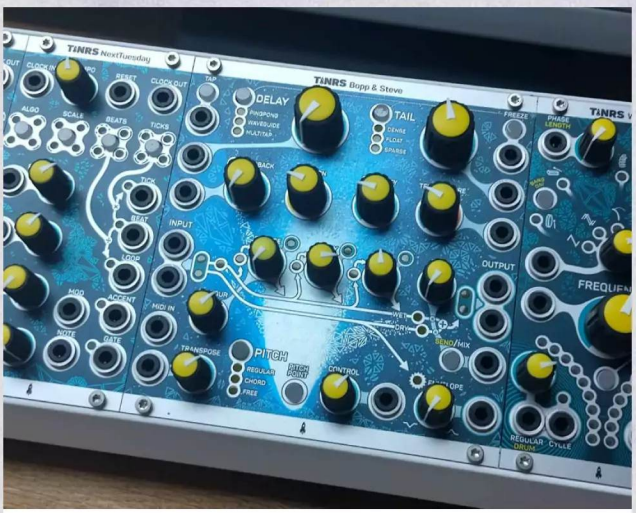
They're not here yet but you'll soon be able to grab these RP2350-powered boards



IRIV IO Controller - IR4.0 Industrial IO Controller

Cytron
magpi.cc/irivioir4
Release window: coming soon

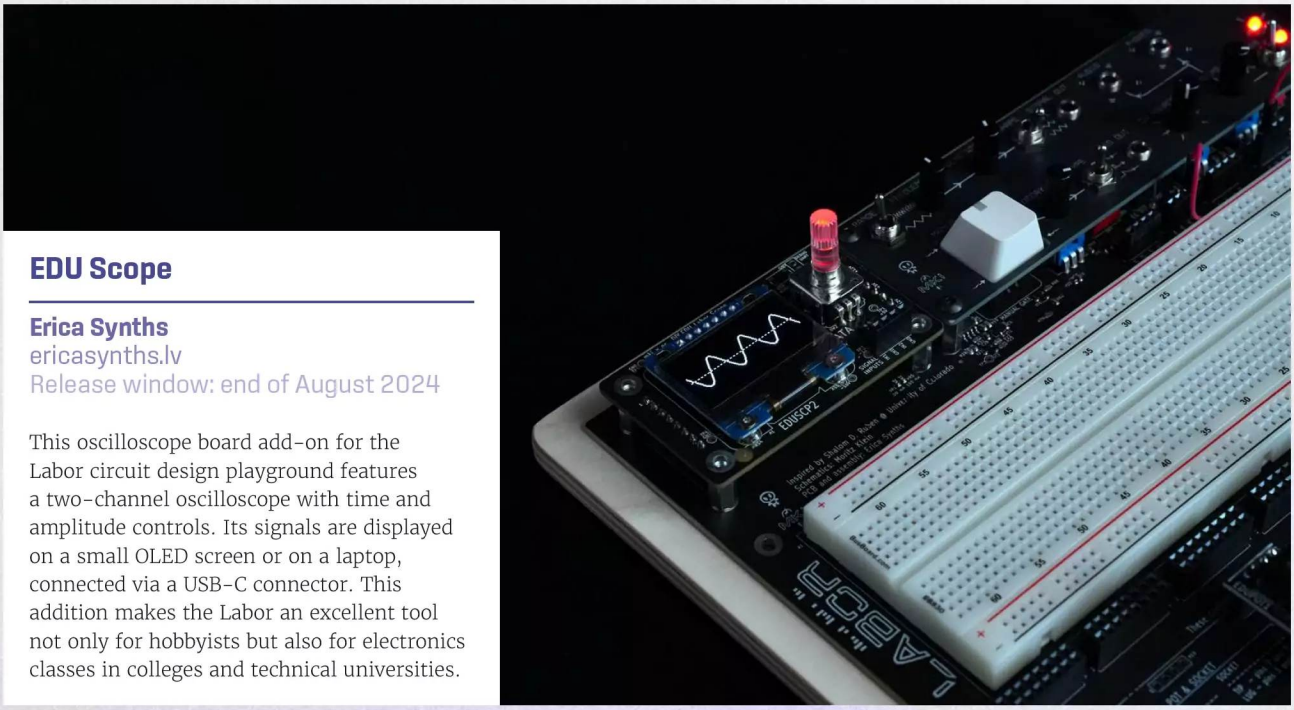
A compact and versatile industrial IO Controller, IRIV IO Controller. Engineered to simplify your industrial application and IO management, the IRIV IO Controller can be more than just a standalone IO Controller.



Bopp & Steve

This is not rocket science
magpi.cc/boppsteve
Release window: Autumn 2024

A space effect synthesizer module – built for the Eurorack system. It reverberates, diffuses, delays and shifts pitch of whatever you send into it, based on a deconstructed reverb audio path. Beautiful chorality, sweeping tails and booming reverb are added to your sound.



EDU Scope

Erica Synths
ericasynths.lv
Release window: end of August 2024

This oscilloscope board add-on for the Labor circuit design playground features a two-channel oscilloscope with time and amplitude controls. Its signals are displayed on a small OLED screen or on a laptop, connected via a USB-C connector. This addition makes the Labor an excellent tool not only for hobbyists but also for electronics classes in colleges and technical universities.



Bullfrog Drums

Erica Synths
magpi.cc/bullfrogdrums
Release window: end of 2024

The main focus of this synth is to teach drum programming and the basics of sampling. Combining Bullfrog with Bullfrog Drums creates a complete and self-sustained contemporary electronic music production and performance setup. Its user interface, inspired by classic drum machines, includes everything necessary for building advanced drum patterns using sampled drum sounds.



Pērkons Voice

Erica Synths
ericasynths.lv
Release window: September 2024

The module encapsulates all four Pērkons voices from the popular Pērkons HD-01 drum machine (a live performance and sound design instrument) , with nine algorithms each, and offers full manual and (a must have in Eurorack modular synths) voltage control over all parameters. The module can save up to 99 user-designed sound presets.

Thumby Color



▶ Tiny Circuits ▶ **magpi.cc/thumbycolor** ▶ £38 / $49

Raspberry Pi's new RP2350 microcontroller powers this wonderful programmable micro games console. **Lucy Hattersley** twiddles her thumbs

Alongside this month's release of RP2350 comes a huge range of products designed with the new microcontroller (see page 92).

One of the first – and most eye-catching – is Thumby Color. This is a fantastic upgrade to the world's smallest games console.

Thumby is made by Tiny Circuits, a company that specialises in building tiny open-source electronics. While the original Thumby took its design inspiration from a Game Boy, this new full-colour version fittingly takes its inspiration from the Game Boy Advance.

The faster dual-core RP2350 processor running at 150Mhz enables Thumby Color to run an 0.85-inch 128×128px 16-bit backlit colour TFT LCD display inside an absolutely miniscule case measuring 51.6 × 30 × 11.6mm. The case has a hole through it enabling Thumby Color to double up as a keychain fob; enabling you to play games when you're not unlocking your door.

Thumby Color comes with pre-loaded with six games (with more planned). These have been custom-built by Glitchbit (**glitchbit.com**) using the Thumby Color API (**magpi.cc/thumbyapi**) and showcase what you can create with the device. With names like *Bust a Thumb*, *Solitaire* and *4connect* they take inspiration from classic arcade and board games.

What surprised us was how playable these games are. We expected it to be a novelty and, while it's not exactly a Steam Deck, we found Thumby Color games to run perfectly well.



▲ Thumby Color is a tiny programmable games console

Verdict

An incredibly fun device that's a great showcase for RP2350. Thumby Color shrinks gaming down to a keychain and enables you to code your own games. The detailed API and tutorials make Thumby special and there's much creative fun to find here.

9/10



▲ Inside Thumby Color is the brand new RP2350 microcontroller . Here we can also see the LiPo battery, USB-C port and a tiny rumble motor

Get developing

Two versions of Thumby Color are currently available. There's the Thumby Color, on Kickstarter (**magpi.cc/thumbykick**) and a slightly larger development version (**magpi.cc/thumbydev**) with larger buttons. We have both in for testing here.

Both have nine buttons: a four-way D-pad, A/B buttons, L/R bumpers, and a Menu button. There's an on/off rocker switch and a USB-C connection for charging and connectivity alongside a 110mAh Rechargeable LiPo battery. The presence of a tiny rumble motor is a particularly nice touch.

Like the original Thumby being able to play games on a 2.1cm display isn't the main attraction (although we found it a surprisingly fun way to pass the time). The real deal is the ability to investigate the API and create games yourself by following the tutorials.

To this end, Thumby has an online Code Editor (**code.thumby.us**) and a starter guide (**magpi.cc/thumbystart**). The web Code Editor is undergoing some integration with Thumby, and we found the filesystem not fully functional at the time of testing.

> The presence of a tiny rumble motor is a particularly nice touch

The second approach is to use Thonny IDE with the MicroPython (Raspberry Pi Pico) interpreter (**magpi.cc/thumbythonny**). We prefer coding in Thonny IDE although the Code Editor has better integration and a built-in Arcade section with over 100 games from the original Thumby. All of these are compatible with Thumby Color, and it's where you'll find new games as they become available. Tiny Circuits tells us that Thumby Color support will be added to the Code Editor soon.

There's also a vibrant forum for Thumby (and other Tiny Circuits projects) that you can find at **magpi.cc/tinyforum**.

We enjoyed Thumby Color tremendously, and it's a great showcase for the extra power of Raspberry Pi's RP2350 microcontroller.

▼ The games are surprisingly playable on the tiny screen. But it's the ability to code your own games that is the real draw



SPECS

PROCESSOR:
150MHz ~ 300MHz Dual Core Raspberry Pi RP2350 processor (with FPU)

MEMORY:
520KiB SRAM

STORAGE:
16MiB flash

SCREEN:
Screen: 0.85" 128×128px 16-bit Backlit Color TFT LCD Display

POWER:
110mAh rechargeable LiPo battery, for around two hours of gameplay

BUTTONS:
Four-way rocker D-Pad
Two A/B face buttons
Two shoulder bumpers
Menu button

AUDIO:
4kHz buzzer

HAPTICS:
DC 14,000RPM 0.24g weight vibration motor

DIMENSIONS:
51.6 × 30.0 × 11.6mm

Raspberry Pi PLC 38R

▶ Industrial Shields ▶ **magpi.cc/plc38r** ▶ From €560 / £472 / $606

Industrial automation is made easy with this powerhouse of a programmable logic controller. By **Phil King**

SPECS

PROCESSING

Raspberry Pi 4 with 2GB, 4GB, or 8GB RAM

I/O

8 × analogue/digital opto-isolated inputs (5-24V), 4 × digital opto-isolated inputs, 16 × relay outputs, 6 × analogue outputs (0-10V), 6 × digital/PWM outputs, I2C, SPI, RS485, RS232/TTL



▶ As well as offering access to Raspberry Pi 4's main ports, the PLC's right-hand side features numerous I/O pins, analogue/digital outputs, and ten relays

Verdict

Protected by a robust case, this PLC is packed with I/Os and relays, making it suitable for a wide variety of industrial applications.

9/10

A powerful, sturdy, and versatile programmable logic controller, the Raspberry Pi PLC 38R packs a whole load of digital and analogue I/O, along with 16 relay switches.

For those unfamiliar with the concept, a programmable logic controller is a robust computer specifically developed for industrial control applications, and used to automate processes. Based around open hardware, the various PLCs (among other products) made by Industrial Shields are used in a wide variety of sectors, ranging from geothermal energy to railways – take a look at **magpi.cc/iscasestudies** for more details.

While the company also produces PLCs based on Arduino and ESP32 microcontrollers, the model reviewed here is one of the Raspberry Pi-based range and therefore benefits from superior processing power – an advantage when handling multiple real-time processes – and the ability to run a full Linux operating system, the familiar Raspberry Pi OS, by default. You can connect the unit to a monitor via HDMI if needed, but in most cases operators will SSH in from another computer.

▲ The left side of the PLC 38R features six more relay connections, opto-isolated analogue/digital inputs, and dip switches

Raspberry Pi power

The PLC 38R model is based around a standard Raspberry Pi 4 (with 2GB, 4GB, or 8GB RAM), with the optional addition of up to two extra communications boards such as 4G cellular and LoRA. Naturally, Wi-Fi and Bluetooth are built-in, thanks to Raspberry Pi 4, along with dual Ethernet ports (the board's built-in port plus an extra one).

> Raspberry Pi 4 is secreted inside a robust plastic case with a large metal heatsink on the base

Raspberry Pi 4 is secreted inside a robust plastic case with a large metal heatsink on the base. The whole unit weighs 711g and is mountable on a DIN rail. The ambient operating temperature is 0 to 50°C, with a humidity level of 10 to 90%, while the case has a shockproof resistance of 80m/s2 in the X, Y, and Z axes.

Cutouts in the case provide access to Raspberry Pi 4's USB and Ethernet ports on one side and – in a recess – micro-HDMI ports and the USB-C power port. You can't power the whole unit that way, however: instead you'll need to connect a 12–24V DC supply via two screw terminals, making sure the polarity is correct. Industrial Shields offers a suitable DIN rail power supply for €25.

To protect the electronics and avoid data corruption during sudden voltage drops in the event of a power outage, the PLC 38R has an integrated UPS shield. When the UPS kicks in, the outputs maintain their last activation state until the unit is rebooted. A real-time clock is also included, powered by a button battery – easily replaceable by removing a plastic panel. Insulation resistance is provided to the tune of 20mΩ at 500VDC between the AC terminals and protective earth terminal. Dialectic strength is rated as 2300 VAC at 50/60Hz for one minute with a maximum leakage current of 10mA.

Pinned to the ground

The most important feature of any PLC is its range of I/Os. Raspberry Pi PLC 38R is absolutely loaded with them, divided into zones and connectable via removable screw terminal blocks. On the right-hand side of the unit are sets of analogue (0 to 10V) and digital/PWM outputs. Underneath, there's a long row of I/O and power/ground pins covering standard protocols such as SPI, I2C, and RS485, plus a couple of direct GPIO pin connections.

The remainder of that side is taken up by ten sets of relay switch connections. Another six are found on the left side of the unit, along with opto-isolator protected digital/analogue inputs, configurable by two sets of four dip switches. Note that other Raspberry Pi PLC models feature varying numbers of I/Os and relays, so you can choose the one that best suits your requirements.

The downloadable documentation is fairly detailed and features examples of how to use pre-installed Bash scripts to read various inputs, and trigger outputs and relays, so it's fairly easy to get started.



▲ The front of the unit features status LEDs, an extra Ethernet port, and access to Raspberry Pi 4's power and micro-HDMI ports, plus 3.5mm AV jack



▲ The top of the robust housing includes technical information; the rear of the unit can be mounted on a DIN rail

Pironman 5

▶ Sunfounder ▶ **magpi.cc/piroman5** ▶ From £62 / $79

A mini PC case for Raspberry Pi 5 with some serious cooling. By **Phil King**

SPECS

FEATURES

Tower cooler with PWM fan, 2 × RGB fans with dust filters, 0.96-inch OLED, NVMe M.2 SSD board, 2 × full-size HDMI ports, power button, RTC battery





▲ Building the case. Components include an NVMe M.2 board to add optional SSD storage

◀ With clear acrylic panels, RGB lighting, and even a mini OLED, this is one of the coolest-looking Raspberry Pi 5 cases around

With aluminium and clear acrylic panels, the Pironman 5 case turns Raspberry Pi 5 into a stunning desktop mini PC with optional SSD storage. Not only does it look cool when lit up with RGB LEDs, it delivers some effective cooling with three fans.

Taking around an hour, assembly is straightforward thanks to an illustrated guide and good labelling of the kit components – just as well, as there are four standoff sizes and three types of screw.

A microSD slot extender enables easy access, while an adapter board extends Raspberry Pi 5's USB-C power port and converts its micro-HDMI outputs to full-size HDMI ones. It also houses a button battery for the real-time clock.

An IO expander board extends the GPIO pins, powers the two RGB fans, and connects the mini OLED. Then there's an NVMe board to add an SSD (not supplied), and a power converter connected to a metal button that permits easy shutdown.

Power and control

Upon first power up, the fans spin continually. For full control of these and the RGB LEDs, you need to install the Pironman 5 software. This then creates a handy web dashboard for detailed system monitoring and the option to switch between several fan modes. Key stats are also shown on the mini OLED.

> "Not only does it look cool, it delivers some effective cooling"

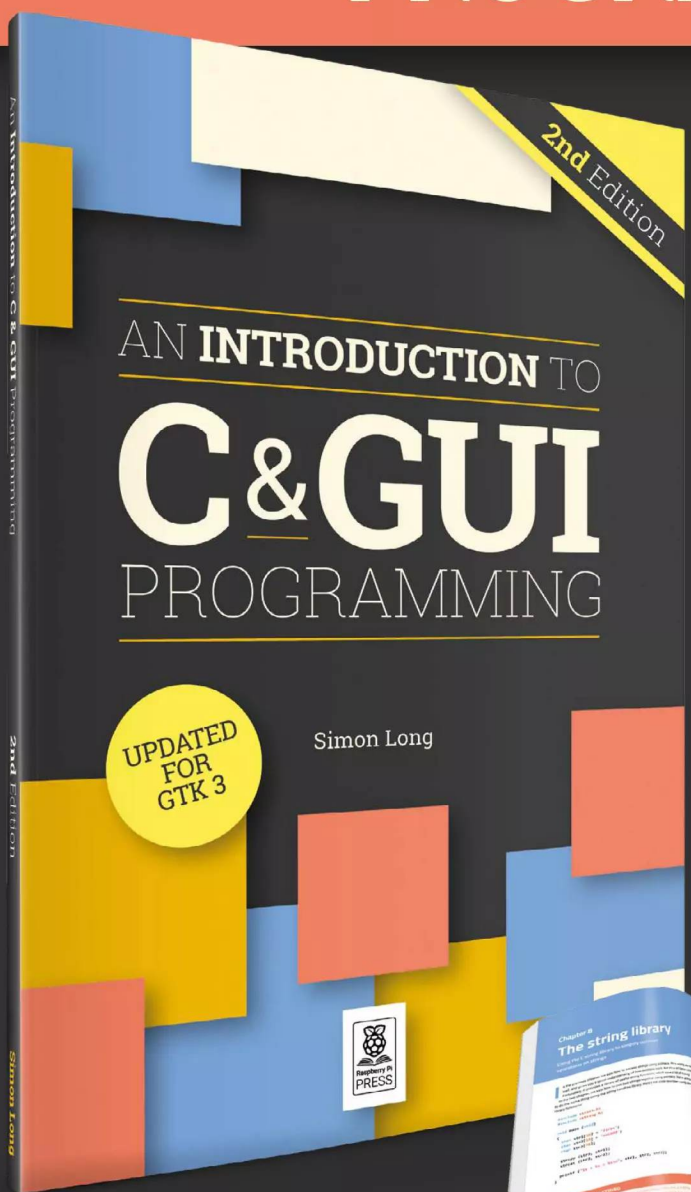
Cooling performance is impressive: in a five-minute stress test of all four cores, the CPU temperature maxed out at just above 60°C. Wi-Fi signal strength and quality does suffer a little due to the metal parts of the case, but it's fine when kept reasonably close to the router.

Verdict

Quality components and detailed documentation make for a robust, beautiful cooling case with excellent performance.

9/10

AN INTRODUCTION TO C&GUI PROGRAMMING

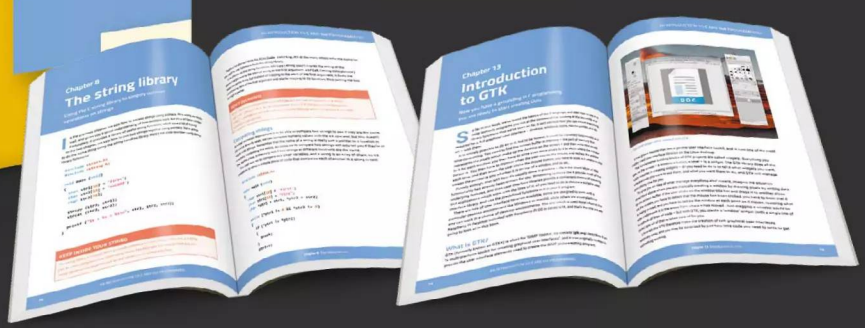


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ReComputer R1000

SPECS

INTERFACES
1×Gigabit Ethernet (with PoE), 1×100MB Ethernet, 3x3-pin RS485 Terminal Block, 2×USB-A 2.0 Host, 1×USB C (for flashing OS), 1x HDMI

WIRELESS
Wi-Fi, BLE, LoRA, 4G LTE, Zigbee

POWER
2~24V AC/9~36V DC, idle 2.88 W, full load 5.52W, overvoltage protection 40V

▶ Seeed Studio ▶ **https://magpi.cc/r1000** ▶ From £132 / $169

An industrial-grade edge IoT controller powered by Compute Module 4 and packed with wireless features. **Rob Zwetsloot** connects with it.

We've reviewed a couple of products from Seeed Studio's reTerminal line in the past and have always been impressed by their incredible build quality and functionality. The reComputer R1000 seems to be using that design ethos for a slightly different kind of product – an all-in-one edge IoT controller.

Out of the box it looks a bit like an unassuming full Raspberry Pi in a nice heat-sink case, albeit a fair bit chunkier. The size comes from the sheer number of features packed into the box – UPS modules, power-over-Ethernet, multiple RJ45 ports, 4G modules, LoRa capabilities, external antenna ports, SSD slot, an array of terminals, and a Compute Module 4 to power it all.

A lot of these add-ons are optional and you can build your preferred R1000 online or get one of the pre-made packages - we specifically have the R1025 build for review, which comes with 4GB RAM and 32GB eMMC – and there are various modules for adding 4G or LoRaWAN that range in price and functionality.



▶ Everything you et in the standard box – note the barrel jack adapter for power





◀ The rest of the connectors on the underside of the box

▲ The clip attaches to the side of the box rather than at the base

Good to go

It comes pre-assembled out of the box like the rest of the range, and is dead easy to disassemble and update, swap out, or add compatible hardware such as the optional extras. There's a comprehensive guide in the Seeed Studio docs (**magpi.cc/r1000doc**) which also covers how to flash a new OS to the hardware. Raspberry Pi OS is supported as you'd expect, with extra drivers you'll need to install when flashing from scratch, and there's also official Ubuntu support. While a product like this will largely be used headless, there is a HDMI port in case you need to do some work at the box itself, such as turn on SSH if you forgot during the flashing process.

The hardware comes with a little clip to mount it on its side, making it jut out from whatever surface it's attached to, which seems a little precarious. Still, it holds strong and does let you keep all the various I/O easily accessible, with the all-important serial ports on the front.

> "It's dead easy to disassemble and update, swap out, or add compatible hardware such as the optional extras"

Full support

Thanks to the installed CM4 it is very easy to use and customise, and it's nice and quick as well. The build quality is really top notch too, just as we'd expected, and the docs are fairly comprehensive whether you want to use it in an industrial setting or even at home as your IoT controller with Home Assistant – and at the lower end of its price scale it's not that uncompetitive for using at home either if you have some serious home automation requirements.

Verdict

Very complete piece of hardware that you can customise for nearly any use of IoT, from consumer to industry

10/10

Olimex Neo6502

▶ Olimex ▶ **olimex.com** ▶ From €30 / £25 / $32

SPECS

DIMENSIONS
80 × 155mm

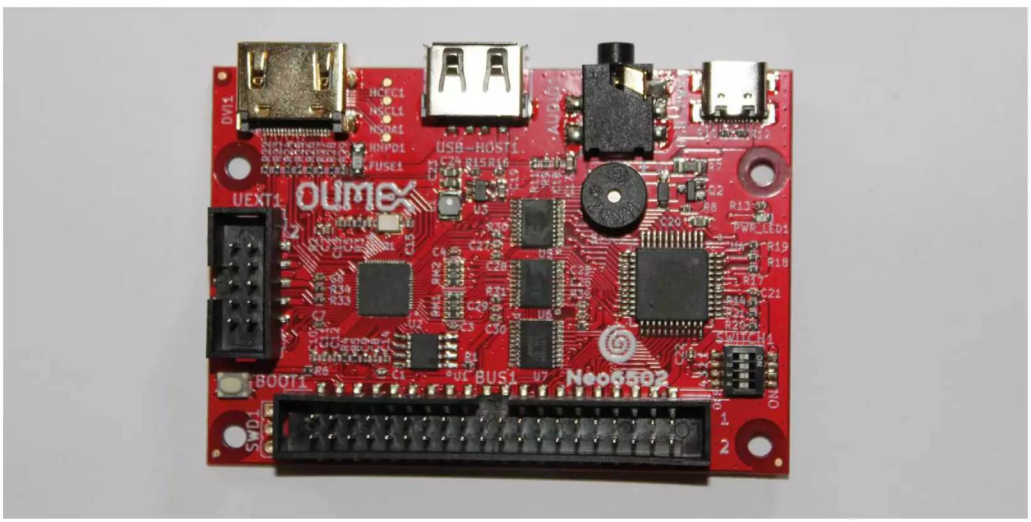
PROCESSOR
6.25MHz
W65C02

MEMORY
64k

GRAPHICS MEMORY
32k

OUTPUT RESOLUTION
320x240
(256 colour)

This modern 8-bit computer uses an RP2040 chip to handle input and output. **K.G. Orphanides** checks out its emulation and development features.



The Olimex Neo6502 is an open-source hardware and software retrocomputing platform that combines a discrete 6.25Mhz 6502 8-bit microprocessor with an RP2040 chip to create a fascinating platform for both modern 8-bit development and retro emulation.

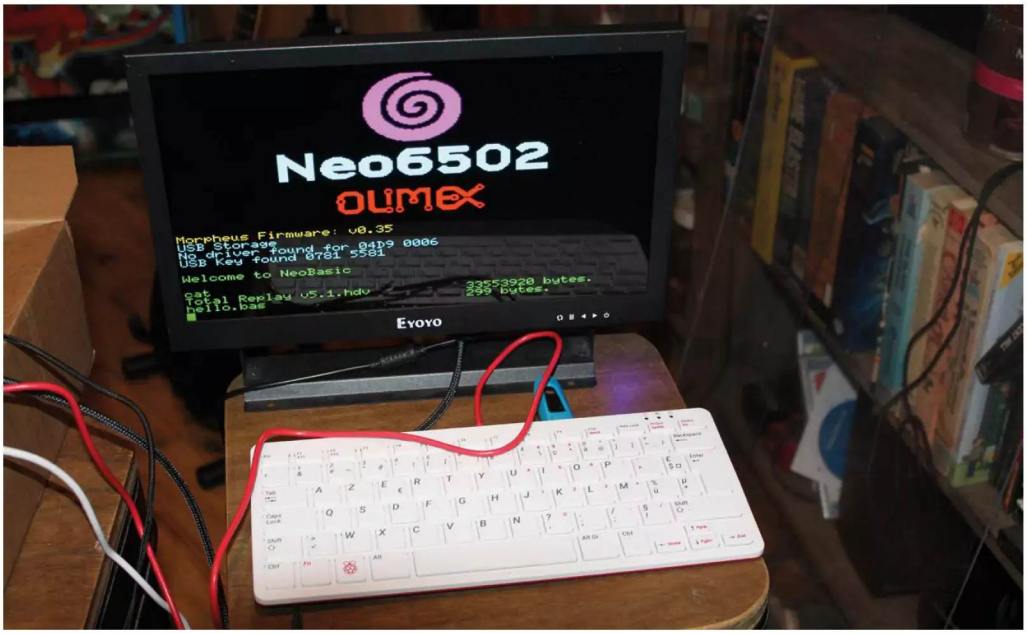
The RP2040 handles video, audio, storage and interface devices. It can be flashed with a variety of firmware to emulate classic 8-bit computers, including the Apple II, C64 and Oric.

Even more interestingly, you can also flash it with Morpheus, which includes a programming interface that allows you to run and create your own software in BASIC and access files on a connected USB stick.

You'll need an HDMI cable, a USB-C power supply, a keyboard, a USB hub, and a fast USB3 storage drive. There's a 3.5mm audio output jack and a piezo buzzer is fitted to the to cover alert beeps, boot sounds and in-game boops. Finally, you'll need an existentially unsettling but



▶ An emulator is available for Windows and Linux based PCs, so you don't need to develop on the hardware itself



standards-compliant USB A-to-A cable to flash the Neo6502's firmware from your computer.

If you use a Raspberry Pi keyboard, its built-in USB hub works perfectly. If you use a different keyboard, Olimex recommends buying its own guaranteed-compatible USB-NeoHub, which costs just €5. You can also use a USB game controller– a generic USB pad should do the trick, and Olimex can sell you one of those, too. More complicated devices such as our Sony DualShock 4 didn't work when we tested them.

Running and writing software

The board ships with an Apple II firmware loaded on it, but to actually boot it, you'll need an Apple II hard disk image from Olimex's FTP server. This comes with a selection of games, many of which have since been placed in the public domain by their creators, but if you're in the UK, there's material here that may be copyright infringing.

We thus recommend immediately flashing the unit with the Morpheus firmware (**magpi.cc/neo6502firmware**). Hold the BOOT button and plug the USB A-to-A cable into your PC, and you'll be able to drag Morpheus's **firmware_usb.uf2** file over to the mounted RPI-RP2 device to flash it, then simply reboot Neo6502 with a connected keyboard and USB storage device.

Paul Robson's comprehensive Wiki (**magpi.cc/neo6502docs**) will guide you through setting up the hardware, installing Morpheus and writing, saving and running your first NeoBasic programs. You can also write programs on your usual workstation and run them from a USB drive later.

If you wish to do this, you'll find the Neo6502 BASIC reference at **magpi.cc/neo6502basic** and an emulator (**magpi.cc/neo6502emulator**) for x86 PCs running Windows or Ubuntu-derived Linuxes. You can also develop software using Mad-Pascal, TaliForth2, C (CC64) and even assembler. You'll find programs to inspire you at **www.neo6502.com/wiki/Software-links**. As well as the Apple II, the Neo6505 can run emulators for the CP/M-65, the Oric Atmos, and C64. C64 firmware licences are available via C64 Forever, fortunately.

▲ The Morpheus firmware allows you to access USB storage, load, write and run software. There's even a basic text editor

> Neo6502 is an intriguing emulation platform, but it's an even more fascinating development platform

Neo6502 is an intriguing emulation platform, but it's an even more fascinating development platform. Like virtual 8-bit computers such as the PICO-8, the limitations of the 6502 processor are what make it appealing to develop for. The hardware is inexpensive, easy to emulator, and the combination of the 8-bit chip with RP2040 means that we get modern quality of life interface features alongside an authentic 8-bit microprocessor.

The Neo6502 is also available as part of the Neo6502 PC mini-computer kit, and can interface with Ollimex's wide range of UEXT modules (**magpi.cc/uextmodules**).

Verdict

The Olimex Neo6502 really is a modern retro computer, and although emulation's fun, it's as a development platform where it's at its most exciting.

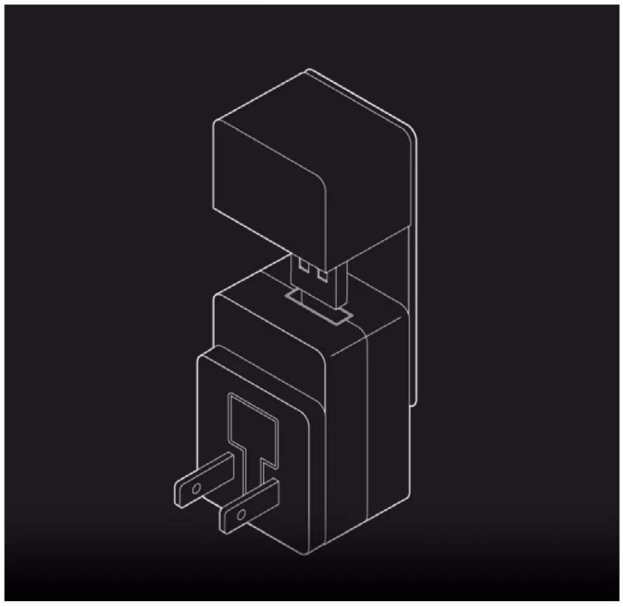
8/10

10 amazing:

Raspberry Pi Zero projects

The tiny microcomputer is still an incredible piece of kit

We're having a lot of fun with Raspberry Pi Pico 2 this issue. However we didn't want Raspberry Pi Zero to feel left out. We've been using one behind the scenes for extracurricular projects and remembered just how good it was, so we thought we'd highlight some of the best things ever made with it.



▲ NODE Nano Server V2

Plug 'n' serve

This upgraded plug-in server works like a lot of modern Wi-Fi boosters where it's just a plug. It's very neat. We like it.

magpi.cc/nanoserver2



▲ Penkesu computer

Handheld computing

A very tiny and a very cool looking laptop made with a 7.9"-wide screen and repurposed GBA SP hinges

magpi.cc/penkesu

▶ ZeroBot

Tiny robot

We had a very similar robot in *The MagPi* when Raspberry Pi Zero launched, and we still love the form factor.

magpi.cc/zerobot



▼ Simpsons Shuffler

Sitcom randomiser

Ever just wanted to watch a random episode of *The Simpsons* without getting out your DVDs or scrolling Disney+? Just press that yellow button

magpi.cc/simpsons





▲ GBA Raspberry Pi Zero

Handheld gaming

Hack your old GBA to make it a very comfy and compact handheld gaming system (with an added backlight)

magpi.cc/gbazero

▼ 3D printed case

Very cool

This 3D printed and laser-cut case is a very pretty way to not only display your Raspberry Pi Zero but also keep it nice and cool during operation

magpi.cc/print0case





◀ Zero Drone

Fly high

Lots of folks love making drones with Raspberry Pi, and Raspberry Pi Zero makes it much easier

magpi.cc/zerodrone

▼ Tiny 3D printed Volumio

Walk, man

This is a bit of a mod on some Pimoroni audio add-ons for Raspberry Pi Zero that turn it into your next MP3 player

magpi.cc/tinyvolumio



▼ My Naturewatch Camera

Critters on camera



This very DIY nature-watching project is a lot cheaper than some, yet can still take some wonderful wildlife photos

mynaturewatch.net

▼ GamePad Zero

Plug 'n' play

One of the first things we did with a Raspberry Pi Zero was glue it into a knock-off USB controller. This project takes it to the next level.

magpi.cc/gamepadzero




CODE
THE
CLASSICS
VOLUME I
SECOND EDITION





CODE THE CLASSICS VOLUME 1

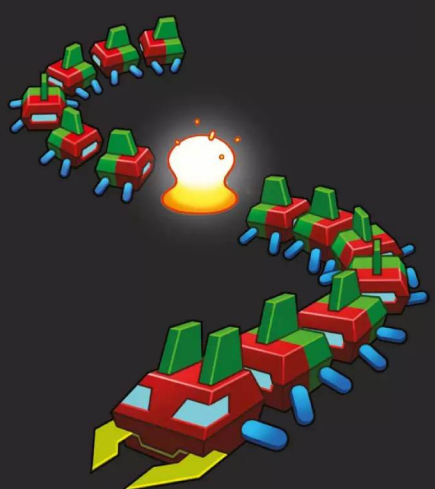
This stunning 241-page hardback book not only tells the stories of some of the seminal video games of the 1970s and 1980s, but shows you how to create your own games inspired by them using Python and Pygame Zero, following examples programmed by Raspberry Pi founder Eben Upton.





New in the Second Edition

- *Expanded Python and Pygame Zero tutorials*
- *A GitHub tutorial for working with example code*
- *Bug fixes and other improvements*



Available now **magpi.cc/store**



Andrew Gregory

A new face in the magazine is a long-time colleague

> Name **Andrew Gregory** | > Occupation **Features Editor**
> Community role **Maker correspondent** | > URL **magpi.cc**

This month we've welcomed *HackSpace* into the magazine, and in the process added 32 pages of the kind of amazing stuff that used to be in that mag. This brand new section of content is being put together by Andrew Gregory, former Features Editor of *HackSpace*, so you know it's in good hands.

"*HackSpace* was all about making things," Andrew says. "Real, physical objects that you could hold in your hand and say 'I made this'. Of course we had a bias toward digital technology, so Arduino and Raspberry Pi projects, plus 3D printing, all featured heavily. But in reality you can put anything in an issue of *HackSpace*: crochet, welding, leatherwork, robotics, laser cutters... all sorts of stuff. I'm really exciting to be bringing some of this to the official Raspberry Pi magazine."

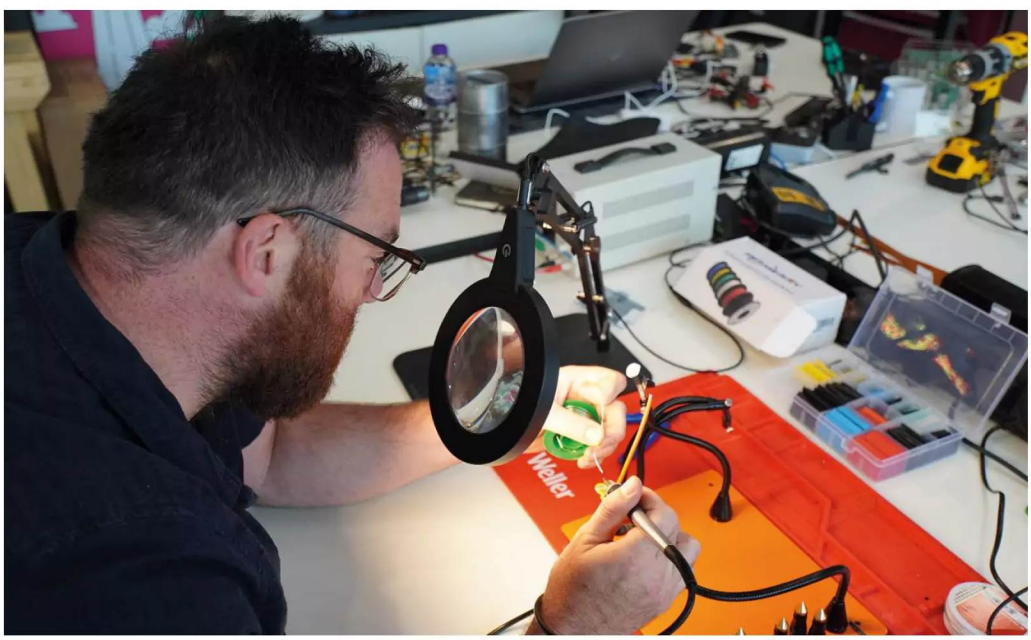
What is your history with making?

A lot of people who get into making reckon that they used to take things apart and put them back together when they were kids. Whenever I tried doing that I got told off. Instead, whenever anything broke, it was my job to take it apart and try to work out how to fix it. That way, it wouldn't matter if I broke it further. I fixed a broken lawnmower for my mum once and was extremely chuffed with myself!

I never did my electronics at school – I still have a scar on my finger from defending myself from a 14-year-old psychopath with a soldering iron – but I got into it a few years ago when I made my first electric guitar effect. It's a simple device, with only a handful of components, but it's identical to the vintage Fuzz Face pedal used by Jimi Hendrix, right down to the new old stock transistors. Pretty much anyone can put one of those together, but mine is unique because I made it.



▲ We'd like to contest that it was Andrew's Linux magazine that helped Raspberry Pi – it was other Features Ed Rob's Linux magazine that did



▲ Despite the scar, Andrew can now solder without teenagers attacking him

When did you first learn about Raspberry Pi?
Ooh, back before it was available. I was one of the first lot of customers who placed an order for this super-cheap computer back in 2012. Back then they didn't have the supply chain they do now, so it took ages to arrive, and when it eventually did my attention had moved on, so the Raspberry Pi just sat in a drawer somewhere. I think I still have it.

At the time I was working on a Linux magazine. We'd heard about this $25 computer and thought it would be lovely to make it famous, so we gave the Raspberry Pi its first magazine cover. Without me, this company would be nowhere!

What is your favourite thing you've made with Raspberry Pi?
My favourite Raspberry Pi project is still my first one: making an LED flash on and off. I had tried several times to learn computer programming, and never got very far. I can very clearly remember being shown how to write 'hello world' in Python by a colleague, beaming from ear to ear as if I was gaining the key to a magic kingdom, but I just didn't get it. How is writing a script that prints 'hello world' any different from typing it in yourself on a word processor? It takes longer, it's more keystrokes… To this day I think that teaching students to start with 'hello world' is counterproductive.

But learning to flash an LED on and off is completely different. If you've got a physical example in front of you of what the code is doing, then it's easy to see how you can go from there to turning a motor on and off, or controlling a robotic arm, or a drone, or an automatic plant watering system.

> "I think that teaching students to start with 'hello world' is counterproductive"

What future project plans do you have?
After the summer we've had, my dream project would probably be a solar-powered laser turret to zap the slugs that have destroyed my pumpkins this year. I don't want to put poison down for them, but I reckon an automated, AI laser might be enough to make them turn around and leave my allotment alone.

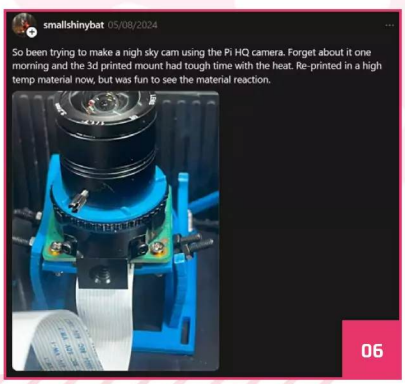
MagPi Monday

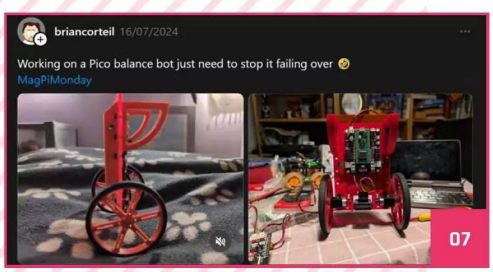
Amazing projects direct from social media!

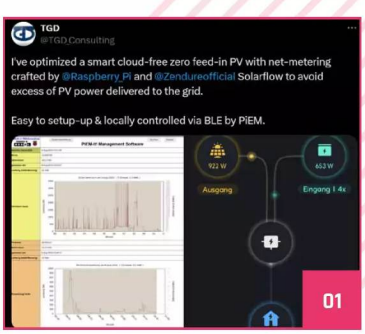
Every Monday we ask the question: have you made something with a Raspberry Pi over the weekend. Every Monday, our followers send us amazing photos and videos of the things they've made.

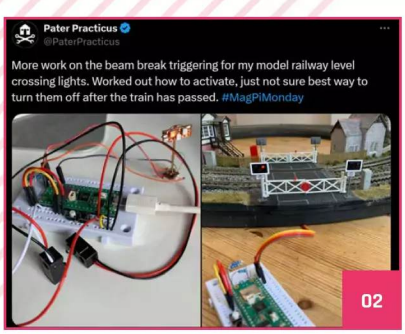
Here's a selection of some of the awesome things we got sent this month. Remember to follow along at the hashtag #MagPiMonday!

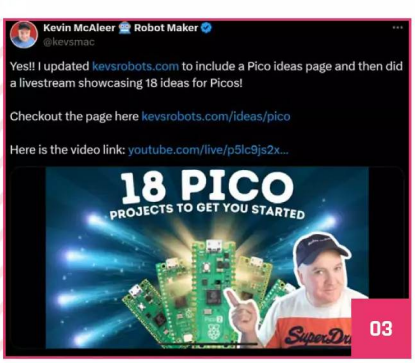
01. We don't know too much about PV power, however this does seem like a very good solution to managing it
02. The age-old question of guessing a time or adding more sensors
03. Kev getting right into he spirit of Raspberry Pi Pico 2 with 18 cool ideas
04. We have been thinking about doing something similar, good to know Stewart has us covered
05. A nice and compact solution from Akkie here, we like that it has the Pico footprint
06. It has been very warm in the UK but we did not realise it had been THAT warm
07. Brian is back at it with more robotic tricks, this time a balancing act

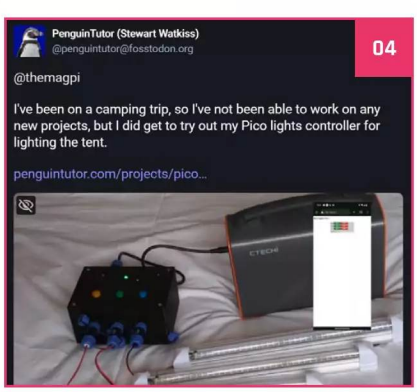


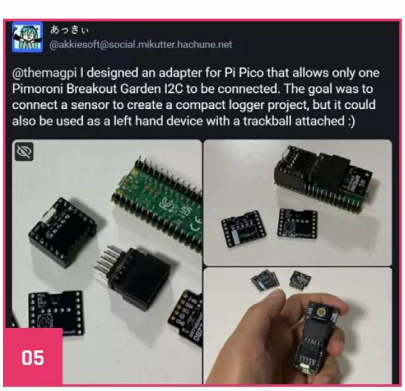












Events in pictures: **Lagos IoT Workshops**

Community and official events in the wild





FIND OUT ABOUT NEXT MONTH'S EVENTS ON PAGE 124





A weekend affair in Lagos, Nigeria, saw Matt Richardson, Community Engagement Manager, and Toby Roberts, Maker in Residence, turn up! The event was centred on programming the Raspberry Pi Pico, and was intended for enthusiasts and local students to learn more about how microcontrollers can be used in IoT and other real-world situations.

01. Matt and Toby see what a couple of participants have been working on
02. A couple of sessions were held, and quickly filled up
03. Local makers and organisers were there to help students and attendees
04. A successful team after a session of learning MicroPython on Raspberry Pi Pico

Pico **Piano Player Robot**

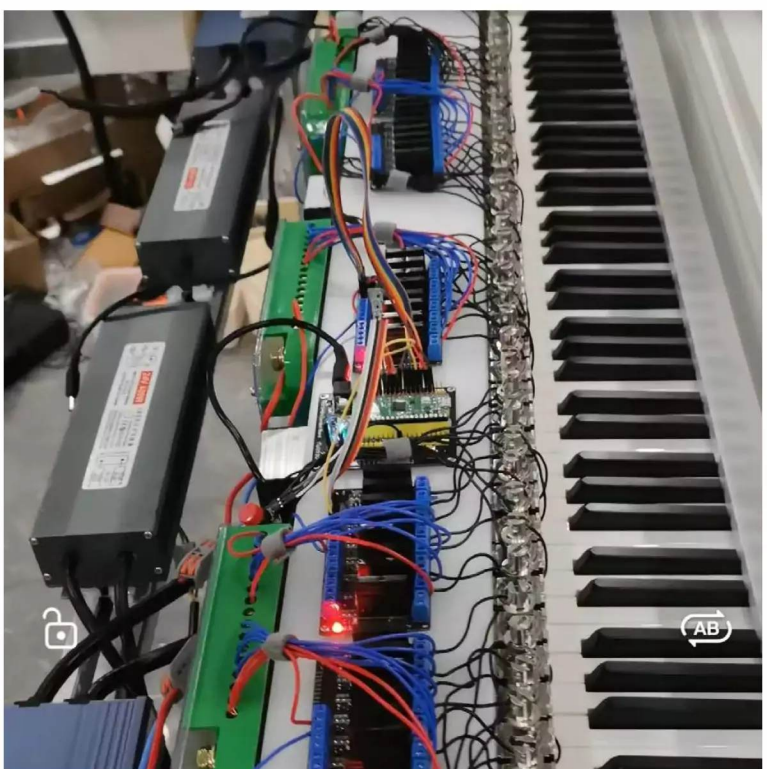
This Raspberry Pi Pico can play you a (complicated) ditty

Hansen Lv, who's 12 years old, dropped us a line to talk to us about his electronic piano player robot, powered by Raspberry Pi Pico.

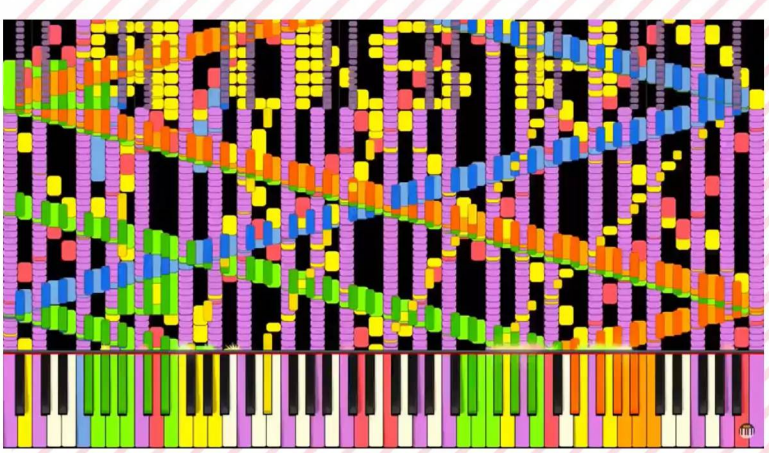
"Some music is quite fast and hard for beginners to play," Hansen wrote. "Some music has more than ten notes to play at the same time like *Rush-E* that people cannot play well... So, I made an electronic piano player using Raspberry Pi Pico to solve this problem."

Rush-E is a song that's impossible for humans to play, made as a sort of joke about music tutorials, that pianists then decided to try and actually play. We don't fully understand the whole saga, but we understand the key point: if it's too hard for humans to play, get a robot to do it.

Hansen tells us his build incorporates a series of aluminium alloy rods that can be moved with precision by Python code to play a real piano to the tune of *Rush-E*.



▶ The robot is more of an automated piano



▼ This looks confusing enough to us, so hopefully people got the joke

Crowdfund this

Raspberry Pi projects you can support this month

Frost-Bye Waterblock



The FrostByte Waterblock is a cooling solution designed specifically for Raspberry Pi enthusiasts and professionals who demand peak performance and reliability from their devices. Built with cutting-edge technologies, the FrostByte Waterblock ensures that your Raspberry Pi operates at optimal temperatures, even under the most intense workloads.

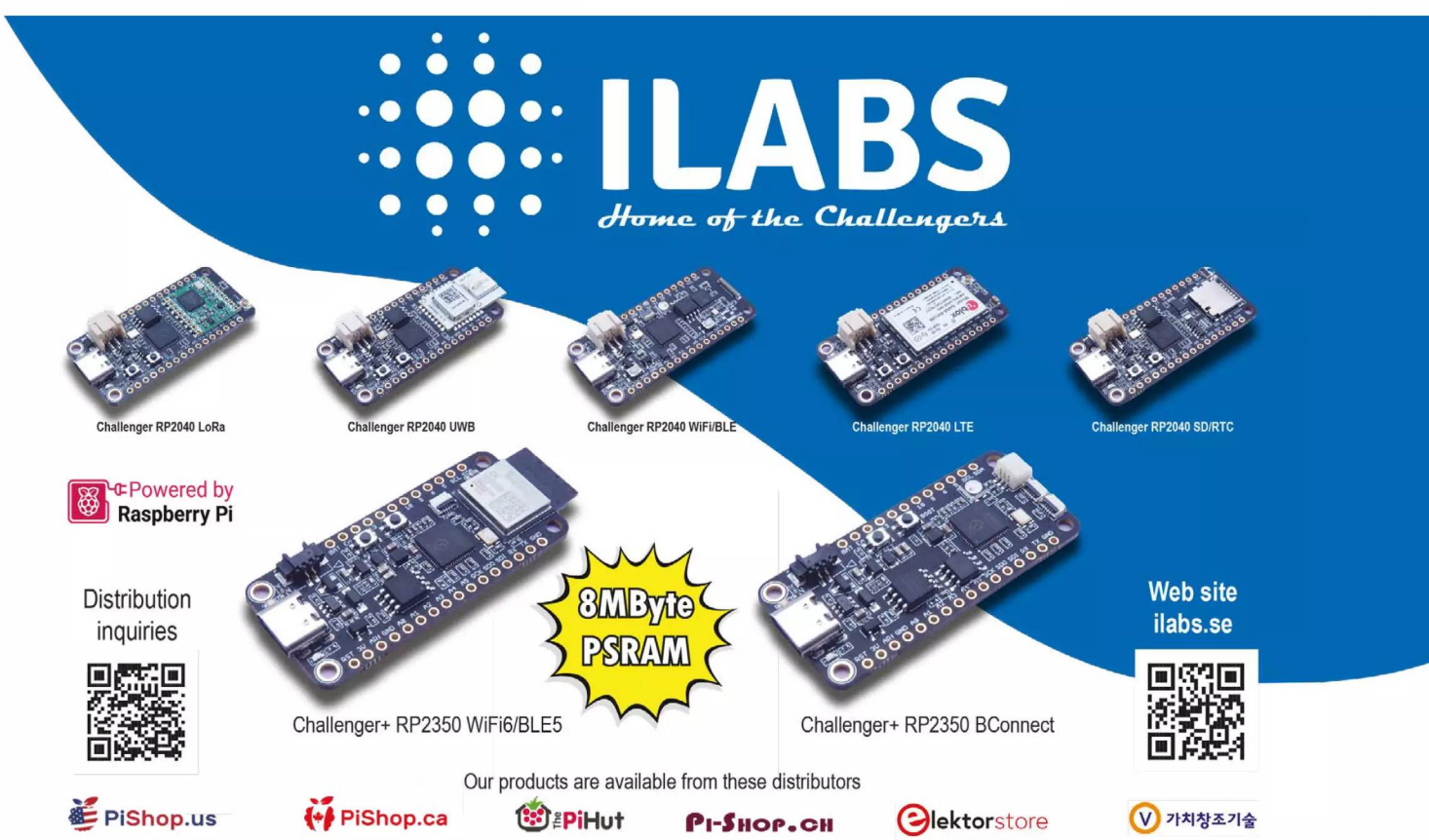
▶ **kck.st/3yh2h44**

CrowView Note



A portable monitor and keyboard that works like a dock for a Raspberry Pi (or a smartphone, or even other devices) to turn it into a full laptop. It has its own battery, so all you need is to supply a Raspberry Pi 5 and you're good to go.

▶ **kck.st/4dZkiDp**



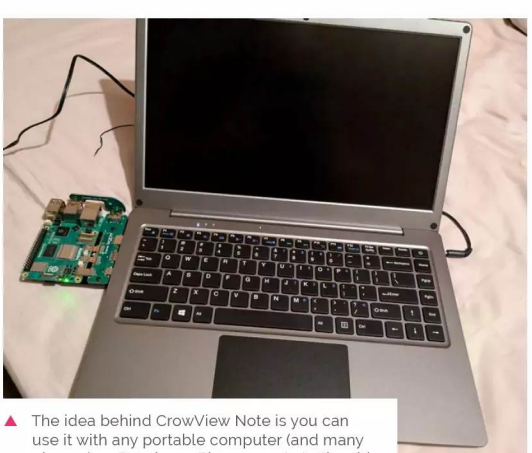
Your Letters

Portability

Are there any Raspberry Pi 5 laptops yet? I'd like a portable Raspberry Pi 5. Do I have to wait until a CM5 is released for this?

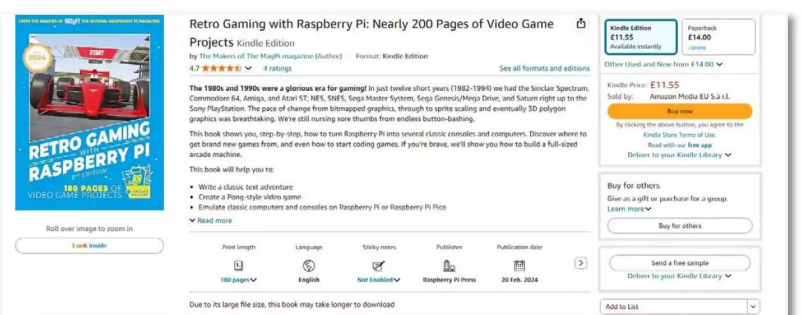
Ploy via Twitter

We've not seen any laptops or kits built around a Raspberry Pi 5 just yet, however CrowView Note just launched on Kickstarter. It's like a laptop dock/portable monitor and has special kit to connect a Raspberry Pi 5 to it, making it basically a Raspberry Pi 5 laptop. Check out the info in This Month in Raspberry Pi, and look out for a review next issue.



▲ The idea behind CrowView Note is you can use it with any portable computer (and many phones) so Raspberry Pi 5 connects to the side

▼ Our books are now available as ebooks on many stores



Digital books

I own *Code the Classics* 1st edition. Raspberry Pi Press offers a free PDF of it. I also have the first two editions of *Retro Gaming with Raspberry Pi*. Those are also available as a free PDF.

Soon I am going to get *Code the Classics* 2nd edition, *Code the Classics 2* and *Retro Gaming* 3rd edition.

None of these books are available as a free PDF (well, *Code the Classics 2* is not released yet, so that could explain that). Are you not releasing PDFs of your books any more? If not, how can I then get a PDF version of said books?

Peter via email

At the moment there's no PDF of our latest book releases, however you can buy a digital version from Google Play, Kindle, and Apple books. The PDFs of our previous releases remain free, and the magazine's three-week delay for a free PDF is still in place too. If this ever changes we'll let folks know!

Silver linings

It's a little disappointing to see *HackSpace* come to an end. I've been a subscriber since the very beginning and have genuinely enjoyed getting the magazine each month, along with *The MagPi*.

I appreciated how *The MagPi* concentrated on Raspberry Pi, while *HackSpace* explored all aspects of making. Regardless, I'm truly grateful for all the wonderful content and articles over the years, and I'm excited for a more extensive *MagPi* magazine.

Maarten via the blog

We've been very grateful to receive a lot of messages from folks who are both sad to see *HackSpace* go, and excited to see an expanded magazine featuring both it and *The MagPi*. To those wanting us to stay in print, that's our continuing goal for the future too. We hope you enjoy the new magazine!



▲ *HackSpace* lives on in the pages of the official Raspberry Pi magazine, *The MagPi*

Contact us!

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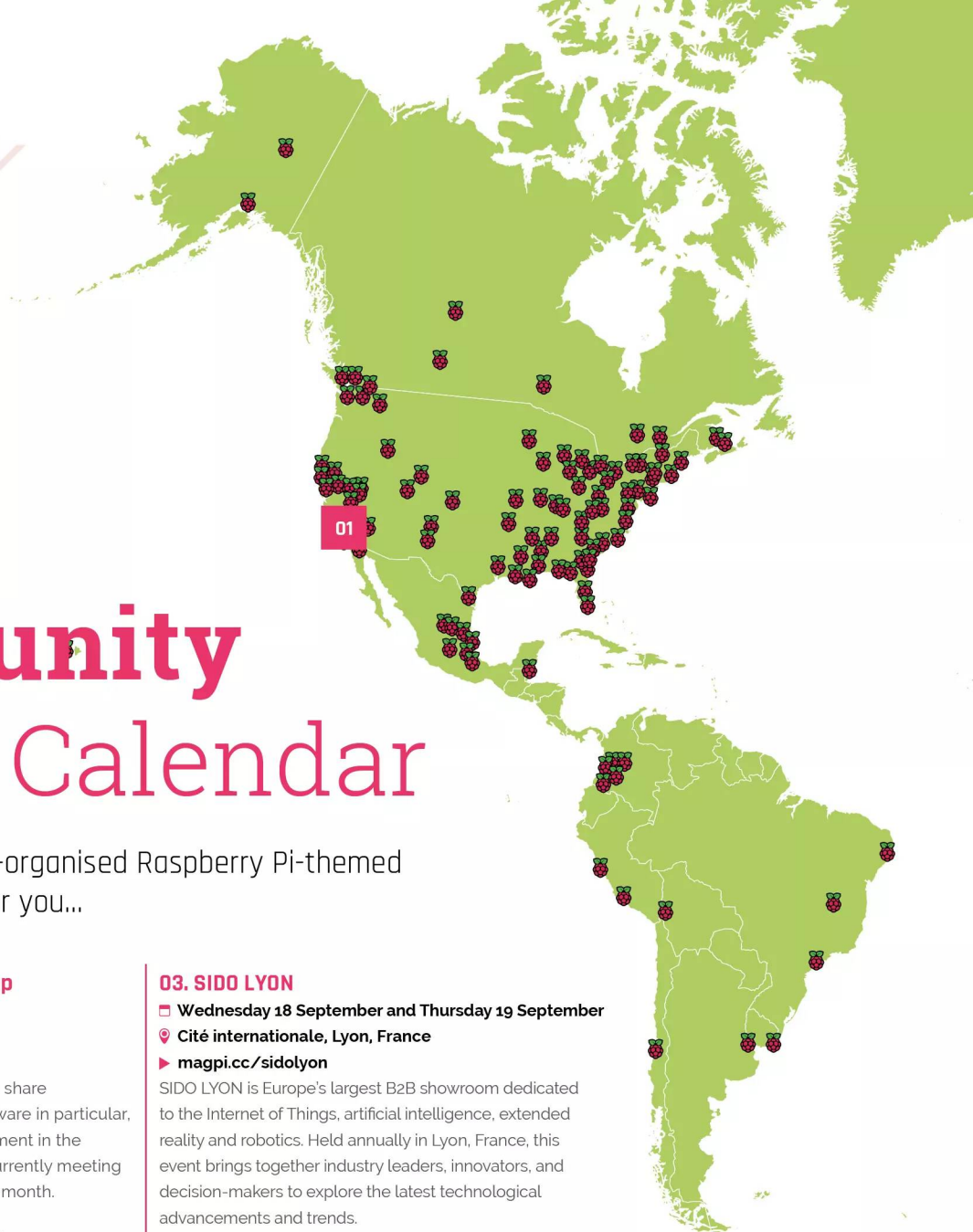


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Community Events Calendar

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

01. Riverside Raspberry Pi Meetup

Monday 9 September
3600 Lime Street, Riverside, CA, USA
magpi.cc/rrpm145

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

Riverside Raspberry
Raspberry Pi Users Group
Let your computer play in the real world!
www.meetup.com/Riverside-Raspberry

02. HYBRID Raspberry Pint

Tuesday 24 September
Online
magpi.cc/hrp145

At Raspberry Pint we share our digital making experiences. Most of our presentations are about building personal or professional projects with Raspberry Pi boards and other maker technology. We also welcome presentations about skills and techniques such as website building, PCB design, software development, 3D printing, soldering, etc. Occasionally, we have had presentations about artificial intelligence, big data, IoT, etc. and would love to hear about what you do in your hobby or professional life.

03. SIDO LYON

Wednesday 18 September and Thursday 19 September
Cité internationale, Lyon, France
magpi.cc/sidolyon

SIDO LYON is Europe's largest B2B showroom dedicated to the Internet of Things, artificial intelligence, extended reality and robotics. Held annually in Lyon, France, this event brings together industry leaders, innovators, and decision-makers to explore the latest technological advancements and trends.

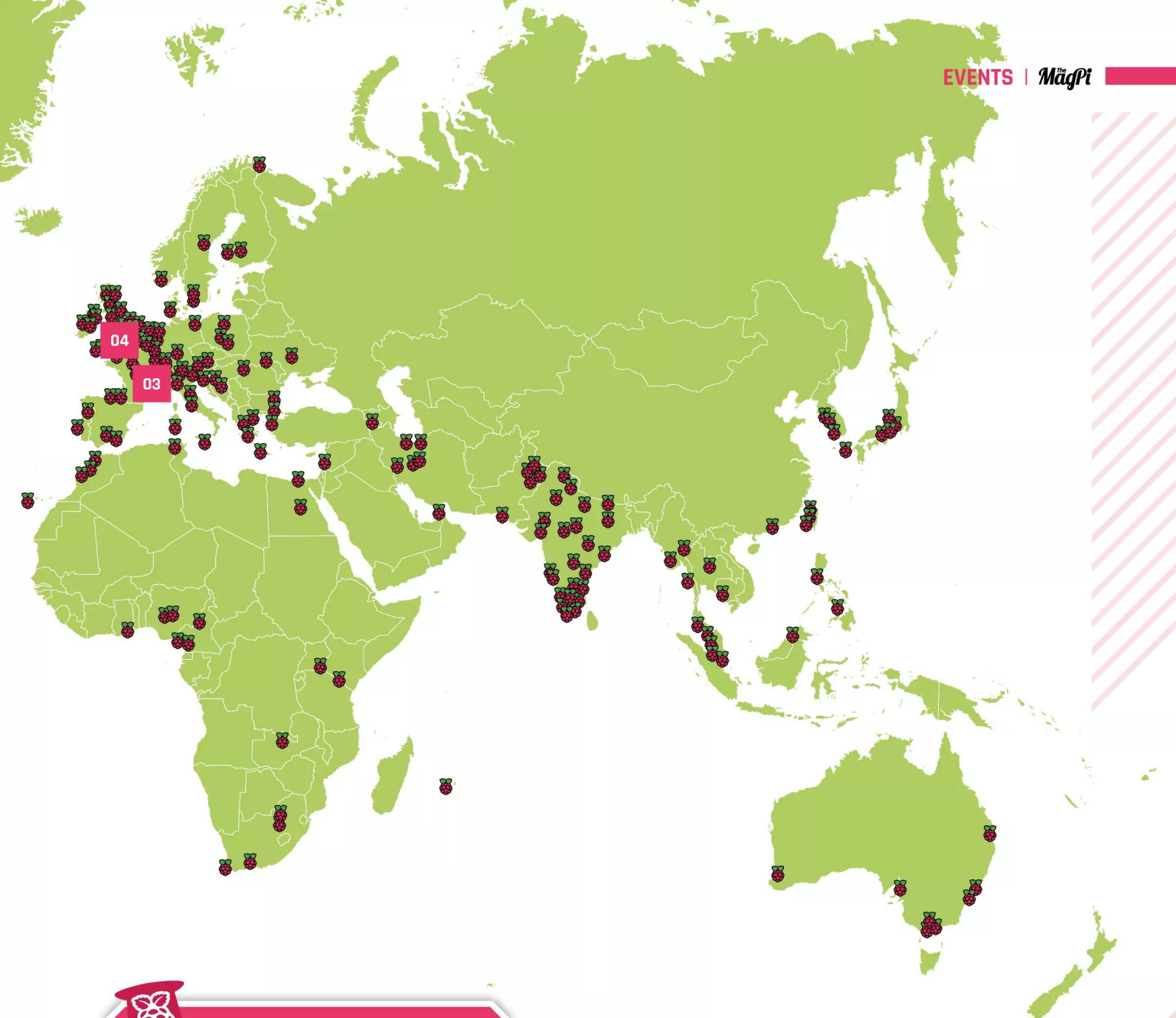


04. Southend Raspberry Jam Maker Meetup

Thursday 19 September
The Board Game Hut, Southend on Sea, UK
magpi.cc/srjmm145

Southend Raspberry Jam Maker Meetup is a monthly meetup for those who are interested in building hardware and software projects using Raspberry Pi hardware and want to join a friendly group of enthusiasts and makers. We welcome anyone from beginners to professionals. If you have any ideas for projects, talks or demos, we're especially keen to hear from you. Over 18s only.

FULL CALENDAR
Get a full list of upcoming community events here:
magpi.cc/events





Maker Faire Rome

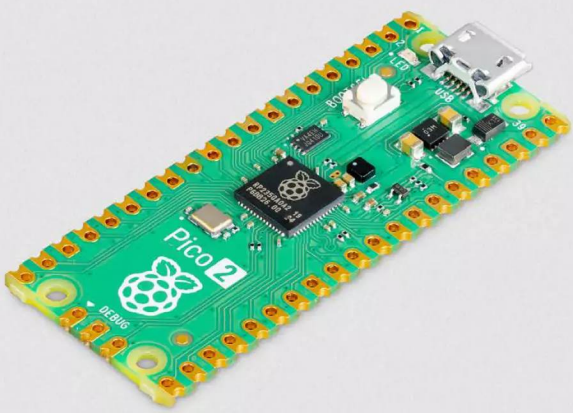
- Where Gazometro Ostiense, Rome, Italy
- When Friday 25 October to Sunday 27 October

"We're proud to partner with Raspberry Pi Approved Reseller Melopero to be at Maker Faire Rome again in 2024. Come and meet members of the Raspberry Pi team, learn about our latest products, and share what you've made with Raspberry Pi technology.

magpi.cc/mfr24

WIN 1 OF 20 RASPBERRY PI PICO 2

The latest and greatest microcontroller from Raspberry Pi is the powered-up Raspberry Pico 2 – you can read all about it on page 40, but we have 20 of them to give away in this month's competition



Head here to enter: magpi.cc/win | Learn more: magpi.cc/pico2

Terms & Conditions

Competition opens on **28 August 2024** and closes on **26 September 2024**. 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 (X) or any other companies used to promote the service.

Your FREE guide to making a smart TV



magpi.cc/mediaplayer

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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Welcoming **HackSpace**

HackMag? MagSpace? **Lucy Hattersley** on joining the tag team

This has been an eventful month for *The MagPi* magazine. The glorious news that Pico 2 and RP2350 could finally be shared with the world was slightly marred by our sister title – *HackSpace* magazine – shutting its doors.

But as one door closes another opens and the good news is that *HackSpace* is now becoming part of a larger version of *The MagPi*. We've added pages to this mag and slotted in projects, tutorials and articles from *HackSpace* magazine. Moving forward we hope to add features that are more *HackSpace*-esque although this month Pico and RP2350 have the spotlight.

From our perspective, this gives us a bigger and better magazine. It also opens up a new aspect of making that we haven't traditionally given as much thought to as *HackSpace*. While *The MagPi* magazine tends to focus heavily on Raspberry Pi products – it is "the Official Raspberry Pi magazine" after all – *HackSpace* covers a much wider range of electronic boards and even maker projects that feature little or no electronics. In particular, *HackSpace* features 3D printing, and it's fascinating to see features like Objet 3d'art make their way into *The MagPi*. And we love their tutorials and group tests.

Andrew Gregory, *HackSpace*'s Features Editor is now working on *The MagPi*, and this month he wrote up an excellent Pico 2 feature. We've also picked up a stable of *HackSpace* freelance writers who will be bringing their skills to our combined publication.

> HackSpace is now becoming part of a larger version of The MagPi

In the moment

Still: I feel for *HackSpace* readers. It's never easy when a magazine closes and we were rather hoping that *HackSpace* would continue alongside *The MagPi* forever. But magazines are often of the moment, even if they do get stored in The British Library for all time. I still miss *Wireframe* as well.

Ben Everard, the outgoing *HackSpace* editor wrote: "For the past six and a half years, we've poured our heart and soul into this great magazine. We've had a great time both building projects and seeing the amazing projects that you have built. In some ways, this is a happy time. By bringing *HackSpace* into *The MagPi*, we're continuing to give space for makers in print media, and securing this space for the future. This space for makers works both ways – it means there's space for you to learn and see the great projects others are making, and it also means there's space for you to teach and show off the great projects you're making. *HackSpace* always was a place both by makers and for makers, and as part of *The MagPi* it will continue to be so."

I do hope *HackSpace* readers who find themselves in *The MagPi*'s extension will feel at home. We're going to lengths to ensure that you are welcome, and that your magazine remains at heart – the same. It'll make everything better in the long run. We're easy to get in touch with via email or social media. So please let me know what you think.

AUTHOR

Lucy Hattersley

Lucy is the editor of *The MagPi* and has more RP2350 products to review than you'd ever believe. Her giant Tim Horton's mug of coffee is beyond reckoning too.

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HiPi.io

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