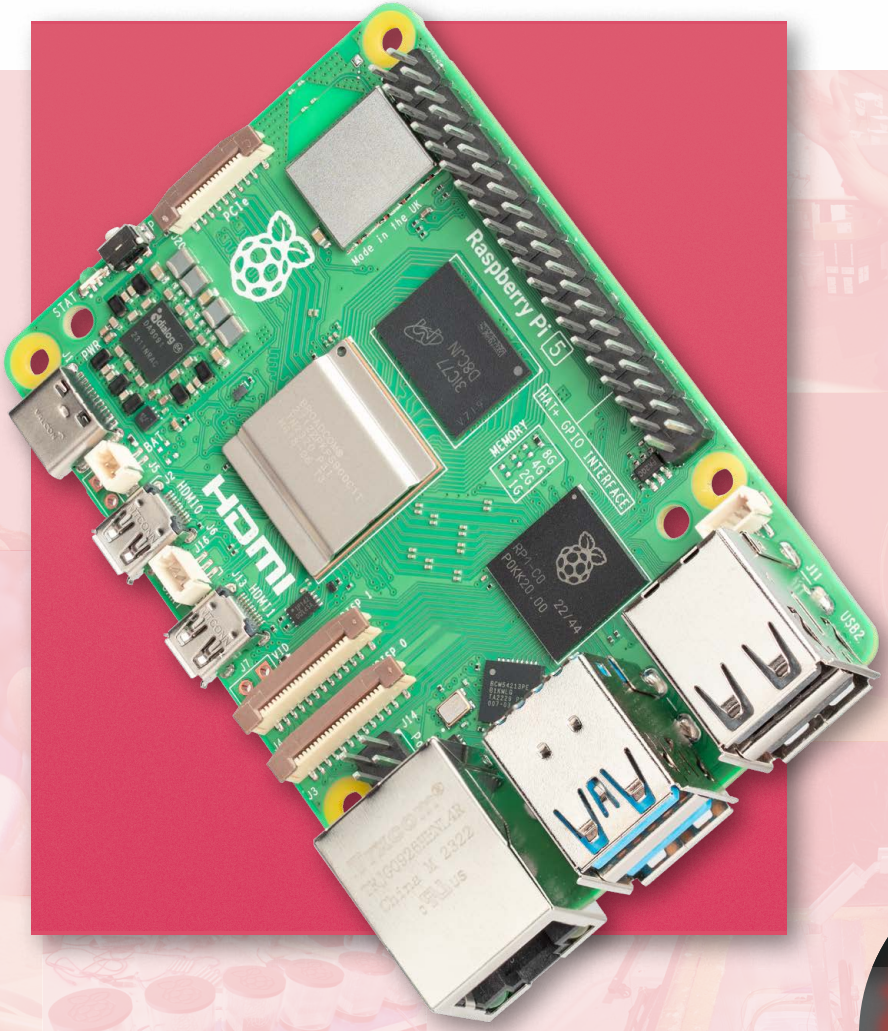
The official

Raspberry Pi Handbook

2026

200
INSPIRING PROJECTS!

- Robot explorers
- CoolCoral
- Andotrope
- Poetry cam
- Cave Mapping
- Pixie Clock
- Private cloud server





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

SFERALABS

Strato Pi Max XL and XS



Powered by Raspberry Pi

Modular Industrial Server

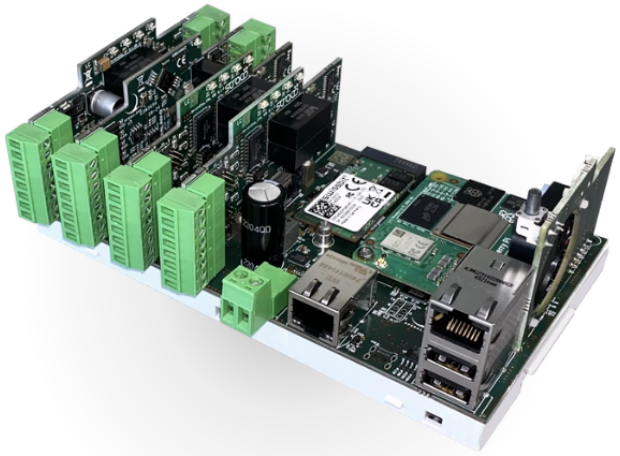
Powered by the **Raspberry Pi CM4** or **CM5** and **RP2040**

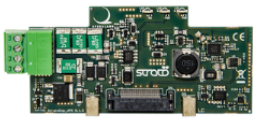
- Up to 4 X2 Expansion Boards
- Dual SD, eMMC and SSD storage options
- 2 x Ethernet ports
- 2 x USB ports with power control
- WiFi & BLE
- DIN rail mounting

Open Technology for the Industrial World

Long Term Availability, High Reliability and Support

X2 Expansion Boards





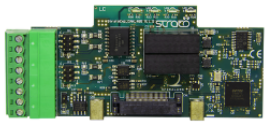
UPS



UPS with Supercapacitors



RS-232 and RS-485



CAN and Dual RS-485



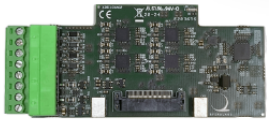
Quad RS-422 and RS-485



Cellular Modem Carrier



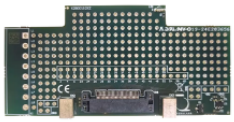
Industrial Analog Inputs



Industrial Analog Output



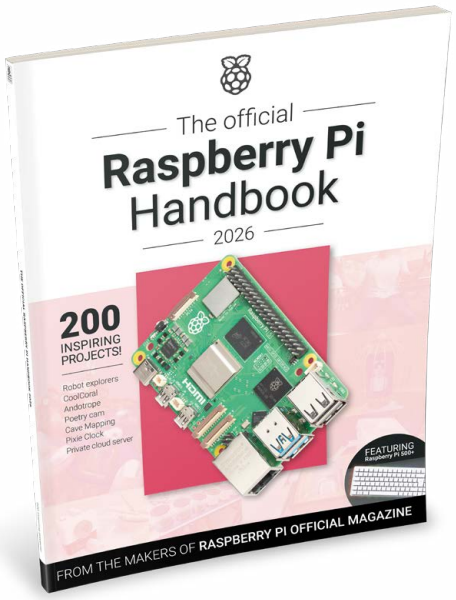
Industrial Digital I/O



Prototyping Board

www.sferalabs.cc

Welcome!



You may have noticed a change. This year's handbook has a new style of cover, which represents the graduation of *The MagPi* into *Raspberry Pi Official Magazine*. Same incredible, community-led articles; new wonderful design aesthetic. Although the articles in this book still have the same look as last year at least.

As well as big changes with the magazine, big Raspberry Pi products were released in the past year. Literally – Raspberry Pi 500 and Raspberry Pi 500+ are full desktop computers in a keyboard, acting as the successor to the wonderful Raspberry Pi 400. We think they're great and we have all the info you'll need on them within these pages.

500 aside, we've not forgotten about Raspberry Pi Zero, Pico, or even the standard models, and you'll find incredible projects and guides using all of them in this book. I think it's very exciting to cover them all.

I'll let you get to reading (and discovering!) then. I hope you enjoy your time here.

Rob Zwetsloot

Find us online

rpimag.co

Get in touch

magazine@raspberrypi.com

Editorial

Editor
Lucy Hattersley
lucy@raspberrypi.com

Features Editor
Andrew Gregory
andrew.gregory@raspberrypi.com

Features Editor
Rob Zwetsloot
rob@raspberrypi.com

Sub Editor
Phil King

Advertising
Charlotte Milligan
charlotte.milligan@raspberrypi.com
+44 (0)7725 368887

Design

Critical Media
criticalmedia.co.uk

Head of Design
Lee Allen

Designer
Sam Ribbits

Raspberry Pi Ltd
raspberrypi.com

Head of Design
Jack Willis

Designers
Sara Parodi
Natalie Turner

Illustrator
Sam Alder

Brand Manager
Brian O Halloran

Contributors

David Crookes, PJ Evans, Rosie Hattersley, Phil King, Sean McManus, KG Orphanides, Louis Wood

Publishing

Publishing Director
Brian Jepson
brian.jepson@raspberrypi.com

Director of Communications
Helen Lynn

CEO
Eben Upton

Distribution

Seymour Distribution Ltd
2 East Poultry Ave,
London EC1A 9PT
+44 (0)207 429 4000

Subscriptions

Unit 6 The Enterprise Centre
Kelvin Lane, Manor Royal,
Crawley, West Sussex, RH10 9PE
+44 (0)1293 312193
rpimag.co/subscribe
rpipress@subscriptionhelpline.co.uk

This magazine is printed on paper sourced from sustainable forests and the printer operates an environmental management system which has been assessed as conforming to ISO 14001.
Raspberry Pi Official Magazine is published by Raspberry Pi Ltd, 194 Cambridge Science Park, Milton Road, Cambridge, England, CB4 0AB. The publisher, editor, and contributors accept no responsibility in respect of any omissions or errors relating to goods, products, or services referred to or advertised in the magazine. Except where otherwise noted, content in this magazine is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0).

ISBN: 9781916868489
UPC: 070550041686 55

Contents





06
Raspberry Pi Starter Guide



12
Raspberry Pi 500+

20
Raspberry Pi Pico 2

Project Showcase

32 **CoolCoral project**
Keep coral cool for research

36 **Bechele 3.0**
A creepy, mouthy puppet

40 **sprinklR irrigation**
Automate watering your garden

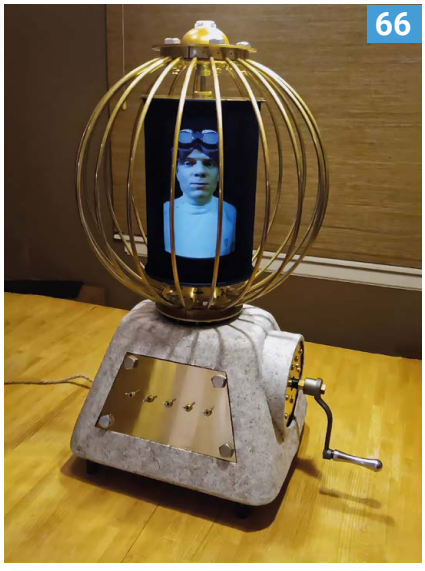
44 **Cat TV**
Gogglebox, feline edition

46 **Colour Word Clock**
A pracgical kit from teen makers

50 **The Dicemaster 2000**
Rolling initiative for the visually impaired

54 **Spin**
Mash up genres with the help of AI

58 **Puttr**
Practice putting with this smart game



62 **LinAmp**
A retro musical experience

66 **Gehn Imager Andotrope**
Riven's visual spectacle made real

70 **Poetry Camera**
Take a photo, make a poem

74 **Gugusse Roller**
Deluxe digitial restoration of film

78 **Portable Pi 84**
Inspired by chunky laptops from yesteryear

82 **VespAI**
Sort the wasps from the hornets

86 **Automatic pressure cleaner**
A robot that can clean your patio

88 **Pixie Clock**
Not a Nixie clock

90 **Smart Pill Dispenser**
Give carers peace of mind

92 **CatBot**
Safely feeding cats outdoors

94 **Bumpin' Sticker**
Honk if you recognise my now playing

98 **Adventure Time self-playing guitar**
Improving cosplay with a smart bass



102 **Floppy Disk Archiver**
Do copy those floppys

106 **Lawny**
A robotic lawnmower with a hint of Rick & Morty

110 **Cave mapping with Raspberry Shake**
A unique use for the earthquake monitor

Maker Guides

116 **Build a Raspberry Pi 5 media player**
Power up your HTPC with a Raspberry Pi 5

122 **Raspberry Pi 5 case group test**
The very best enclosures, tested thoroughly

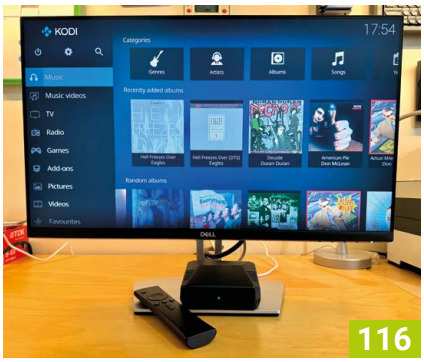
130 **Make a private cloud server**
Save on subs and improve your privacy

148 **Essential Electronics**
Basic components and simple circuits

156 **Robot explorers**
Get out in the world with these automatons

164 **Play retro horror classics on Raspberry Pi 5**
How to play scary games on Raspberry Pi

175 **Handheld gaming with Raspberry Pi**
How to play on the go, and make your own





Reviews and Resources

186 **Home Assistant Yellow**
Home automation made easy

188 **PiDP-10**
A modern take on a classic

190 **ArmPi FPV AI Vision**
A robot arm that can see

192 **Plasma 2350**
All-in-one LED control board

194 **PiDog**
A very smart dog

196 **10 amazing gaming accessories**
Level up your game time

198 **10 amazing Pico 2 builds**
Showing off what Pico 2 can do

200 **10 amazing Raspberry Pi monitors**
The best displays for you



Get started with your Raspberry Pi

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

By Phil King



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

Raspberry Pi models

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

Raspberry Pi 500+ / 500 / 400

rpimag.co/500plus | rpimag.co/rpi500
rpimag.co/rpi400



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

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

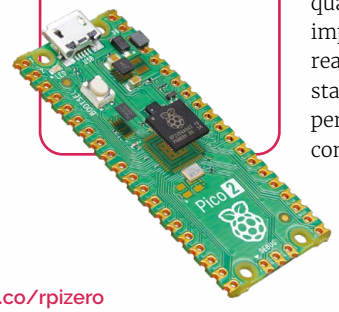
Raspberry Pi 400 is based around the same quad-core 64-bit processor as Raspberry Pi 4, with 4GB of RAM. Raspberry Pi 500 features a higher-speed Broadcom BCM2712 processor for even better performance, along with a VideoCore VII GPU and 8GB of RAM. 500+ is beefier still – check out page 12

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

Raspberry Pi Pico

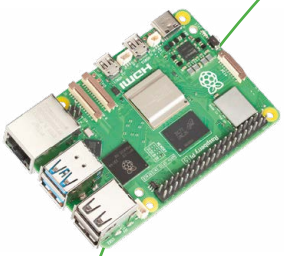
Not a fully fledged computer, this is a microcontroller. Measuring just 21 × 51mm, it's designed for use in physical computing projects. You can connect electronic circuits to its twin GPIO headers. It can be programmed by connecting a computer via USB.

Raspberry Pi Pico 2 has a more powerful processor.



Raspberry Pi 5 & 4

rpimag.co/raspberrypi5 | rpimag.co/raspberrypi4



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

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

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

Raspberry Pi Zero / W / 2 W

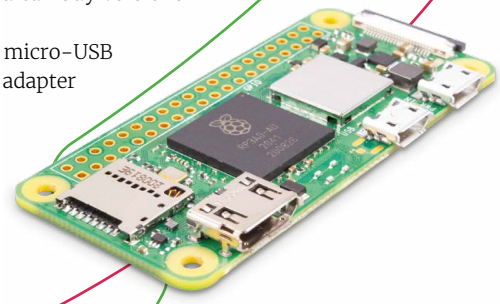
rpimag.co/rpizero2w | rpimag.co/rpizerow | rpimag.co/rpizero

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

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

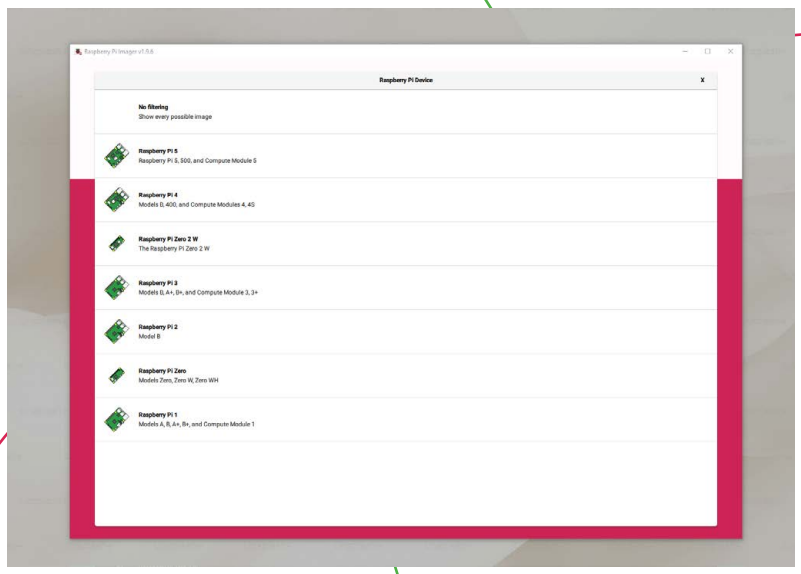
While the standard boards come with an unpopulated 40-pin GPIO header requiring users to solder on a set of male pins, you can buy versions with the pins already attached.

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



Set up your Raspberry Pi

Install an OS and connect everything



▲ Filter OS versions by model in Raspberry Pi Imager

▼ Select the top option in the list of operating systems

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

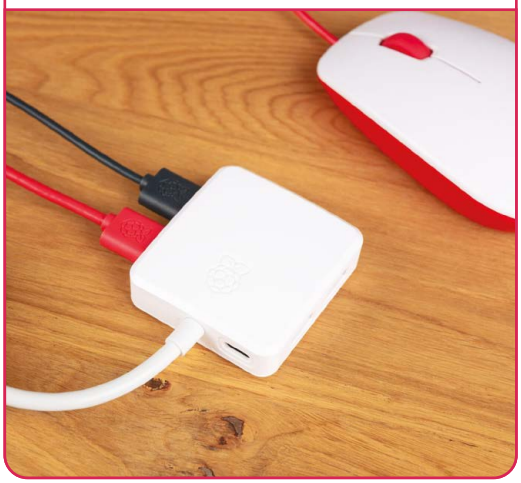
If you bought the Raspberry Pi 500+ (or 400/500) Personal Computer Kit, you'll already have Raspberry Pi OS preloaded onto the internal SSD. If not, you'll need to write the OS to a microSD card. A high read/write speed is recommended, along with a capacity of 32GB or more, as it will also act as Raspberry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

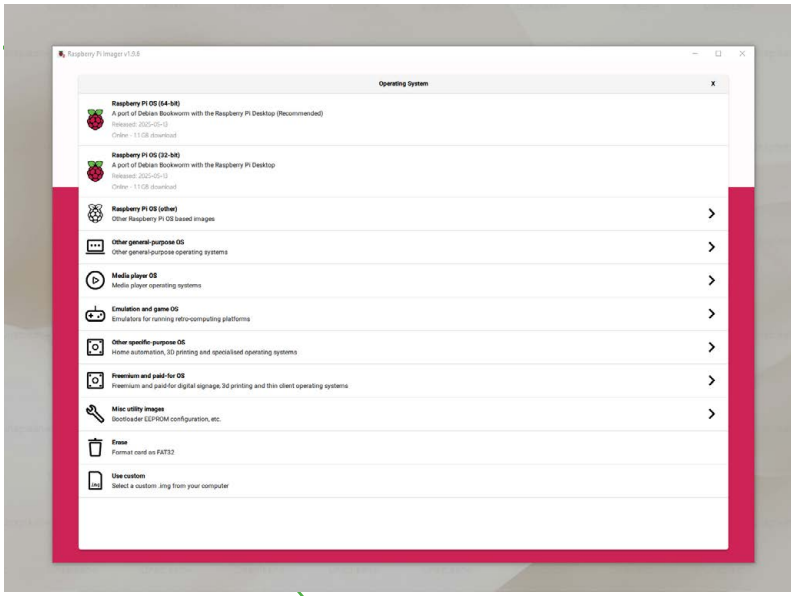
The easiest way to write an OS to the card is to use the official Raspberry Pi Imager tool (**rpimag.co/imager**), which is available for macOS, Windows, and Raspberry Pi computers. In Imager, you can click on 'Raspberry Pi Device' to filter the OS versions for your model. Then click 'Operating System'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

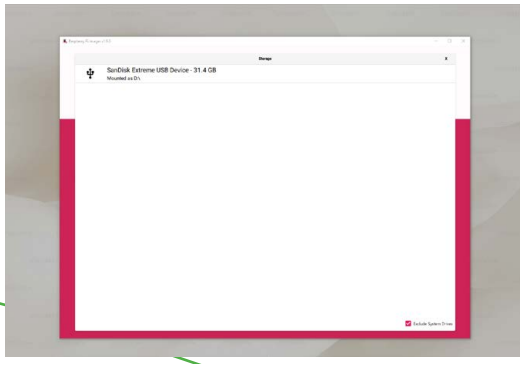
Then click on Next and you'll be asked if you want to apply OS customisation settings; click 'Edit Settings' and you may be prompted to prefill your

USB Hub

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



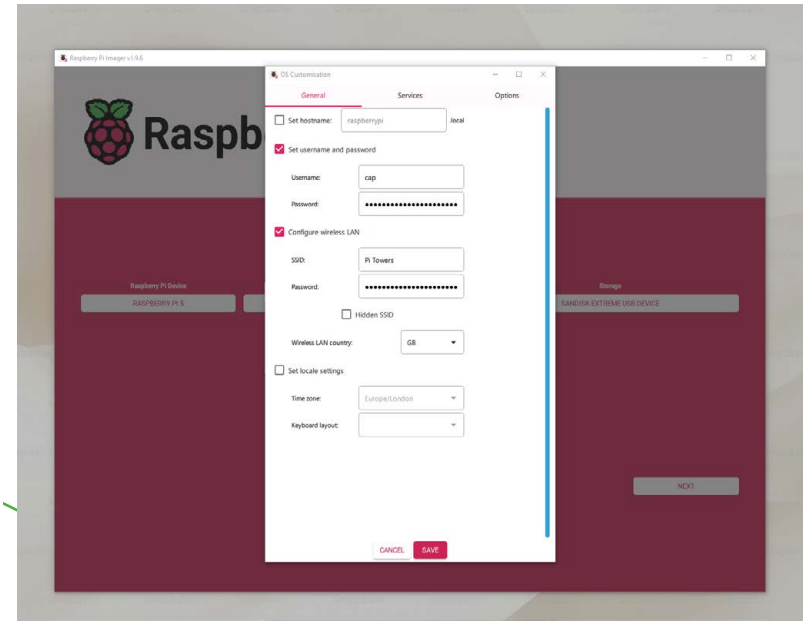




▲ For 'Choose Storage', select your microSD card

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

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



▲ Add a Wi-Fi connection in OS Customisation settings

CONNECT IT UP

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

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

Finally, you'll need a suitable power supply – for this you should use an official 45W USB-C Power Supply (**rpimag.co/psu**).

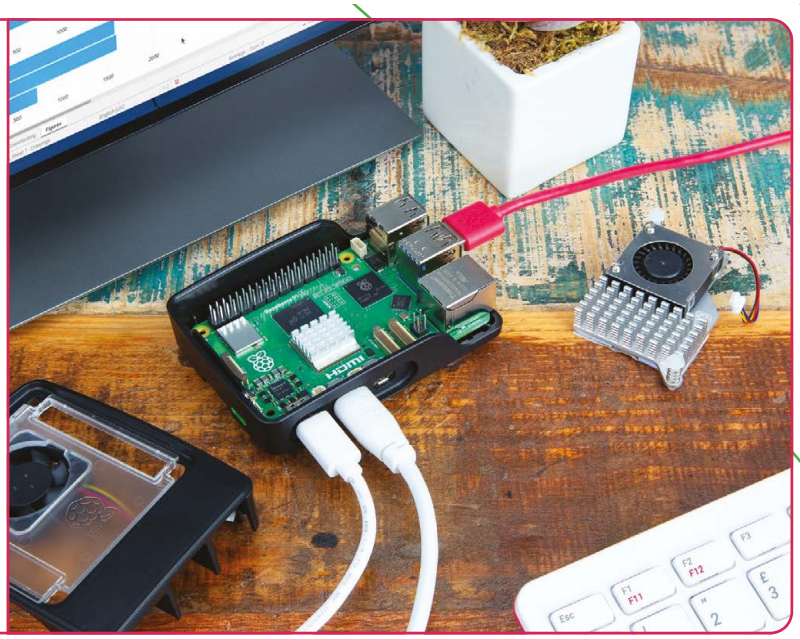
With everything connected and the microSD card inserted, turn on the power. Once Raspberry Pi OS boots up, you'll be greeted by its Welcome Wizard, where you can configure a few settings before you start using the OS. It will also give you the option of installing software updates before prompting you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

Raspberry Pi 4 & 5 setup

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

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

For both models, you can use the 45W USB-C Power Supply (**rpimag.co/psu**) again.



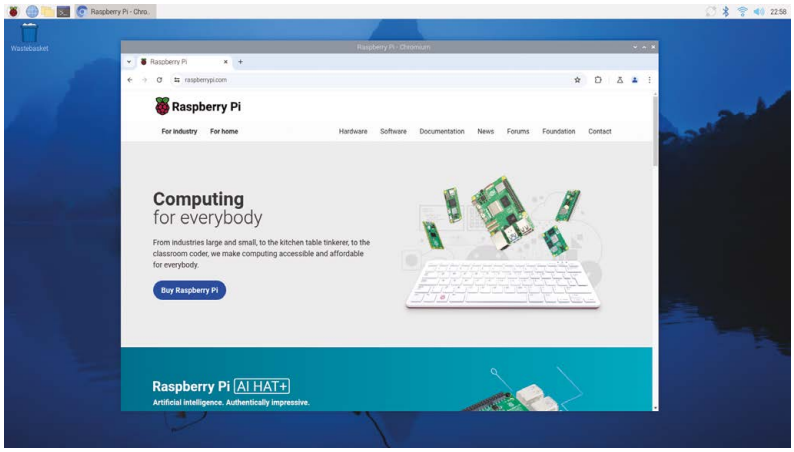
Desktop computing with Raspberry Pi

You can use your Raspberry Pi as a standard desktop computer

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

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

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



▲ Browse the world wide web with Chromium

INSTALLING SOFTWARE

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

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

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

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

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

Shutting down

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

OFFICE WORK

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

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

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

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

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

Draw: An illustration program for creating pictures and diagrams.

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

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

Coding and digital making

Learn to code and start creating your own projects

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

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

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

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

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

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

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

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

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

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

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

Raspberry Pi projects

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

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

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

Smart home
Manage your smart home devices and set up custom automations. The most popular platform is Home Assistant (**home-assistant.io**), a free, open-source operating system. To learn more, check out our 'Home Automation Made Easy' guide in *Raspberry Pi Official Magazine* issue 154: **rpimag.co/154**.

Raspberry Pi 500+

The **dream machine** is **here**.
Master physical computing with a mechanical keyboard, built-in SSD, 16GB RAM, 2.4GHz Arm processor, and GPIO.
Uncompromising performance, perfectly tactile.

By **Lucy Hattersley**



We are pleased to finally reveal the latest Raspberry Pi computer: 500+. This is the machine we have been waiting to share for over a year. It offers "uncompromising performance, perfectly tactile."

In the words of its engineers: This is the "dream machine". And this is the one that the editorial team want to use to code and write with.

Raspberry Pi 500+ puts the power of Raspberry Pi into an ergonomic and tactile mechanical keyboard with 16GB of RAM and a 256GB NVMe SSD. If you've ever wanted a modern-day Linux machine that you can plug in and start using for product development, coding, circuit building, and engineering, this is the perfect computer.

There are no compromises with Raspberry Pi 500+. The mechanical keyboard features Gateron KS-33 Blue keys with Cherry MX-style switches; the keys are low-profile with the top half of each key backlit. It is a 75% keyboard layout, which is our preferred layout, and offers the perfect balance between size and functionality. It's a clickable joy to type on.

Inside is a quad-core 64-bit Arm processor paired with 16GB RAM and a 256GB NVMe SSD with Raspberry Pi OS pre-installed.

We've been using 500+ at work for a while now, slowly phasing out our laptops and migrating to it for writing, research, and coding. It's a pure powerhouse and is a wonderful computer to use. Raspberry Pi OS is lightning fast and Linux is the best operating system around.

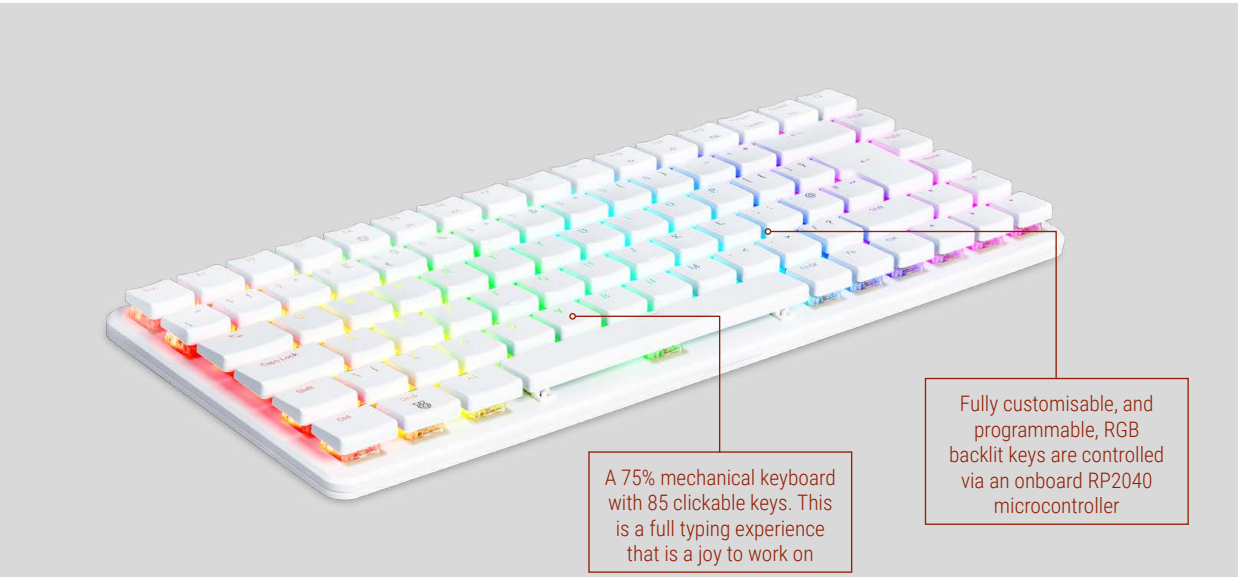
So, if you're looking for a seriously fun computer that's a coding and development control centre with a wonderful keyboard, fully upgradable and repairable, with a host of features that you just don't find on other computers, then Raspberry Pi 500+ is the one for you.

There are no compromises with Raspberry Pi 500+

SPECIFICATIONS

- Quad-core 64-bit Arm Cortex-A76 processor
- 16GB LPDDR4X SDRAM
- Integrated 256GB NVMe SSD with Raspberry Pi OS pre-installed
- Opening tool included for access to SSD (also requires screwdriver, not included)
- 2 × micro HDMI ports (supports up to 4Kp60)
- 2 × USB 3.0 ports
- 1 × USB 2.0 port
- Gigabit Ethernet port
- microSD card slot
- Horizontal 40-pin GPIO header
- 802.11b/g/n/ac Wi-Fi
- Bluetooth 5.0
- 5V DC via USB-C connector
- 85-key mechanical keyboard with clicky switches
- Replaceable keycaps (keycap puller included)
- Per-key programmable RGB LED backlighting

This is the *dream* machine



The clicky keyboard

Undoubtedly the star of Raspberry Pi 500+ is the mechanical keyboard. This provides a much more tactile experience than the chiclet-style keyboard found on a regular Raspberry Pi 500. Giving Raspberry Pi a mechanical keyboard makes it ideal for programmers and office workers who want the best keyboard around. It makes Raspberry Pi 500+ a unique experience that offers powerful desktop computing in a small package with a great keyboard.

A huge amount of time went into developing and determining the perfect keyboard for Raspberry Pi.

The keycaps are a custom in-house design by John Cowan Hughes. "We had a few different designs and took a poll," says Simon Martin, Senior Principal Hardware Engineer at Raspberry Pi. The keyboard has a flat, and low, profile, with a tapered edge at the bottom of each key.

The keycaps can be replaced to a design you prefer (see 'Change the keycaps', overleaf).

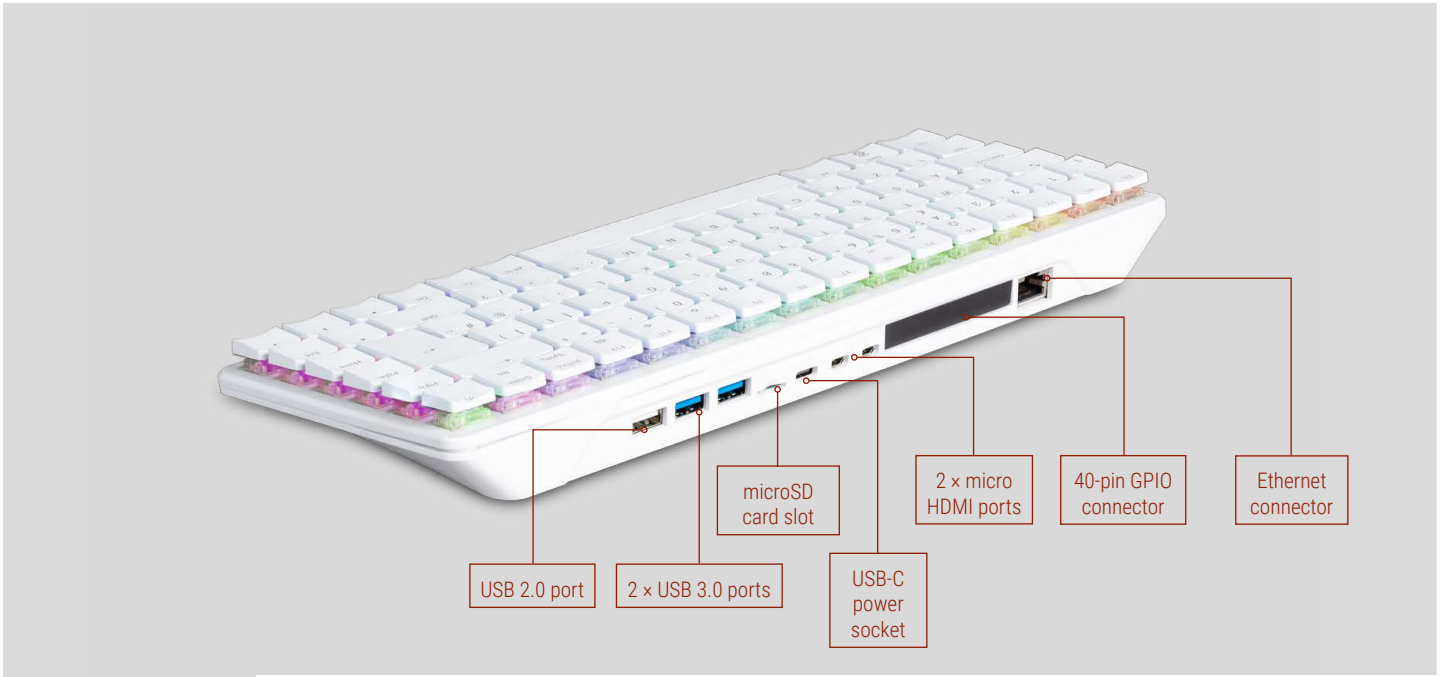
The switches below are Gateron Blue. This is a version of the classic Cherry MX Blue switches which are famous for a tactile bump and classic click noise. It has a sound like a typewriter key that is adored by writers, coders, and gamers.

These Blue-style switches are distinct from Brown and Red counterparts. Brown switches are tactile but have a gentle bump halfway down, which removes the click; Red switches have a linear switch with no tactile feedback or click at all – they are quiet but feel squishy.

Mechanical switches are usually a matter of taste, but almost everyone we know prefers Blue keyboards – although Blue switches can be quite conspicuous.



▼ Around the back, we can see a range of useful ports



Light it up

As well as being mechanically minded, the new keyboard has fancy RGB lighting. Underneath each key sits an RGB LED that can light up the keyboard in different patterns. Pressing **FN+F4** cycles through a range of keyboard patterns:

- Pure white
- Pure red
- Rainbow
- Cycle rainbow
- Heat map
- Single key press
- Off

Pressing **FN+F5/F6** adjusts the brightness of the keyboard backlighting.

Get started: raspberrypi.com/500-plus

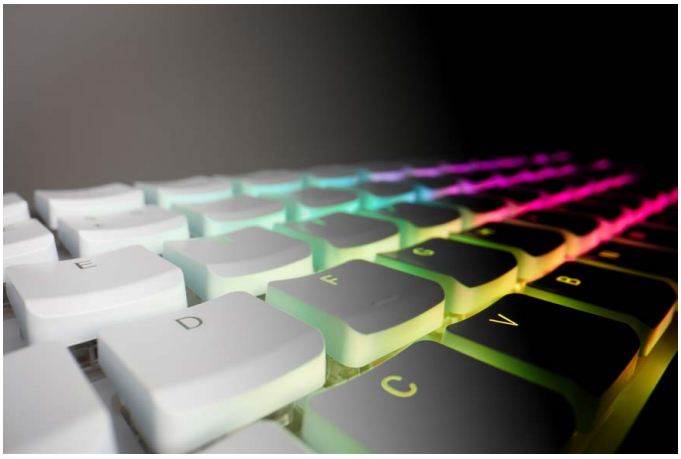
Keyboard variants Raspberry Pi 500+ is available at launch in the following keyboard variants: • UK • US	These keyboard variants will be available in the following weeks: • Spanish • Nordic • German • Japanese

Program the keyboard RGB lighting

Inside Raspberry Pi 500+ sits an RP2040 microcontroller, used to control the keyboard and lighting. This makes it possible to reprogram the keyboard and lighting and create your own custom light displays.

As a demonstration, the team has developed a keyboard light version of Flappy Bird that you can play using the Raspberry Pi 500+ keyboard. This program, written in Python, can be uploaded to RP2040 inside Raspberry Pi 500+.

We will have an exploration of programming the keyboard and recreating Flappy Bird on it in a future edition.



▼ Colour us impressed by the RGB lighting



▲ The keycap design used in Raspberry Pi 500+

Change the keycaps

Raspberry Pi 500+ comes with a key remover tool that is used to remove and replace the keycaps.

Raspberry Pi 500+ keycaps are a custom design and don't conform exactly to any of the standard profiles. Keycaps come in different profiles, such as:

- **OEM**. These are the default shape found on most factory-made keyboards.
- **Cherry**. Similar to OEM, but shorter.
- **Spherical All Row (SA)**. These are taller, with a 1970s retro vibe.
- **DSA (Double Shot ABS)**. Short, flat, and round. Most importantly, every row has the same shape.
- **XDA**. Similar to DSA but with a larger, flatter top surface.
- **MT3**. Very tall keycaps with a distinctly retro feel. As found on old terminal keyboards.

Note that most sets won't have a power button, and the volume and RGB keys won't be labelled. So you'll have to remember which function keys to use. The quality of RGB lighting is also dependent on the keycaps.

The keycap remover tool is easy to use. Simply place it under the edges of the keycaps, gently squeeze together to grasp the keycap, and pull it gently up. The keycap will pop off, revealing the mechanical switch underneath. To refit it, simply push the keycap back down and it will clip back into the switch.

▼ Using the remover tool to change the keycaps



NVMe M.2 SSD

Moving deeper down from the keyboard, we find the other stars of the show. The integrated M.2 NVMe SSD is connected to the motherboard via a PCIe interface and is easily upgradable.

This provides the same kind of speed boost that using an M.2 HAT and SSD with Raspberry Pi 5 does, and is vastly faster than using a stock microSD card (although note that a microSD card slot is also provided – which is incredibly useful for backup and quickly prototyping alternative operating systems).

By default, Raspberry Pi OS uses PCIe Gen 2, and you can gain a further speed boost by switching to PCIe Gen 3. To do so, open Terminal and enter:

```
$ sudo raspi-config
```

Then select `6 Advanced Options` > `A9 PCI Speed`.

Choose `Yes` to 'Would you like PCIe Gen 3 to be enabled?'

Choose `Finish` and `Yes` to the option to reboot your Raspberry Pi OS. When the operating system restarts, you will be running Raspberry Pi 500+ with PCIe Gen 3 enabled, which offers roughly twice the SSD speed. You can test the speed before and after using the Raspberry Pi Diagnostics app (found under menu > Accessories). The SD Card Speed Test

option is designed to check if microSD cards are fast enough for Raspberry Pi, but will also speed-test the internal SSD. Click Run Tests.

Here are our results:

PCIe Gen 2

```
seq-write;0;0;420776;102
seq-read;442064;107;0;0
```

PCIe Gen 3

```
seq-write;0;0;799219;195
seq-read;853889;208;0;0
```

	PCIe Gen 2	PCIe Gen 3
Write (MB/s)	411	780
Read (MB/s)	432	834

Raspberry 500+ vs Raspberry 500

Of course, Raspberry Pi 500+ isn't the only option and Raspberry Pi 500 remains available. This previous model has some advantages. While some people might love the clacky nature of the mechanical keyboard, an office full of the chiclet-style keys found on Raspberry Pi 500 will be more amiable to the ears.

Likewise, the lack of backlit keyboards can be seen as a benefit in some low-light environments and a sealed unit may be better for some office environments (although the microSD card is easily removable). The 500 has a Kensington lock, which is useful for physically restraining the movement of the device.

Still. There's no getting away from the fact that Raspberry Pi 500+ is a substantial upgrade and – to our eyes and hands at least – the one we want to use. Here is a handy guide to some of the differences we've spotted:



▲ The SSD inside Raspberry Pi 500+

500	500+
2.4GHz CPU	2.4GHz CPU
8GB RAM	16GB RAM
microSD card slot	256GB M.2 NVMe & microSD card slot
Tactile keyboard	Mechanical keyboard
No backlight	RGB backlight
10 Function keys (11, and 12 as Fn alternatives)	12 Function keys
No media keys	Separate media keys (Volume, brightness)
Power LED light	Power button with LED
Page keys with arrows	Dedicated PgUp, PgDn, Home, End keys
Fn on left	Fn on right
Sealed unit	Screw access with spudger included
Kensington lock	No Kensington lock



▲ Underside of a 500+, along with useful tools

Getting inside

Staying true to the maker ethos, Raspberry Pi 500+ is easy to get into. There are five pan-head Pozi cross-head screws on the back of Raspberry Pi 500+ that can be easily removed.

Then a coin slot located on the plastic case underneath the space bar can be accessed, using the supplied spudger. Move the spudger around the line in the case to separate the keyboard from the lower case.

Gently lift up the keyboard and remove the cable connecting the two. Use the spudger to lift the black plastic retaining clip on the ZIF connector (Zero Insertion Force) on either the underside of the keyboard or the mainboard.

The SSD in our Raspberry Pi 500+ is a 2230. Your model may come with a larger 2280 size SSD. Raspberry Pi 500+ accepts the following sizes:

- 2230
- 2242
- 2260
- 2280

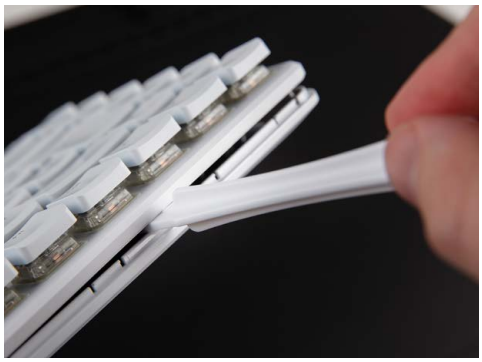
The default size is 256GB and you can easily upgrade this to a larger (or smaller) storage size. Remove the screw that holds the M.2 NVMe SSD in place and then gently ease it out. Now fit your replacement M.2 NVMe SSD in place and use the screw to secure it. Make sure the SSD is lined up with the groove in the screw so that it sits level.

CUSTOM SCREW

The SSD screw is a custom design by Raspberry Pi. Normally these screws are found on the underside, but Raspberry Pi wanted the drive to be accessible without going underneath the board.



◀ Raspberry Pi 500+ is easily accessible with five standard screws



◀ A spudger is included to get inside the case

Pricing and options	
	Raspberry Pi 500+ only **$200**
	Raspberry Pi 500+ Kit **$220** • Raspberry Pi 500+ • The Official Raspberry Pi Beginner's Guide • Raspberry Pi Official Mouse 2 • Raspberry Pi 27W USB-C Power Supply • Official micro HDMI to HDMI cable



▶ Flipping the keyboard up to take a look inside

Gently lift up the keyboard and remove the cable

ELECTROSTATIC PROTECTION

You will see a small pad fixed to the metal plate. Its primary function is to help with electrostatic discharge (ESD) protection, ensuring that static electricity is safely discharged and does not damage the keyboard's internal electronics.

Going deeper

Once you have flipped the keyboard off the top of Raspberry Pi 500+, you will see the metal head spreader beneath. This can also be removed to provide access to the mainboard.

You will find inside the plastic light port blocker which, as the name suggests, blocks the light from the RGB keyboard from escaping out of the ports at the rear.

On the mainboard you will find the CPU, 16GB RAM (not upgradeable, sadly), and the connections. It is essentially a Raspberry Pi 5 transformed into a size suitable for the case of Raspberry Pi 500+.

Keen eyes will notice the PoE (Power over Ethernet) circuit that is unpopulated. While those with sharp soldering skills may be able to get PoE installed, this isn't planned as a standard feature and 500+ isn't qualified for PoE.

There is a J5 connector for a power cell battery if you want to add time permanence to your 500+. And there is a UART which can be used to obtain early boot stage information.

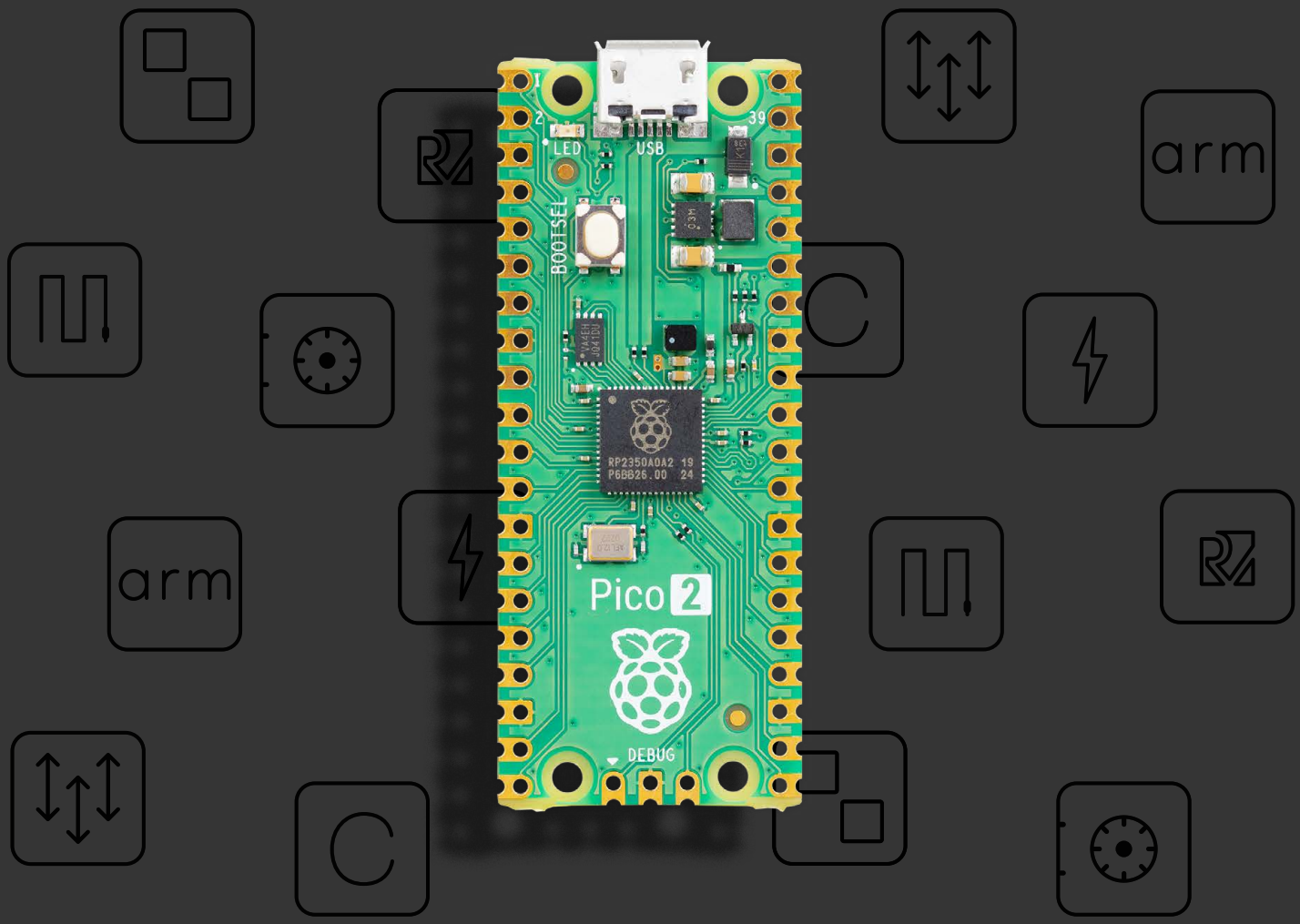
Mouse 2

The eagle-eyed might have spotted the new Mouse 2. This looks the same as the standard Raspberry Pi Mouse, but has redesigned innards and a new all-white design (instead of red and white). The sensor and performance remain as excellent as before. There is also going to be a black model of Mouse 2 available.

rpimag.co/mouse



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

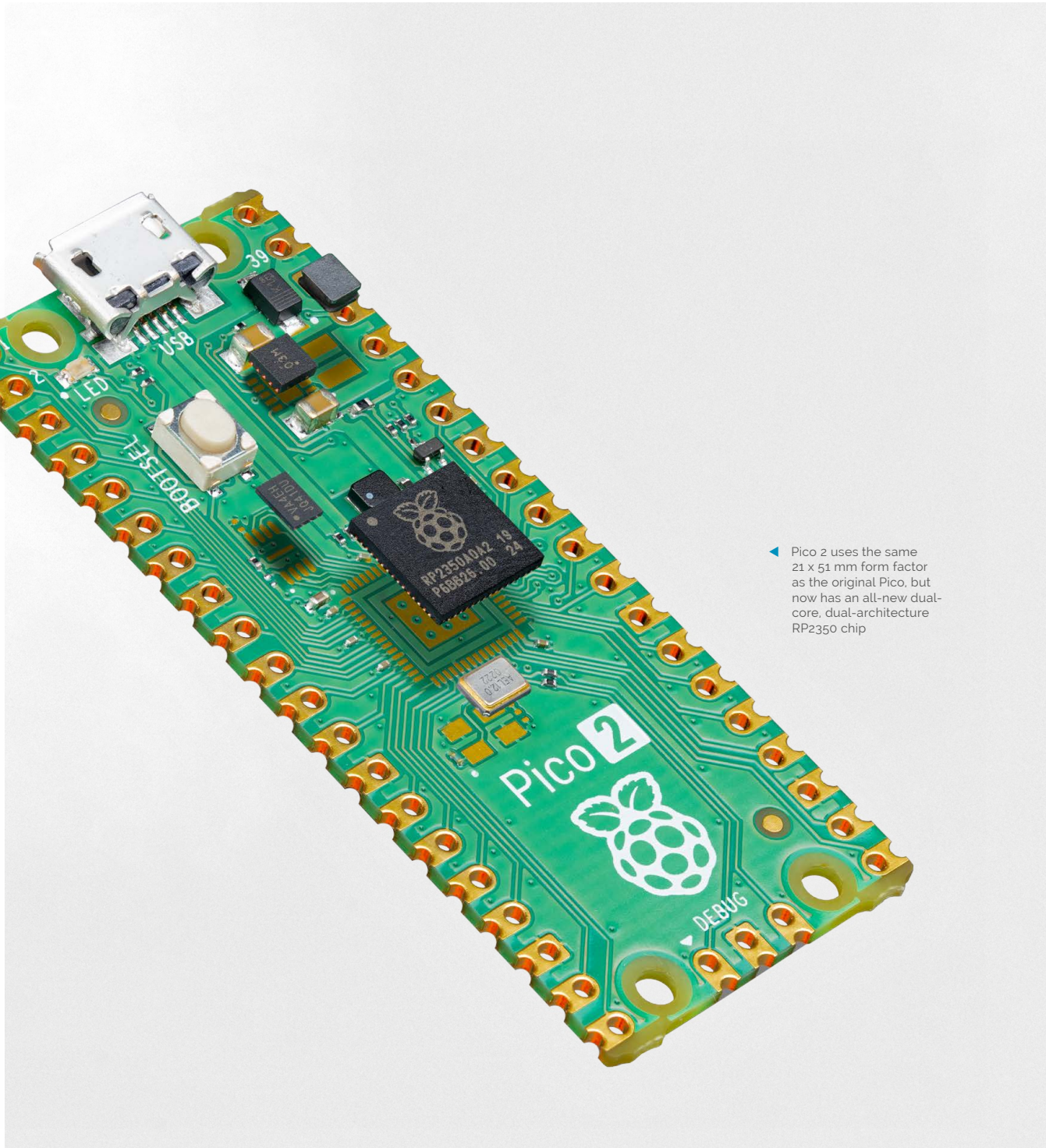
Memory
520 KB on-chip SRAM;
4 MB on-board QSPI flash

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

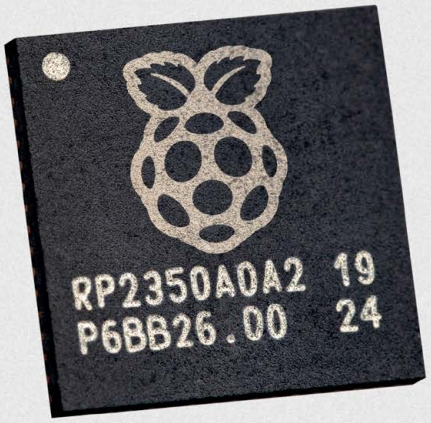
Peripherals
- 2 × UART
- 2 × SPI controllers
- 2 × I2C controllers
- 24 × PWM channels
- 1 × USB 1.1 controller and PHY, with host and device support
- 12 × PIO state machines

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?

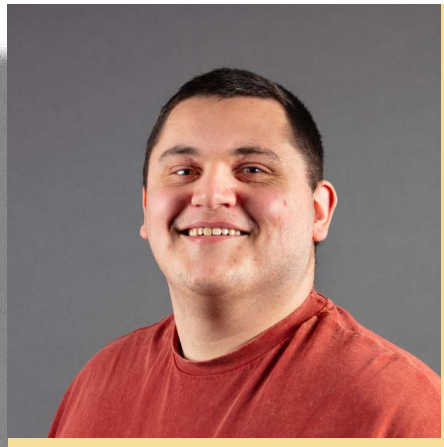
R P 2 3 5 0

- **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?

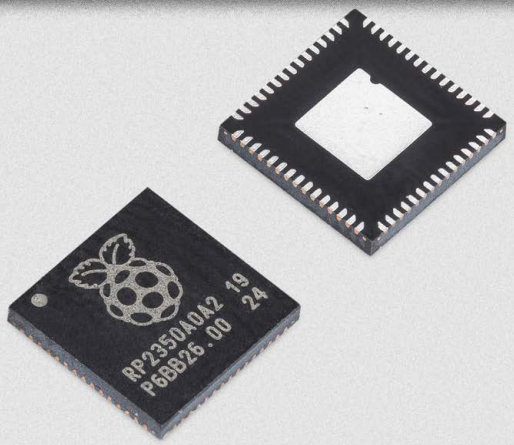
"[We've also been thinking] about how people could try and crack it, and putting mitigations in there. We have a special peripheral that means when the thing's actually booting from its boot code, it has to feed this peripheral with state [information] continuously. So as you're booting, you kind of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



SUBSCRIBE TODAY FOR JUST £10

Get **3 issues** + **FREE** Pico 2 W

SUBSCRIBER BENEFITS

Free Delivery
Get it fast and for free

Exclusive offers
Great gifts, offers, and discounts

Great savings
Save up to 37% compared to stores

SUBSCRIBE FOR £10

Free Pico 2 / Pico 2 W

3 issues of Raspberry Pi Official Magazine

£10 (UK only)

SUBSCRIBE FOR 6 MONTHS

Free Pico 2 / Pico 2 W

6 issues of Raspberry Pi Official Magazine

£30 (UK)	**$43** (USA)
€43 (EU)	**£45** (Rest of World)



Subscribe by phone: 01293 312193

Subscribe online: rpimag.co/subscribe

Email: **raspberrypi@subscriptionhelpline.co.uk**

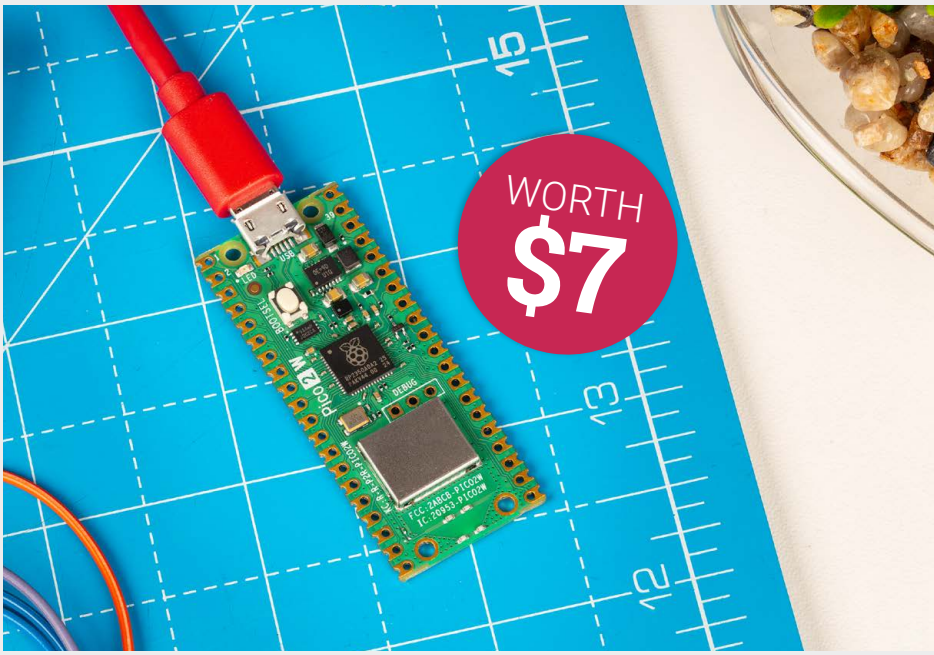
Subscribe for £10 is a UK-only offer. The subscription will renew at £15 every three months unless cancelled. A choice of free Raspberry Pi Pico 2 W or Pico 2 is included with all subscriptions.

SUBSCRIBE TODAY AND GET A

FREE Raspberry Pi Pico 2 W (or Pico 2)

Subscribe in print today and get a **FREE development board**

- A brand new RP2040-based Raspberry Pi Pico 2 W / Pico 2 development board
- Learn to code with electronics and build your own projects
- Make your own home automation projects, handheld consoles, tiny robots, and much, much more



Free Pico 2 or Pico 2 W. Accessories not included. This is a limited offer. Not included with renewals. Offer subject to change or withdrawal at any time.



Buy now: **rpimag.co/subscribe**

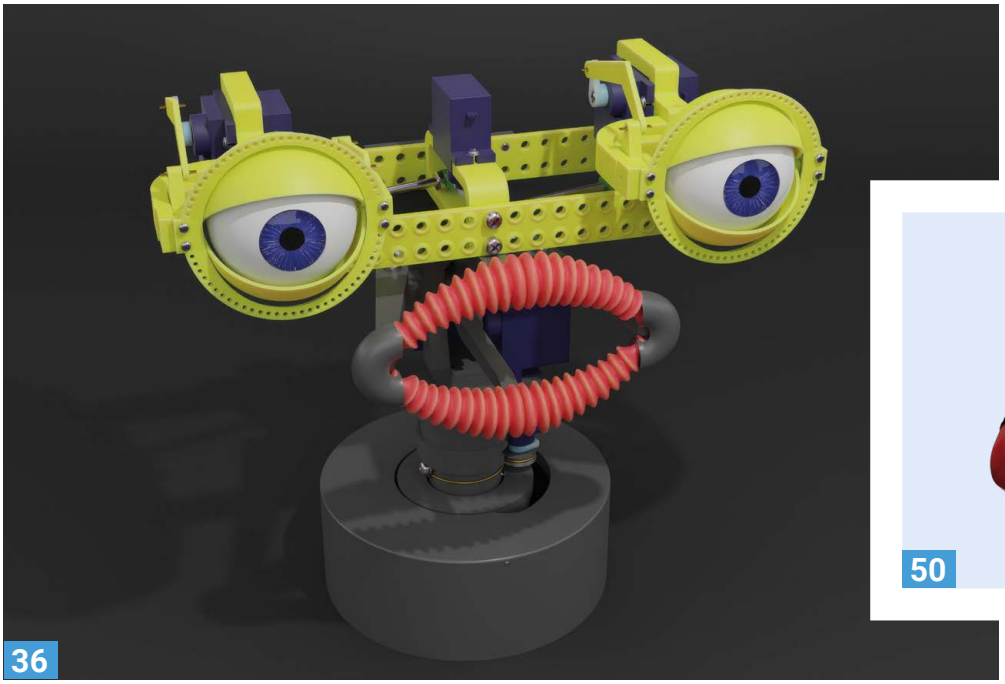
SUBSCRIBE on app stores

From **£2.29**

Available on the App Store

GET IT ON Google Play

Project Showcases







32 **CoolCoral project**
Keep coral cool for research

36 **Bechele 3.0**
A creepy, mouthy puppet

40 **sprinklR irrigation**
Automate watering your garden

44 **Cat TV**
Gogglebox, feline edition

46 **Colour Word Clock**
A pracgical kit from teen makers

50 **The Dicemaster 2000**
Rolling initiative for the visually impaired

54 **Spin**
Mash up genres with the help of AI

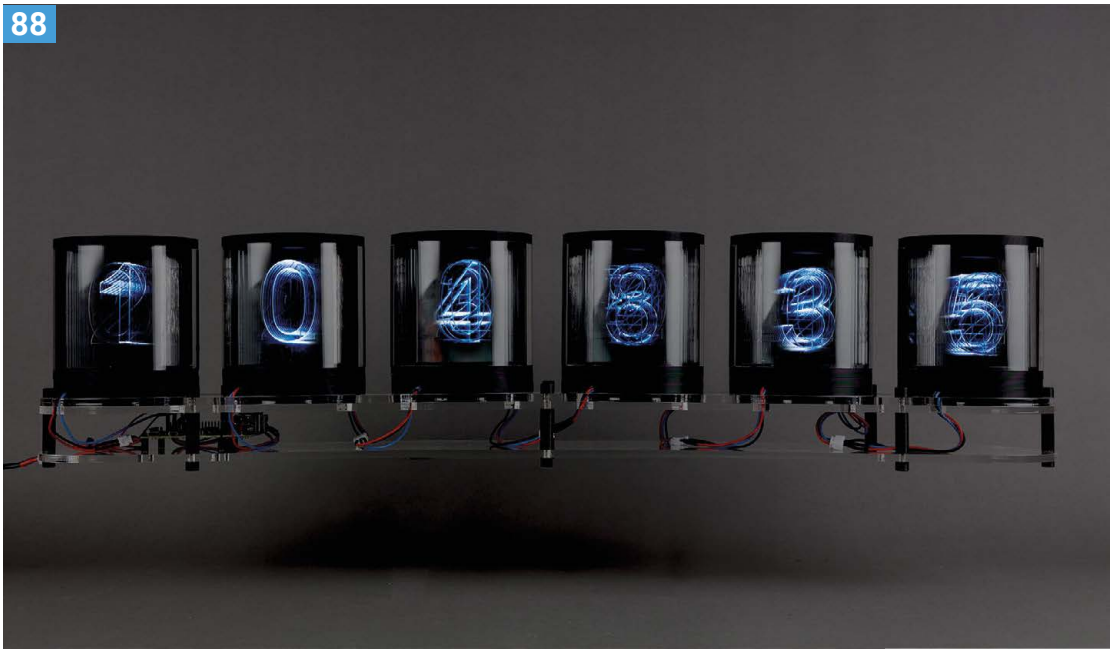
58 **Puttr**
Practice putting with this smart game

62 **LinAmp**
A retro musical experience

66 **Gehn Imager Andotrope**
Riven's visual spectacle made real

70 **Poetry Camera**
Take a photo, make a poem

74 Gugusse Roller
Deluxe digitial restoration of film



78 Portable Pi 84
Inspired by chunky laptops from yesteryear

82 VespAI
Sort the wasps from the hornets

86 Automatic pressure cleaner
A robot that can clean your patio

88 Pixie Clock
Not a Nixie clock

90 Smart Pill Dispenser
Give carers peace of mind

92 CatBot
Safely feeding cats outdoors

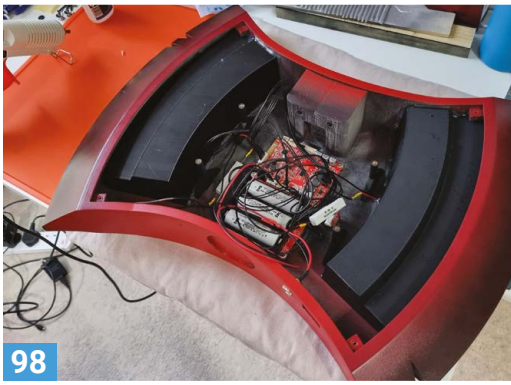
94 Bumpin' Sticker
Honk if you recognise my now playing

98 Adventure Time self-playing guitar
Improving cosplay with a smart bass

102 Floppy Disk Archiver
Do copy those floppys

106 Lawny
A robotic lawnmower with a hint of Rick & Morty

110 Cave mapping with Raspberry Shake
A unique use for the earthquake monitor





CoolCoral Project

How do you cool ocean coral? A group of volunteers discuss this regularly and their current solution makes use of Raspberry Pi Pico. **Rob Zwetsloot** takes a look



MAKER

Iestyn Jones

Iestyn is an engineer with an interest in climate science. He's part of a volunteer group of people seeking to help researchers maintain coral for study.

magpi.cc/coolcoral

As the climate around the globe changes, nature itself is being affected. Ocean reefs and their coral are just one of the ecosystems under threat, so research into them is very important.

"Field experiments involving coral in tropical climates are increasingly hampered by heatwaves – and that's a pleasant turn of phrase," Explains Iestyn Jones, a member of the volunteer group CoolCoral Project. "Basically, unpredictable heatwaves cause unpredictable temperature shifts that can overwhelm and, more often than not, kill coral samples and render oceanographic experiments fruitless."

These fatal heatwaves are becoming more regular due to global warming, however the device the group have been working on "concentrates cool water onto coral samples and alleviates the fatal effects". Water cooling for coral then, like a high-spec gaming PC.

"It'll be a solar-powered machine that'll be cooling sea-water temperatures and running a Raspberry Pi Pico for data readings and collection," Iestyn tells us. "It's simple science –KS4, I'd estimate – but it's a combination of ideas that's gone untested… until now!"

Pico at sea

Members of the team described the build process as "agile, rapid prototyping," so it's no wonder they chose Pico for the job.

"Not only is Raspberry Pi Pico extremely accessible and uncomplicated, but it offers a comprehensive range of functions and capabilities that our device requires," Iestyn says. "For example, Pico's ability to run two different threads simultaneously allows us to run the device itself, its pumps and whatnot, while also hosting a website."

The web server is accessible remotely, not only allowing easy access to data across the globe, but also to update the system thanks to the wireless connection on Pico W. The system itself does a lot more than take readings, though.

"From the outside, the device looks like a wheelbarrow drawn by a three year old: it's a cumbersome brown box with handles and some dinky wheels but, inside, it's a toybox of entropy," Iestyn says. "Pumps take in seawater through a hose before sending it through a digestive tract of more hose, copper pipes and a ribbed-metal refrigeration unit that's filled with ice. It doesn't need saying that the water cools on this journey.



▶ The solar panels are currently not equipped, but would provide power to the system

Quick **FACTS**

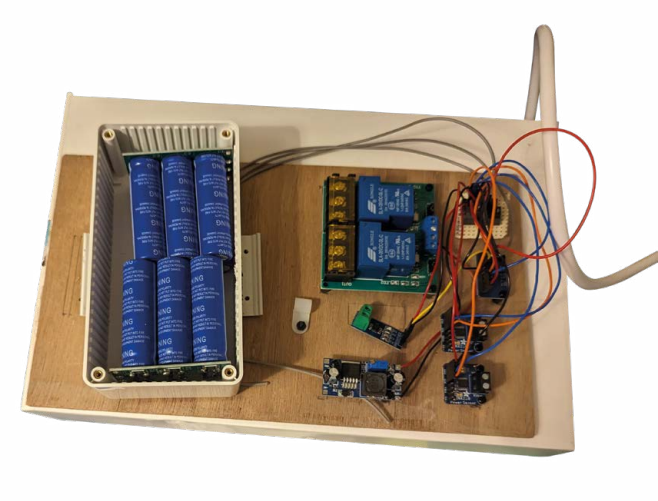
- Members of the team previously worked on the Real Ice Project...
- ...which looked at restoring and preserving Arctic sea ice: **realice.eco**
- CoralCooler will aid the study of marine biology, oceanography and climate science – to name just a few
- The analogue-to-digital converters on Pico allow for high precision data
- As well as data recording, Pico is great for pump and voltage control

Coral would be kept cool inside the wooden box

The various cooling mechanisms, pumps, and electronics are kept in the crate

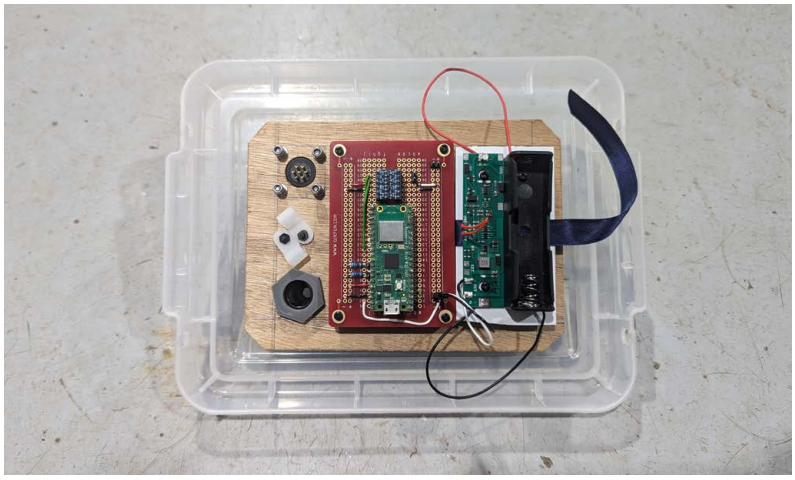
The current prototype is akin to a wheelbarrow, as the team puts it





▶ Serious battery power is required to keep the system going without solar panels

▼ The development involved a lot of rapid prototyping, a perfect use for Pico



> The device the group has been working on concentrates cool water onto coral samples and alleviates the fatal effects. Water cooling for coral then, like a high-spec gaming PC

Eventually, the cooled seawater enters another external pipe that runs towards the seabed and, hopefully, a chunk of coral that's shivering its timbers over the prospect of a heatwave.

"Meanwhile, floating above the sea level in a hermetic box is our Raspberry Pi Pico. Up there, [Pico] is running constant temperature and performance readings which are being sent in real time towards a device connected to the Wi-Fi. If anything goes awry, a notification is zapped across the air and the device can be reeled in for repairs."

The team has made sure that the mechanical aspects of the device can be fixed as easily as possible, in fact all it requires is a single type of spanner. "The whole thing, meanwhile, is being powered by two enormous solar panel wings held afloat on either side of the device by rubber tyres, or buoyancy aides." Iestyn says.

Prototyping stage

The device is still undergoing tests, with most of the electrical and mechanical system done. Currently float tests are being conducted.

"If anything [it was] too successful," admits Iestyn. "With the device floating much higher than it needed to and answering the question: 'Will we require ballast?'"



▶ Testing is meticulous to make sure everything works perfectly

Once all the testing and prototyping is finished and combined into a single test, the team reckon they'll start on a second model in the future based around their findings.

"We're conscious that the CoolCoral Project is coming across as oppressively niche because, well, it's a machine that chills-out diddy clumps of coral – it's hardly carbon capture technology," Iestyn says [*Ed note: we think it's very cool*]. "However, the project is terribly exciting because of its flexibly multifaceted nature. There's already interest being shown towards utilising this device for experimenting with substrate microbes, and that interest isn't even concerning the coral-cooling part of it. A floating device that has the potential to store masses of energy is, frankly, unheard of in ocean sciences. Most ocean-based experiments running today require boats and diesel engines to run. Our machine uses solar panels! This is how untouched this kind of thing is! We're tinkering on the tip of a vast iceberg of possibilities when it comes to ocean-centric energy devices, and we're very excited to see where further experimentation can take us."



▼ Ballast can be added to the metal frames at the front of the device

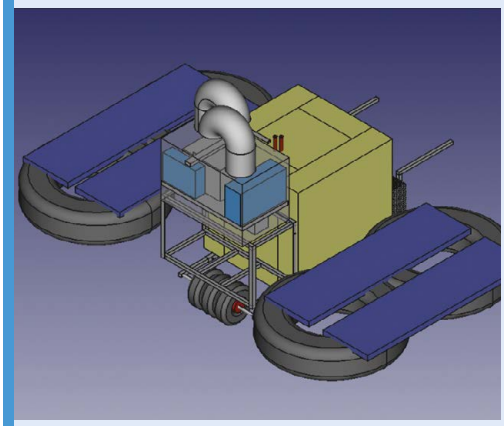
Cooling coral



01 Get the device into the water and prepare the coral sample you need to cool down.



02 Water is pumped through a refrigeration system and cooled before being pumped to the coral to make sure it too keeps cool.



03 With enough power this cycle can be repeated indefinitely, which is where the large floating solar panels will come in eventually.

Bechele 3.0

Keen to delight family members, maker Rolf Jethon used Raspberry Pi to animate a puppet. **Rosie Hattersley** listens in



MAKER

Rolf Jethon

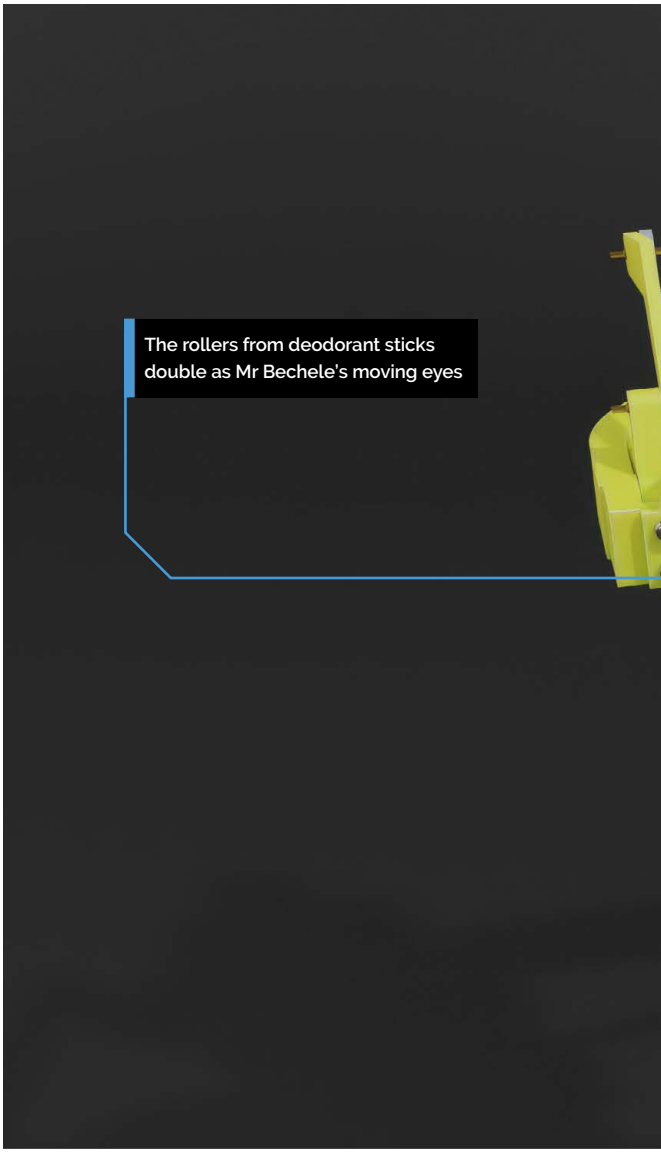
Rolf Jethon enjoys using hardware and software to overcome problems as well as perfecting his clever ventriloquist designs

bechele.de

Puppets and play are always popular at children's parties, and the concept struck maker Rolf Jethon as an equally fun diversion for his father's birthday celebration. The hand puppet he made for the occasion was a hit, but Rolf found himself tongue-tied, somewhat muting his own experience: "Though I thought I was prepared well, I forgot part of the text, couldn't master the ventriloquism and the performance stuck several times." As a technical engineer of many years, Rolf decided to use Raspberry Pi to add motion and speech to the existing doll, named Mr Bechele, and have it make another appearance, this time at his mother's 80th birthday party. Although he still had performance issues, things went better once Rolf mechanised some of the actions. Over the subsequent years, he has refined both Bechele's 3D-printed design and the software used to animate him and has just launched Bechele 3.0.

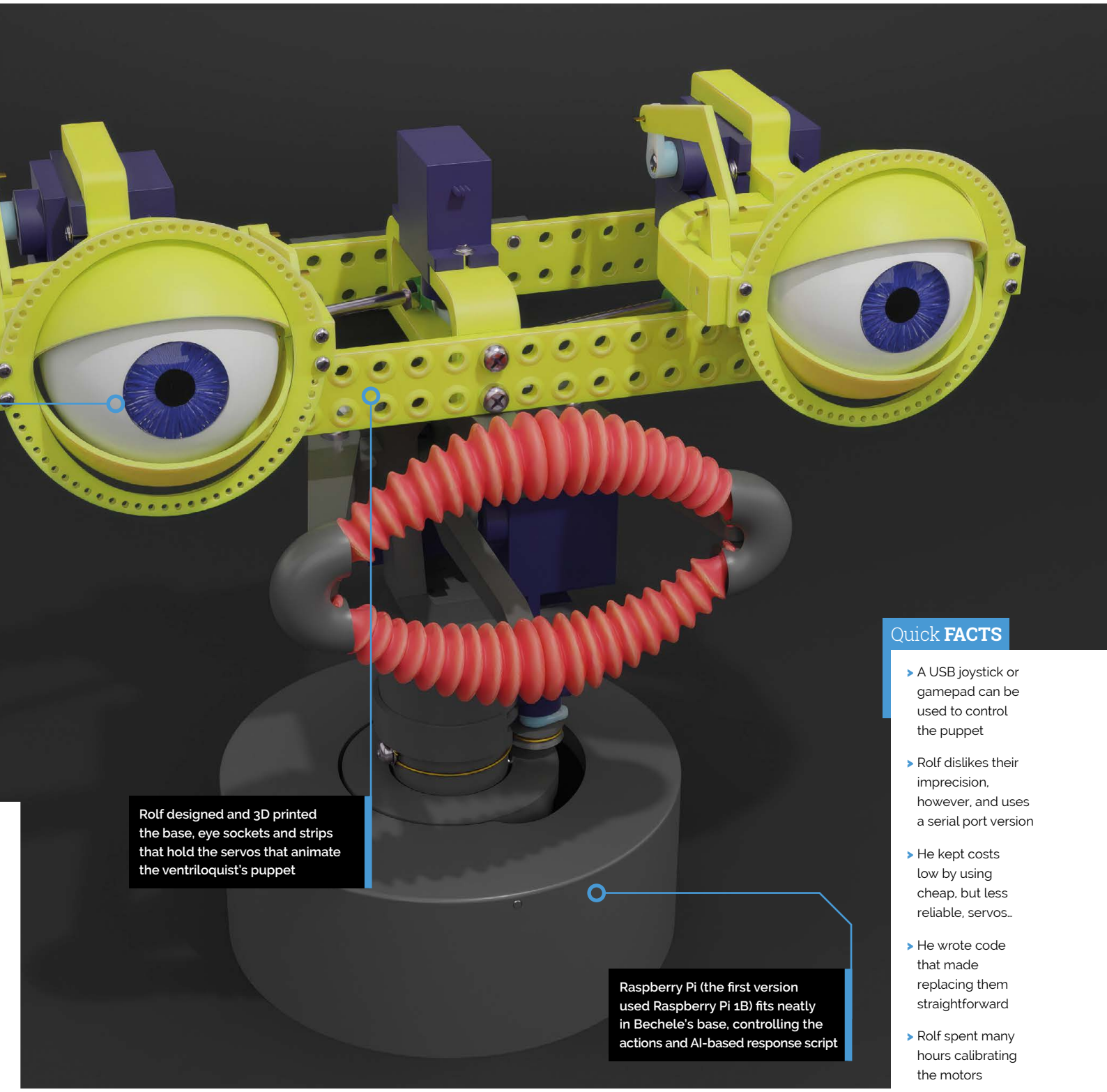
A well-rehearsed speech

A precision mechanics degree followed by a technical career meant Rolf soon encountered and embraced Unix, and latterly Raspberry Pi, both of which came in useful in his free time in which he enjoyed both hardware and software design challenges. "I felt familiar with Raspberry Pi from the beginning: it came with all the well-known tools of Linux, but also provided a cheap, space- and resource- demand reduced way of realising projects."



The rollers from deodorant sticks double as Mr Bechele's moving eyes



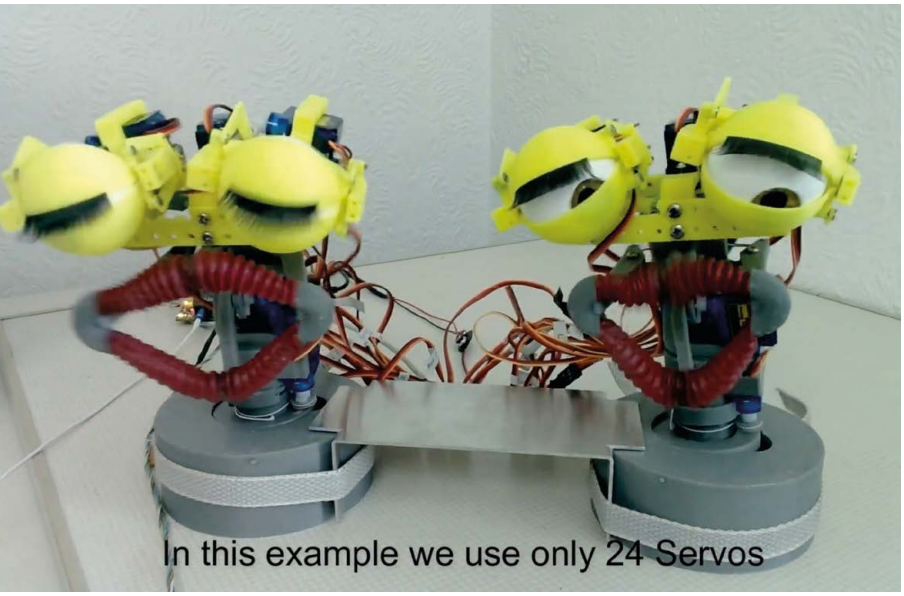


Quick **FACTS**

- A USB joystick or gamepad can be used to control the puppet
- Rolf dislikes their imprecision, however, and uses a serial port version
- He kept costs low by using cheap, but less reliable, servos…
- He wrote code that made replacing them straightforward
- Rolf spent many hours calibrating the motors

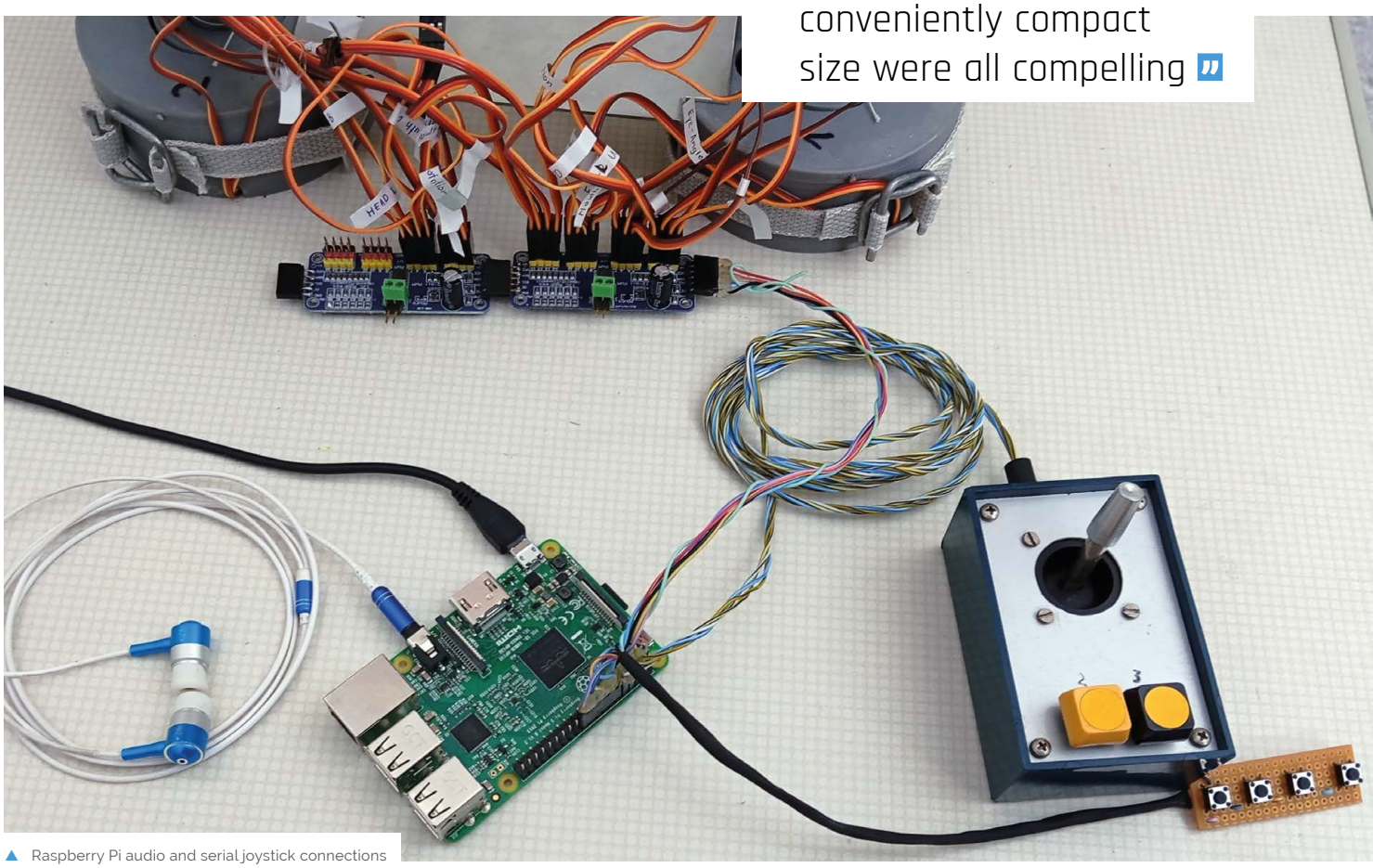
◀ Rolf's Bechele puppets and their 3D-printed ventriloquist heads

▼ Animating this 24 servo model took roughly two hours



Rolf particularly likes using Raspberry Pi headless and getting it to run things as a 'sophisticated worker' in the background. Using a Raspberry Pi-based setup to turn his hand puppet into a ventriloquist's dummy seemed a natural extension of this idea. The audio outputs, GPIO connections and the conveniently compact size that meant Raspberry Pi could fit inside the puppet's head were all compelling. "The idea was to build a puppet that talks to me and does the face movement on its own. The whole thing should work mainly fully automated [with the] eye, mouth and face movements recorded before, and following a prepared conversation. My task was finally just to ask the puppet the right questions."

> "The audio outputs, GPIO connections and the conveniently compact size were all compelling"



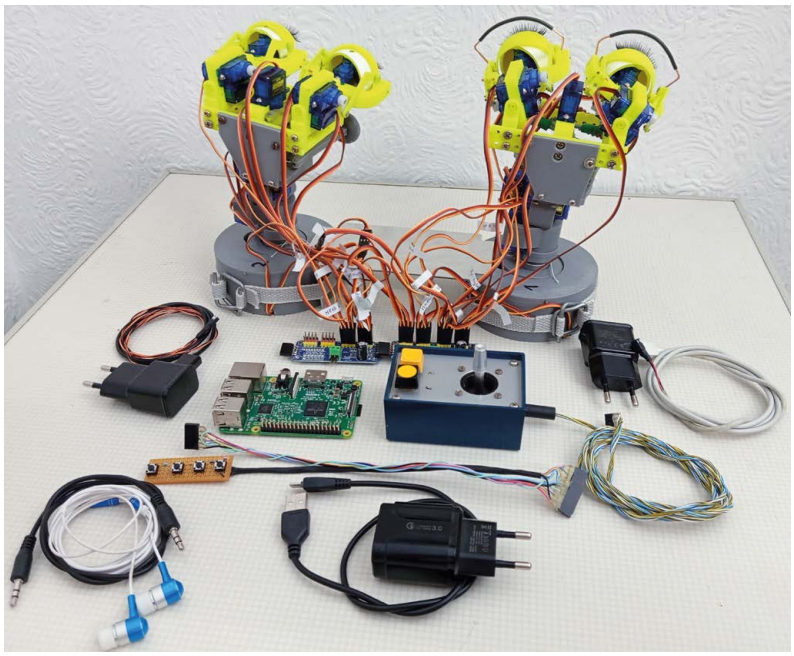
▲ Raspberry Pi audio and serial joystick connections

Resourceful approach

Rolf designed and made any hardware for the Bechele puppets that he couldn't readily source. The eyes are balls from roll-on deodorant sticks with eyelids and sockets, and the control mechanisms are designed in Rhino CAD and then 3D printed. These can be downloaded from Thingiverse (**magpi.cc/eyething**).

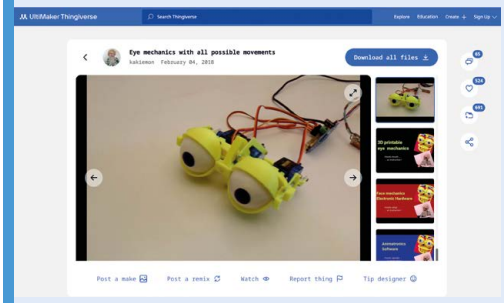
However, it was servos that gave Rolf the biggest headache: Bechele uses 24 SG90 servos, so there were challenges to controlling them all, which Rolf partially solved by using PCA9685 PWM circuit boards he'd used successfully in Arduino projects. Resource overheads meant it was very slow driving these using the existing Perl script and the Raspberry Pi i2C connection, but Rolf overcame this by writing his own Perl driver. His code meant the Raspberry Pi could theoretically control up to 64 servos at once.

Getting the most from his chosen hardware involved careful and time-consuming calibration of the joystick and recording the movement parameters for each of the servos, but having optimised them, Rolf was then able to swap out any servos as needed easily. He explains that the Bechele software "is fully written in Perl and can be used headless. It loads quickly and has a graphical interface for the teaching process". The number of devices and interfaces involved make installation a challenge, Rolf warns, but he's created a SD card image that anyone can download from **magpi.cc/bechele**.

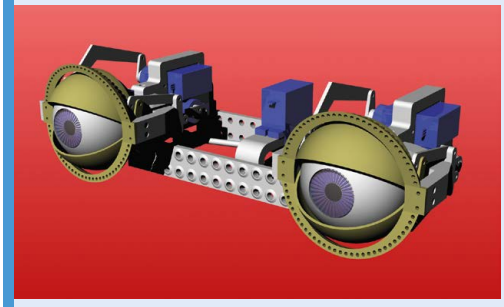


▼ The heads are fitted with servos and other parts ready for assembly

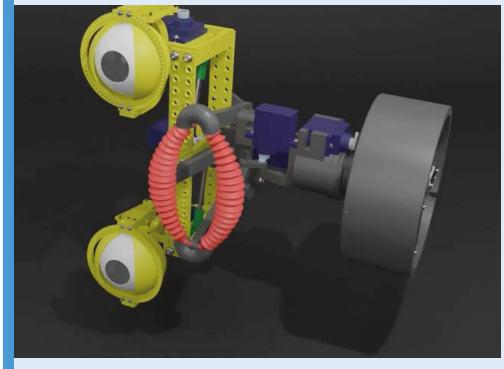
Feeling animated



01 The Bechele blog (**magpi.cc/becheleblog**) explains how to 3D print, assemble and install code to animate a doll or puppet, as well as how to learn the process yourself.



02 Seven servos are used to animate the eyes. Rolf suggests this version (**magpi.cc/eyemechanics**) is simpler to replicate than the one in his main setup demonstration video. The background audio files are used under a Creative Commons licence.



03 Raspberry Pi fits in the base and connects to the 16- or 24-servo configuration via GPIO. Rolf provides downloadable Bechele 3.0 software for models up to Raspberry Pi 4B.

sprinklR irrigation

Keen computer programmer Mark made use of Raspberry Pi to create his own automatic watering system. By **Rosie Hattersley**



MAKER

Mark Niemann-Ross

Mark has written several books about using technology, particularly the R programming language.

niemannross.com

Automatic watering systems that tend to your plants' irrigation needs cost only around £30 and work perfectly well. As maker Mark Niemann-Ross points out, they reliably turn on and off, sprinkling thirsty crops when the season demands.

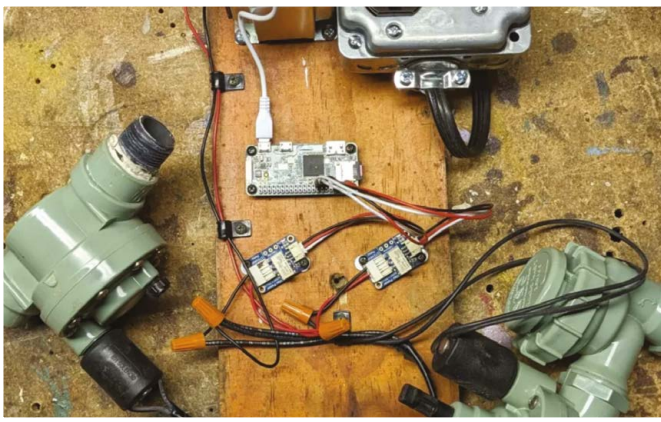
Unfortunately, they score far less highly for longevity: replacing a worn-out system every year or two soon becomes an uneconomical chore. Such a system can be made smarter with internet connectivity, but this adds roughly $100 to the cost, and the system invariably still falls foul of harsh winters. Mark's DIY irrigation project uses Raspberry Pi Zero WH and a cheap, but clever, waterproof housing to ensure it lasts year after year.

Harsh environment

Portland, Oregon-based Mark has an urban garden that needs to be irrigated each summer. Judging from the description of his irrigation system, the garden is a little larger than the 30-foot back lawns often attached to suburban UK homes. Commercially available timers provide reliable irrigation, but Mark found they don't last: "If you forget to bring them in during the winter, they freeze and break. After a few years, the plastic valves wear out and they jam closed (bad for plants) or jam open (bad for water bills). They don't adjust to rain or hot weather." Pricier, more robust timers plus web connectivity to check the weather forecast work better but still fail. Mark had several Raspberry Pi boards at home, and decided to put them to good use. Having written extensively about Raspberry Pi as well as coding



▼ Components and code were tested over several days in a prototype design





Warning!
Water & Electricity

Running water and electrical currents can seriously damage your beloved tech hardware! Follow Mark's lead and encase your plant irrigation device in a waterproof housing such as a sealed glass jar.

magpi.cc/electricalsafety

Mark's R-based automated irrigation system uses standard irrigation valves from a hardware store

Raspberry Pi Zero WH, kept secure and dry in a sealed upturned Mason jar, checks Open-Meteo's weather forecast and adjusts the water flow accordingly

A single line of R code initiates plant watering once each evening and monitors usage for billing purposes



A web dashboard Mark created shows rainfall trends and his irrigator's status

Quick **FACTS**

- The system runs off a 1 amp 5v phone charger
- It is set to water Mark's plants daily at 6pm
- But checks the weather forecast first
- Mark is now planning to automate feeding his chickens
- With each chicken having its own RFID tag

> Households can reduce their water usage by roughly 7600 gallons a year



Mark designed a robust replacement for a commercial irrigation system

using R (see his blog at **niemannross.com**), the combination seemed obvious, although R is a less common choice of programming language. "My preferred language is R, which I can run from a Linux operating system, but not from MicroPython or C. Irrigation only happens once a day, so I don't need speed. What I need is the most convenient way to express my logic to Raspberry Pi." Using Raspberry Pi Zero WH as the controller "makes it easy to connect to the internet and the headers provide a convenient way to connect relays and buttons," he explains.

Bits and pieces

Creating his irrigation system involved assembling lots of fairly standard components and a certain amount of planning. Prior knowledge of plumbing and electronics is helpful, Mark observes. The planning aspect required Mark to work out how much rainfall was likely to offset the total number of gallons of water his garden would need and how long the valves would need to be open at a time. He calculated the rate at which his house pipes could pump water to the irrigation valves (and the putative number of gallons per hour) as well as the voltage required for the relays to deliver it.

To see whether his idea would work Mark began by screwing irrigation valves, two servos and Raspberry Pi needed to power the system, as well as a Raspberry Pi Zero, on to a piece of wood. "There isn't any water connected to the system at this point – I'm only trying to test the electronics and develop and test the code."

After writing and testing the code on Raspberry Pi he "ran it with the relays for days without any valves connected, then tested the plumbing in a sink before I attached it to the board".

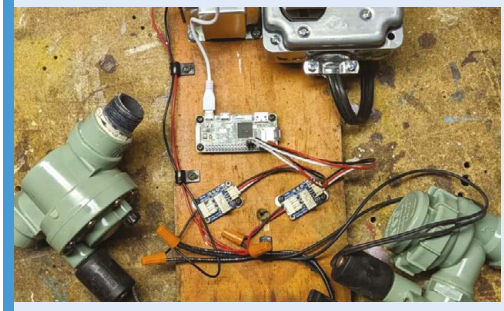
The US Environmental Protection Agency estimates 28 million US homes have an automated watering system, and that households can reduce their water usage by roughly 7,600 gallons a year using a weather-based system to gauge requirements (**magpi.cc/irrigationepa**). Mark wanted to see whether he got realistic readings, and how well the system performed, before deciding to risk linking it up with his water meter for billing. He continues to tweak and update it and is delighted with just how well his $75 irrigation system is performing.



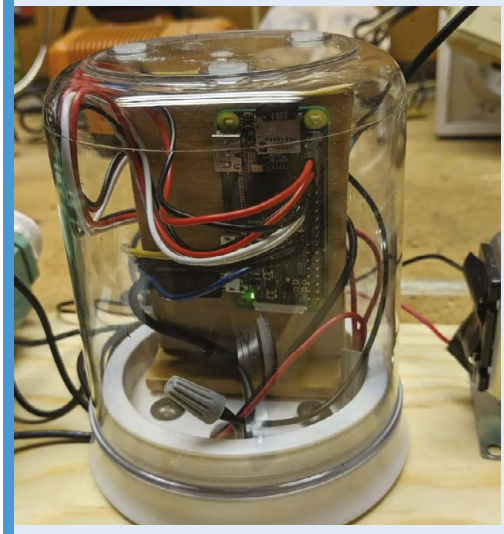


▲ Daily irrigation helps keep plants in Mark's garden healthy

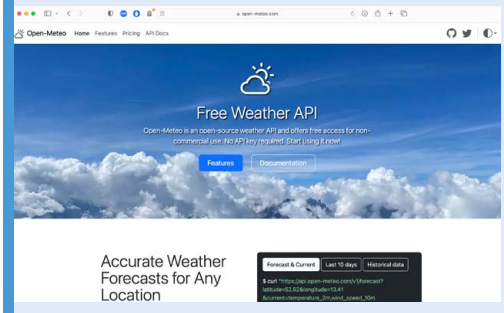
Thirsty work



01 Mark documents setting up his irrigation system at **magpi.cc/sprinklrwiki** including setting up the power supply, servos and valves and using R code on Raspberry Pi to implement daily watering.



02 An upturned Mason jar provides a useful means of waterproofing the electronics, with cables fed up through the board and the jar's sealed lid.



03 Code running on Raspberry Pi pulls weather data from Open-Meteo to help determine how much water the plants need.

Cat TV

Prolific maker Becky Stern chose a Raspberry Pi display to entertain her favourite feline. **Rosie Hattersley** wholeheartedly approves



MAKER

Becky Stern

Becky is lifelong maker with interests in art and electronics who loves sharing her creations online.

beckystern.com

Becky Stern is a content creator extraordinaire! During her six years as director of wearables at Adafruit she created, wrote, recorded, presented, and edited 140 videos showing other makers the possibilities of body-worn tech.

Her enthusiasm for tech shines through in her current role at DigiKey, while her personal blog and extremely popular YouTube channel present such gems as Cat TV (**magpi.cc/cattvyt**), a self-explanatory project based on Raspberry Pi Zero and a Elecrow touchscreen. With such a busy companion, we're relieved to hear that Becky's feline friend is being entertained.

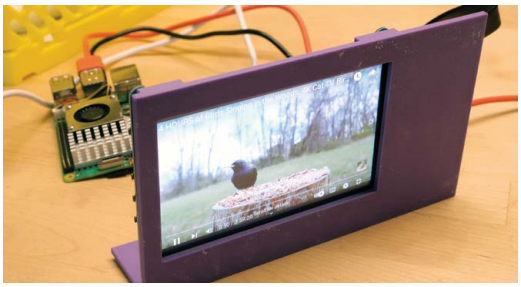
Dress to impress

Becky's interest in electronics began at art school. "I have no formal engineering background, but I did drop out of a PhD programme," she explains. Becky was already working at Adafruit when Raspberry Pi came out in 2012. The company immediately saw its potential for makers and for wearable tech: "I remember we delayed the FLORA launch to focus on Raspberry Pi content," says Becky. Her numerous makes include Raspberry Pi ones, of course, including an automated GIF camera (**magpi.cc/gifmaker**) and a smart mirror: **magpi.cc/beckymirror**.

While chasing his own reflection in the mirror might have diverted her cat, Benchley, for a while, Becky thought it was about time he had something tailored specifically to his interests. "My cat loves watching TV. The Raspberry Pi streams his favourite YouTube channel, full of birds and squirrels." Other feline goggleboxers may already be aware of Birder King (**magpi.cc/birderking**), which is also beloved of parrots and dogs.



▼ Benchley sometimes tries to locate the wildlife show on Cat TV



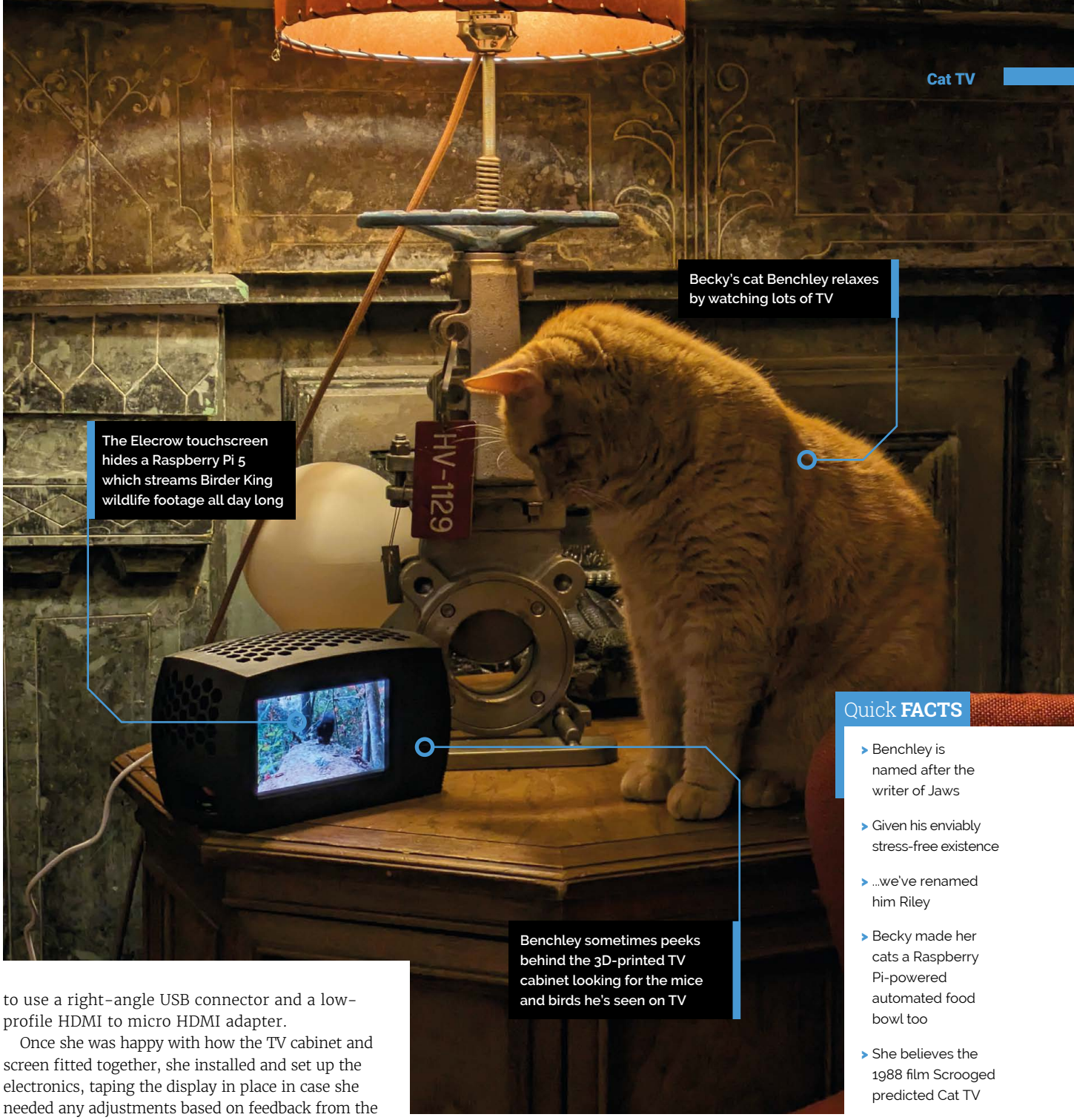
▲ Raspberry Pi Zero and an Elecrow touchscreen form the project's basis, all wrapped in a custom enclosure

Tiny telly

Becky chose Raspberry Pi 5 as the basis of Cat TV, since she wanted to stream video and wanted the extra processing power, but she has also tested it with Raspberry Pi 4. She had a five-inch touchscreen she was keen to use: "I knew I wanted to use this particular display from Elecrow, so I 3D-modelled an enclosure that would fit to its dimensions." Becky used Tinkercad to design a CRT-style cabinet complete

> "My cat loves watching TV. The Raspberry Pi streams his favourite YouTube channel, full of birds and squirrels"

with ventilation holes so the miniature TV setup looked authentic (**magpi.cc/tinkercadcat**). "I used the honeycomb shape generator in Tinkercad to make grids of holes that are too small for my cat to reach through," she says. A bit of glitz was added by using Galaxy Black PLA filament for the front of the 3D enclosure. The whole project cost roughly $100, and Becky was able to get all the electronics she needed from DigiKey (where she works) including a USB speaker and keyboard. Due to Cat TV's miniature proportions, she had



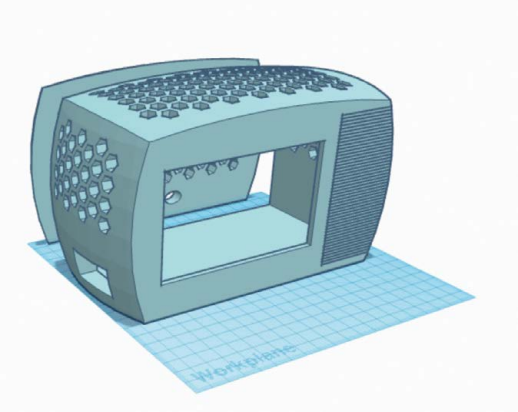
to use a right-angle USB connector and a low-profile HDMI to micro HDMI adapter.

Once she was happy with how the TV cabinet and screen fitted together, she installed and set up the electronics, taping the display in place in case she needed any adjustments based on feedback from the ever-watchful Benchley. Becky explains that Cat TV doesn't use any software besides Raspberry Pi OS: "I boot up, open the web browser, navigate to YouTube, make the video fullscreen, then unplug the keyboard. If I were to add some software, I'd write a startup script that performs the same steps."

During trials, Becky discovered the touchscreen was a bit of a problem as the cats would paw the screen and pause the video, so she replaced the screen's USB cable with a charge-only lead, disabling the data connection for the touchscreen. Once this was done she sealed the case and presented it to Benchley and his brother Hamlet. "Cat TV gets used every day! The cat loves it, though it would be cool to add some way for him to change the channel."

Quick FACTS

- Benchley is named after the writer of Jaws
- Given his enviably stress-free existence
- ...we've renamed him Riley
- Becky made her cats a Raspberry Pi-powered automated food bowl too
- She believes the 1988 film Scrooged predicted Cat TV





▲ The Birder King YouTube channel streams cute wildlife all day long

◀ You can download Becky's 3D TV cabinet design from Tinkercad

Colour Word Clock

The GurgleApps siblings return to their roots with this fun and practical word clock kit. **Rob Zwetsloot** spends some time with it.



MAKER

GurgleApps

Amelia, Caleb, and Zivya are the three-person team of GurgleApps, a STEM YouTube channel focusing on electronics that has been going for years. They're also siblings.

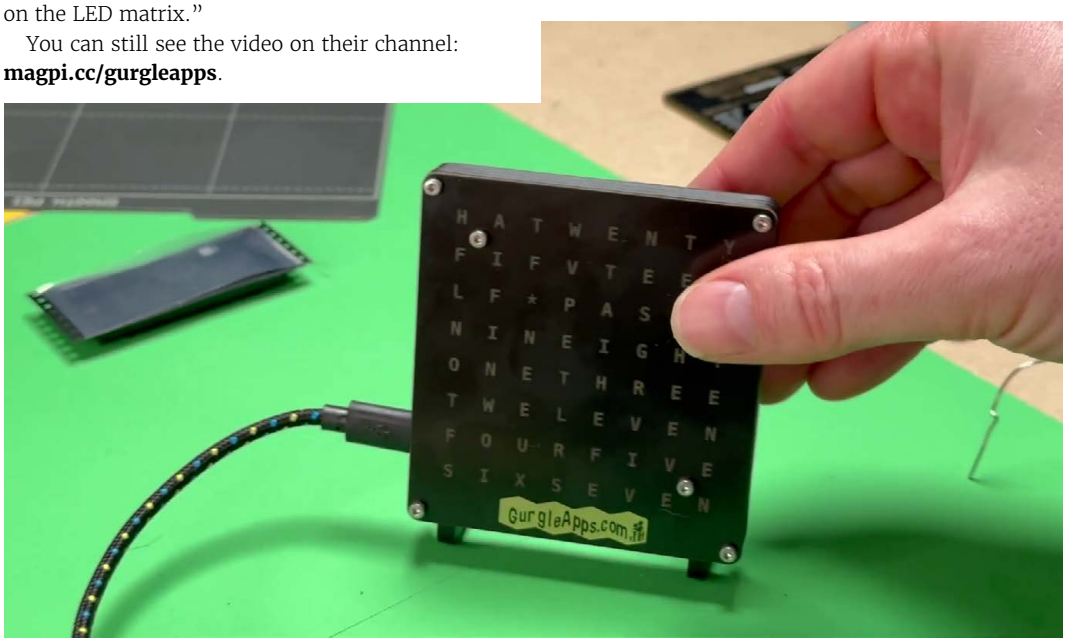
magpi.cc/colwordclock

Gurgle Apps has been making fun electronics projects (and tutorial!) videos for years now, and we've included what they've made in the mag several times. The three siblings Amelie, Caleb and Zivya are back again in these pages with a kit that you can actually build yourself – the Colour Word Clock.

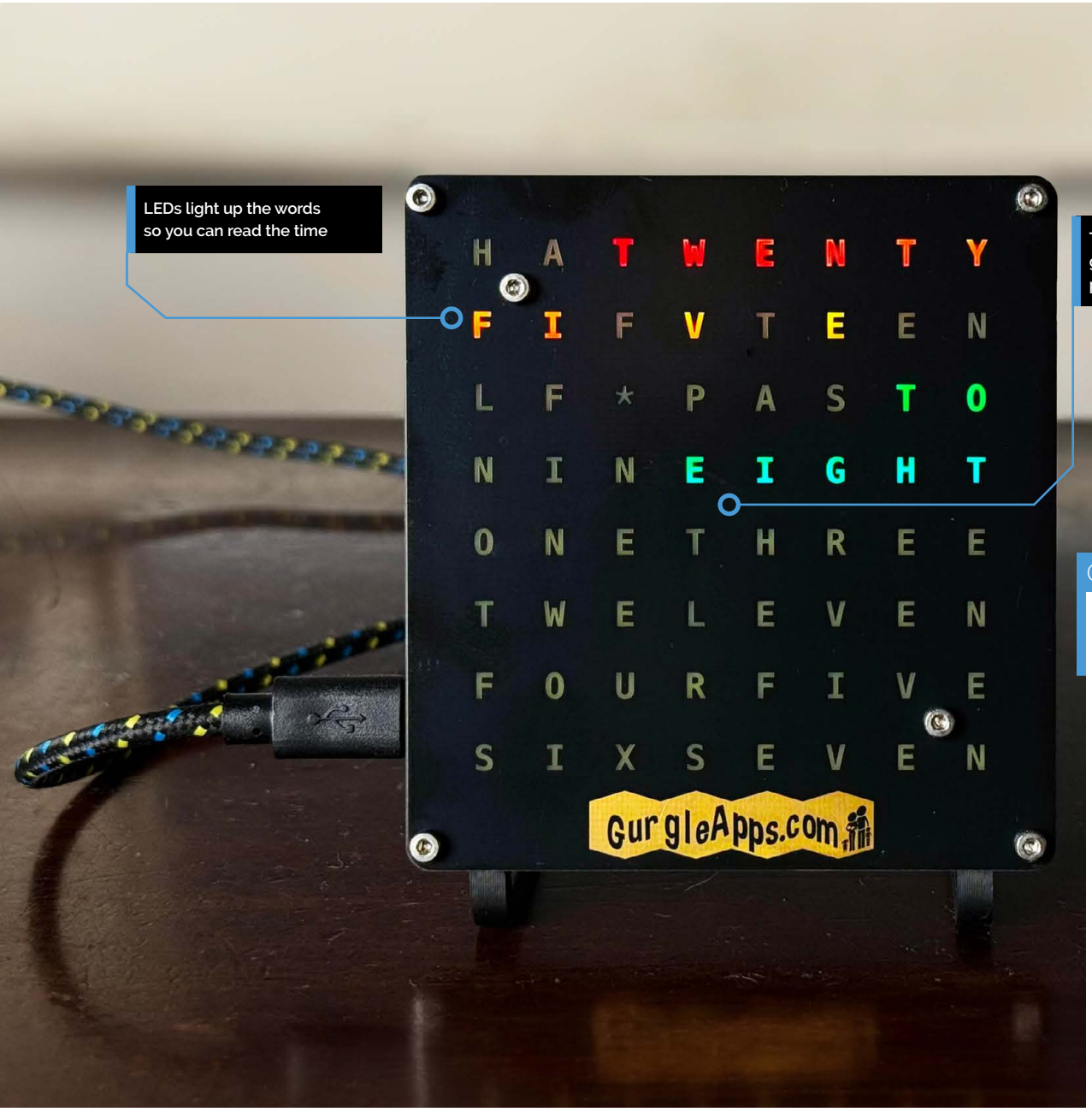
"One of our first ever projects was a tiny 8x8 LED matrix word clock using a Raspberry Pi," the siblings explain to us. "At that time we were too young to do it on our own, our Dad made it to teach us a bit of Python and electronics. We remember making little pictures on an 8x8 grid on paper then turning it into binary then hex to get it to display on the LED matrix."

You can still see the video on their channel: **magpi.cc/gurgleapps**.

"We wanted to make some kind of kit for people to build and hack and remembered that fun little project," they continue."[It] can be controlled via a web interface on any device connected to the same network. The clock displays the time in words and has a variety of display modes... It was important to us that the code was open source and the kit was easy to build and modify. The kit is aimed at beginners and experienced makers alike. It was also important to us that the kit was affordable, and if you don't want to buy the kit you can build it yourself using the open-source code and easy-to-source components, and 3D-print the case. All the case files are open source and free to download."

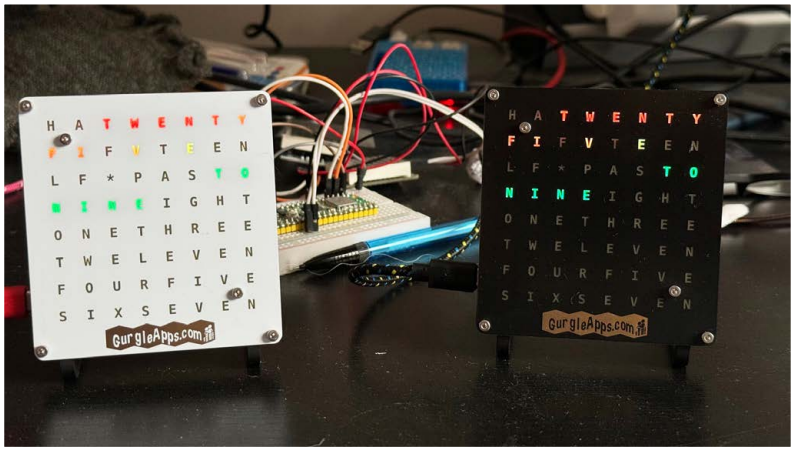


▶ The completed kit, ready to tell the time

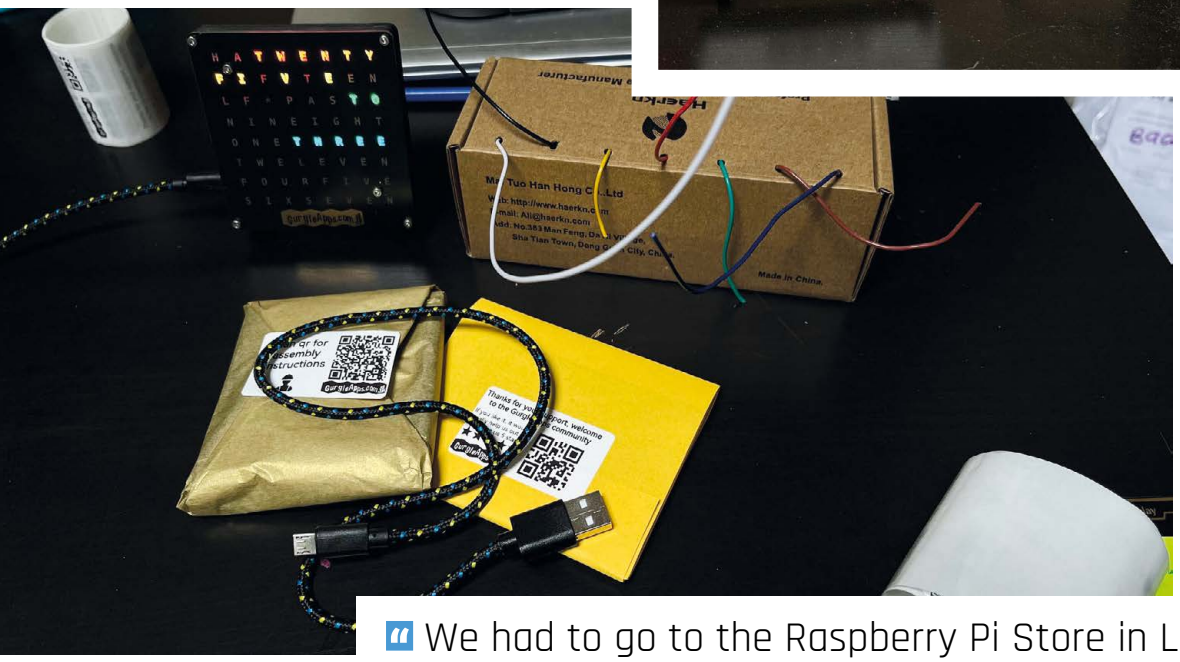


Quick **FACTS**

- This is not their first product – that was the Raspberry Pi Pico Pinout Coaster
- You can still get the code for the original LED matrix used
- There's a limited run of white face plates for the clock
- The code is being updated with features added by the community
- They admit to treating their Picos pretty roughly, but they always keep working



▶ The white version was requested by viewers



▲ The kit is compact but comes with everything you need for the build

> We had to go to the Raspberry Pi Store in Leeds to get more Picos and had both 3D printers running pretty much constantly to get more kits made

Reliable Pico

The wireless capabilities of the project were extremely important to the siblings.

"We'd just open-sourced a MicroPython Web Server (**magpi.cc/mpwebserver**) to control projects using a browser, and thought it would really show off what it could do," they say.

Despite their love of Raspberry Pi Pico ("we usually use Raspberry Pi Pico unless there is a specific reason to use something else,") they began experimenting with another microcontroller, however it just couldn't hack it.

"We found the Wi-Fi connection degraded when we left it running for a few days, we went through four different [microcontrollers] and they all had the same issue," they explain. "At this stage the clock was still a tiny 8x8 LED matrix word clock which used I2C and SPI, and we also had intermittent issues with the I2C connection. We have so many Raspberry Pi Picos lying around that we decided to try one of those and it was bulletproof from the start."

Like a lot of products, the clock went through many design changes – as you may have noticed, it definitely doesn't ship with a tiny 8x8 LED matrix.

"If you've seen any of our videos you'll see projects stuck together with Blu Tack and gaffer tape, but you can't do that with a product you're going to sell," they admit. "We went through hundreds of different designs and prototypes. The 3D-printed faceplate alone we tried with dozens of different fonts, sizes and colours. Dropping the small 8x8 LED matrix was a big decision, we had to start again with the code and the faceplate. We had to make the clock bigger to fit the larger LED matrix and completely redesign the case but it started to come together and look like a product we'd be proud to sell."



Warning!
Hot solder

Soldering irons get very hot, and stay hot for a long time after they're unplugged. Make sure that you put the iron in the stand when you're not using it and don't touch the metal parts – even after it's unplugged.

magpi.cc/soldering

Rave reviews

Like Raspberry Pi itself, GurgleApps had modest expectations for the Word Clock – and they were completely smashed.

"We only had 10 kits and they sold out immediately," they say. "We had to go to the Raspberry Pi Store in Leeds to get more Picos and had both 3D printers running pretty much constantly to get more kits made.

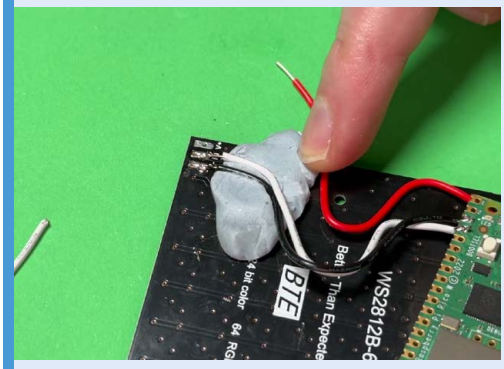
"What we are most pleased about though are the comments and support from people who have bought the kit. We've been astounded by the way it has been hacked and modified by people who have bought it. A teacher sent us a photo of him using it in class to teach English. Pretty quickly we'd seen the clock doing things we'd never thought of. The ingenuity of the people who have bought the kit has been amazing. We've had something new to show every week on our Sunday live streams and get to chat to the people who have built their clocks."

Rob has one ready to build for his office desk, a topic you may remember causing him some concern in a previous issue's Final Word. We hope they make their way to desks around the world.

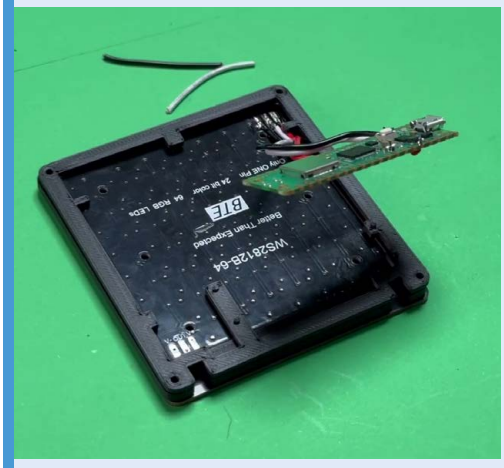


▼ The complete Word Clock is a great looking accessory to your techy desk

Layers of fun



01 You'll need to solder the correct wires to Raspberry Pi Pico and then to the LED board – there's only three to worry about though.



02 Much like a Pimoroni PiBow, you assemble the case up in layers, starting with the faceplate with the words on.



03 Add the backplate to secure Pico and you're ready to go – you'll just need to add the software and turn it on.

The Dicemaster 2000

It looks like a game controller but for visually impaired people this dice-rolling device is actually a game changer as **David Crookes** discovers



MAKER

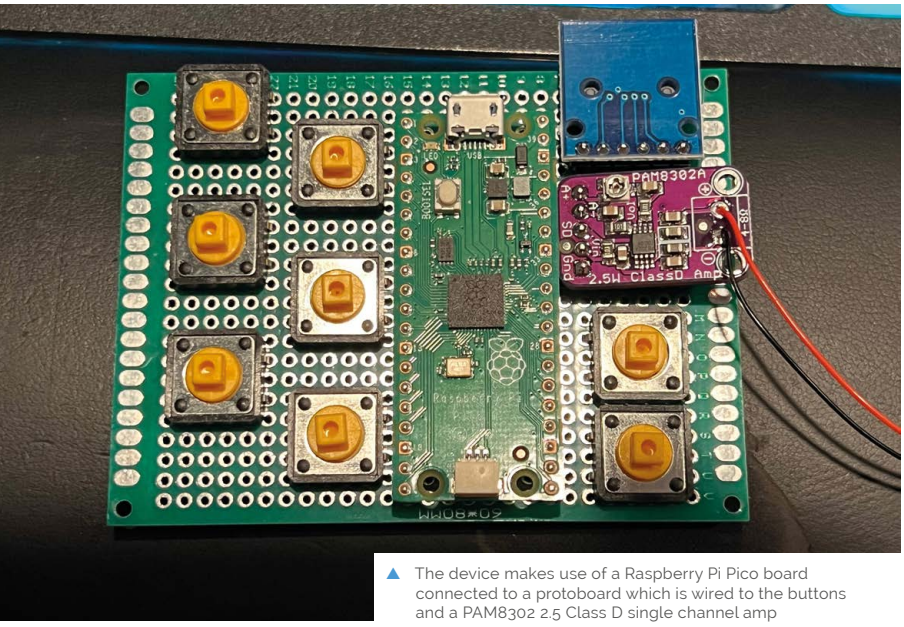
Christopher Hall

Christopher Hall is a Senior Network Engineer from Pikeville, KY, USA. He's a maker at heart and lover of all things geeky.

magpi.cc/dm2000

Chris Hall enjoys playing board games and he's part of a local gaming group. He attends with his best friend and the pair have had many happy times but a medical condition affecting his pal's vision has threatened to spoil the fun. "About a year ago, my best friend was diagnosed with a degenerative eye disease," says Chris. "So when his birthday was coming up, I wanted to do something special for him."

Most of the games played by the group involve the rolling of dice and the problem for his friend was all too apparent: without someone reading out the result, he wouldn't know what numbers were showing. The answer, Chris surmised, was a dice-rolling device that his friend could use independently which would read out the results and incorporate some other handy features. "I figured it would help him out and be a surprise gift," he tells us.



▲ The device makes use of a Raspberry Pi Pico board connected to a protoboard which is wired to the buttons and a PAM8302 2.5 Class D single channel amp

From the start, Chris had an idea of what he wanted from the device. "I knew what I wanted to achieve – for my friend to press buttons, for virtual dice to be rolled and the result to be announced," he says. "From there it was just about figuring out which components to use and how to lay them out efficiently. This needed to be hand-held, so a compact design was a must."

To that end, Chris modelled the device on a gamepad. "I tried to imagine a controller, like an Xbox controller," he says. "I sought to work out how it would look, feel and where the thumbs would rest. I wanted to make something that was comfortable and felt familiar and I also needed it to operate without being plugged in so I chose a Raspberry Pi Pico and used an 18650 battery shield to power it along with the other components."

Roll with it

Selecting the Raspberry Pi Pico meant the dice roller could be compact and use minimal power. "It's instantly on and it was able to handle the different components I needed, such as a microSD card reader, an audio amp with speaker and a litany of buttons," Chris says.

Those buttons would be 3D printed with Braille so that his friend would be able to read their various functions and control the device effectively and independently. "Adding Braille wasn't very difficult," Chris says. "I designed flat button caps then added the Braille numbers to them in Blender, the free open-source 3D computer graphics software."

Board games often make use of non-traditional dice – in other words, they're not always familiar cubes with six marked faces. The standard polyhedral dice set also includes those with four, eight, ten, 12 and 20 sides (the entire set being referred to as d4, d6, d8, d10, d12 and d20). "I needed to have a button for each one," Chris says. He also added two extras: Reset and Roll.

Quick **FACTS**

- It's a handheld dice-roller for visually impaired people
- Each of the buttons is imprinted with Braille numbers
- It can mix and match six different die types
- Die pools can be saved and loaded
- There's a power switch to save battery life

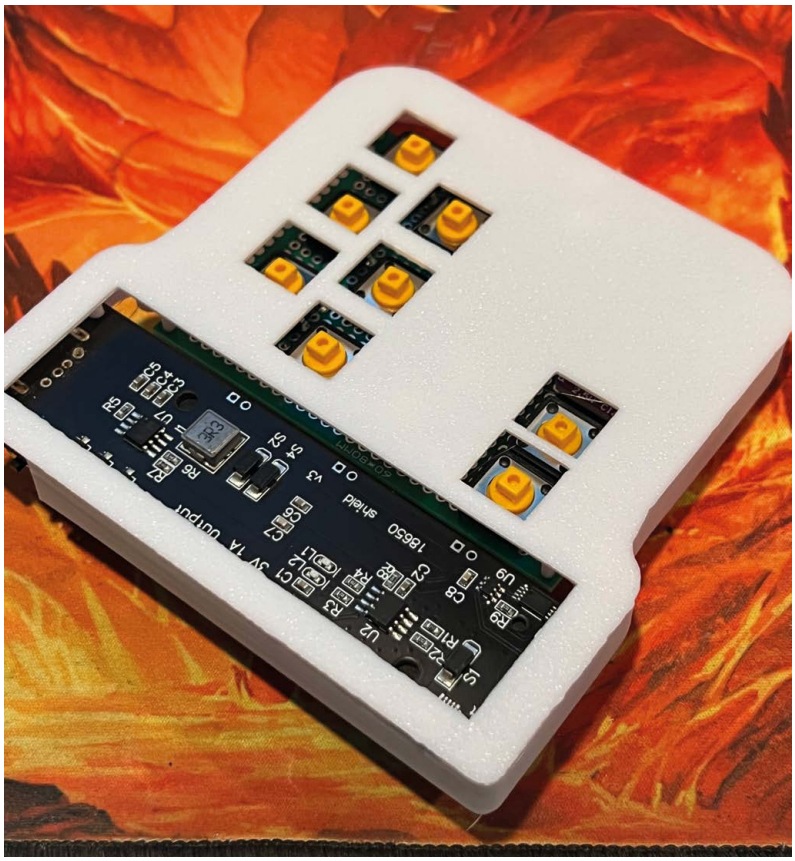
Each button to the left represents the six dice in a polyhedral set. Four of them can be long-pressed for extra functions

Dicemaster 2000 doesn't actually mean anything. "I always thought it was funny when people talked about future tech by slapping 2000 in the name," Chris says



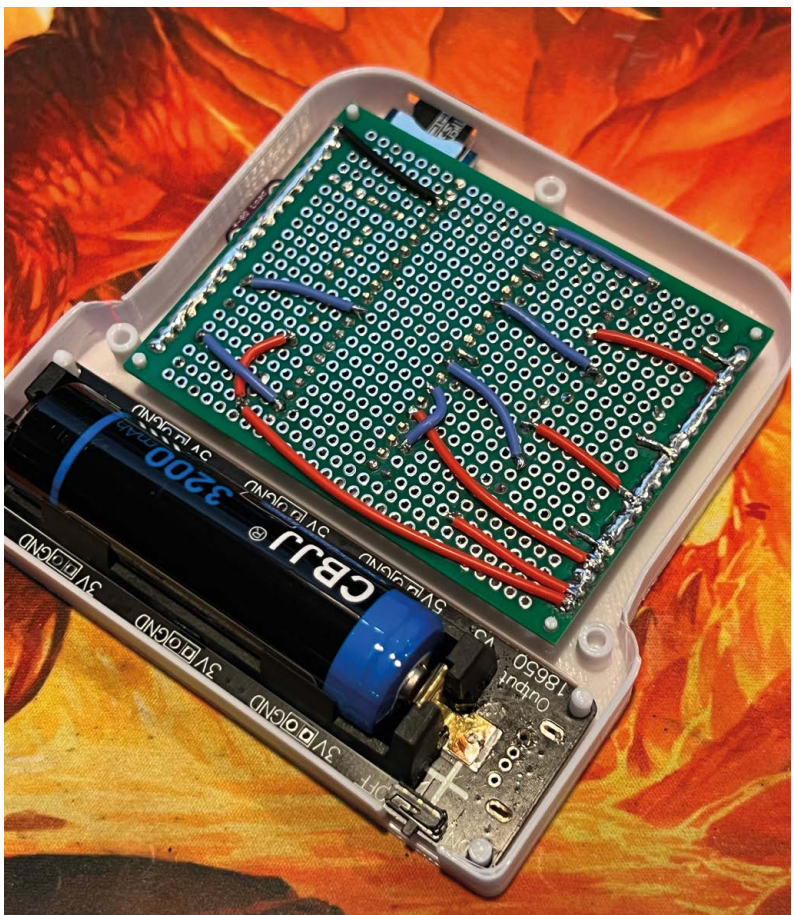
To make the device easier to hold, Chris added some grips to the 3D-printed casing. It also makes it look more striking

> "I designed flat button caps then added the Braille numbers to them in Blender"



Writing the project in CircuitPython, he created a device that would allow his friend to press one of the numbered buttons to add it to the die pool. When the dice are ready to be rolled, it'd be a case of pressing Roll and listening to the result when it's announced. "In addition, there are some long press modes," Chris adds. "If you hold the d4 button for a few seconds, you will enter quiet mode which plays chimes rather than speaking out every die entered and describing what it's doing. It still announces the results of the roll, but it can cut down on time and I added it in case the normal mode was too distracting to other players at the table."

Holding down d6 saves the current die pool. "This is useful if you're playing something like Dungeons & Dragons and constantly need to roll that big 8d6 fireball [that's eight d6 dice being rolled at once]," Chris continues. "Long-pressing d8 will load the saved die pool from the microSD card, and that means the saved pool will persist across uses." Long-pressing the d10 enters percentage mode which, rather than rolling dice, will simply give a percentage between one and 100.



▲ The prototype Dicemaster 2000 with its eight buttons and 18650 battery shield

▶ As you can see, as well as a rechargeable battery and a lot of soldering, the device is neatly wired



▲ The case took some time to perfect, but it's been designed to be comfortable to hold while giving easy finger access to the buttons

Play the game

Coding all of this was a challenge. "Interfacing with the audio amp was tricky and I wish the device was a bit easier to understand in terms of audio quality, but this may have been due to everything being built on a prototype board," Chris laments. He also found it difficult to perfect the controller shape. "The housing was 3D printed in a single colour and the top was painted red. I had a good friend of mine help with the ergonomics of it. There was also a lot of soldering," he adds.

Even so, it's been worth the time and effort. Chris' friend loves using the device and he finds it allows him to fully participate in games. It's also comfortable to hold, easy to use and very effective. What's more, you can replicate it because Chris has made the code open source and he has also shared the 3D files on Printables (**magpi.cc/dm2000files**). In that sense, it's capable of helping many other people with a visual impairment.

Chris is certainly happy overall even though he would have done some things differently. "If there is one part of this project I wish I had done, it would have been to design a custom PCB using something like KiCad – if only I'd had issue 138 of The MagPi [**magpi.cc/138**] when I started! It probably would have helped a lot with audio issues and made for a cleaner build overall. It's definitely on my list of things to learn for future projects."

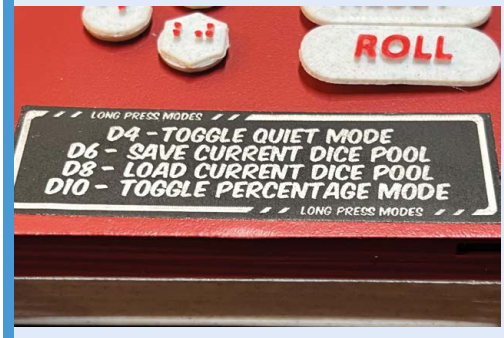
Rolling the dice



01 Users press buttons representing the six types of polyhedral dice (d4, d6, d8, d10, d12 and d20) to add them to the dice pool. Dicemaster 2000 will hold a pool of up to 20 dice, either all the same type or a mixture.



02 Once the correct number and type of dice have been added, the user presses the Roll button. The result is verbally announced via the built-in speaker. If Roll is pressed again, the result will be repeated. Reset empties the pool.



03 The different modes make life even easier. A die pool can be saved and loaded to a microSD card which is inserted in the top of the device. The device can be made to talk less by long-pressing d4 to make use of chimes instead.

Spin

Ever wondered what death metal disco sounds like? Spin will not only create it, but let you scratch it, too, as **Sean McManus** discovers



MAKER

Arvind Sanjeev

Arvind is a design technologist who loves to experiment between the boundaries of the physical and digital.

magpi.cc/spin



Danger!
Mains Electricity

This project involves disassembling a mains-powered record player.

magpi.cc/electricalsafety

"My idea was to remove AI experiences from black boxes and put them into the physical world," says Arvind Sanjeev. "It's an open invitation for people to forget about the digital world and to try to create something with AI."

His previous project was Ghostwriter, a typewriter which he converted to use text generator ChatGPT. Humans type their messages and Ghostwriter types its replies onto the same sheet of paper.

He wanted to create a family of devices and was thinking about where else AI has been disruptive. "The latest music AIs have become so good that it's really hard to distinguish them from a human creator," he says. "Spin is this curiosity tool that allows you to explore the boundaries of creating music with AI. I took a lot of inspiration from old analogue synthesisers and combined it with a digital vinyl system DVS."

Using AI platforms, you usually describe what you want in text. "It's hard for someone who's using it for the first time to come up with a really nice prompt," says Arvind. "I wanted to bring as much physicality into this interaction as possible, rather than using a keyboard to type in what you want."

Play that funky music

At first glance, Spin looks like a record player. In fact, half of it is. The other half is a grid of buttons. One row allows you to select a mood, such as spacey, warm or dark. Two rows set the genre, including death metal, trance and jazz. Three rows are dedicated to sounds. There are instruments (including drums, sitar, and violin) but also the sounds of water, nature and opera. There are no constraints on how many buttons you select, or what combinations you use. If you can't decide, there's a random button.



The duration of the music and tempo are set using sliders. Knobs control the volume and speed. "I thought: What are the maximum different kinds of physical interactions I can bring to this device?" Arvind says.

When you press the generate button, your chosen options are used to create music. When it's ready, the record starts to rotate. "It is a signal or

The record player controls playback and is used for scratching

The user's choices of moods, genres, and sounds are used to generate the music.

These knobs control the speaker volume and speed of the record player motor

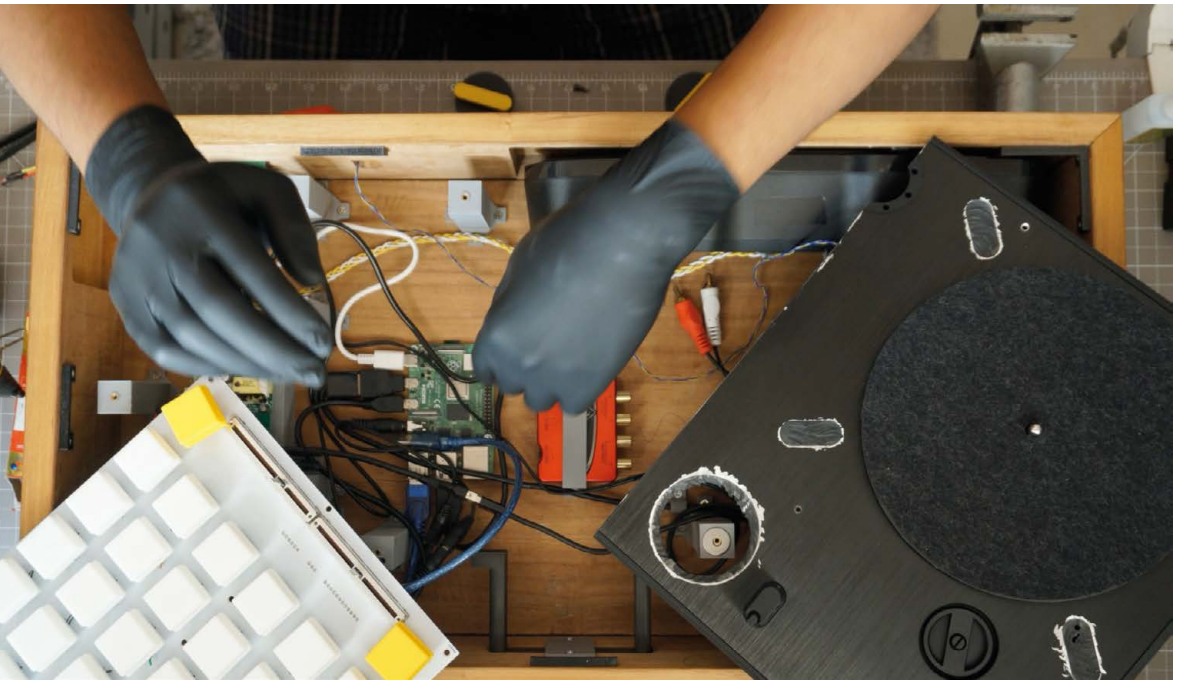
Quick **FACTS**

- Raspberry Pi stores all the music files to revisit later.
- Meta trained MusicGen with 20,000 hours of licensed music.
- The record player is a Numark PT-01.
- The Arduino Mega has 54 digital input/output pins.
- The project took just under two months, outside work.



Raspberry Pi 4 is mounted under the record player. The tiny HDMI screen is shown bottom right.

▼ Arvind removed the record player from its casing so it would fit his cabinet.



invitation for you to listen to it," says Arvind, "but in order to listen to it, you need to physically take the needle and put it on the record." By turning the record backwards and forwards (scratching), you can manipulate the sound.

Leave a light on

Inside the cabinet, Spin houses an Arduino Mega, Raspberry Pi 4, and Behringer audio interface. There is also a speaker and a tiny HDMI screen at the back, connected to Raspberry Pi, to help with debugging.

The buttons have individual NeoPixel LEDs on them (WS2812b) that light up when the button is selected. They're illuminated in an animated pattern, using the FastLED Arduino library, when the device is switched on, and 3D-printed enclosures act as diffusers for the LEDs.

Arvind prototyped Spin on a breadboard, and then used the open-source design software KiCad to design a printed circuit board (PCB). The PCB was made for him by a company in India.

He chose the Arduino Mega so he could be certain he'd have enough input pins. "I always want a little more freedom," he says. "I can use extra pins if I want to add something in the future."

A keyboard matrix library takes the input from the buttons and maps it as if it's a keyboard. The Arduino creates the text prompt for the AI by combining the words associated with the buttons and the tempo and duration options. The prompt is sent to Raspberry Pi through a serial to USB cable.

Arvind's Python program on Raspberry Pi sends the prompt to MusicGen, running in the cloud. "At the time, MusicGen was one of the most flexible and creative platforms out there and it sounded relatively good compared to others," says Arvind. "The other models didn't have openly accessible application programming interfaces that I could use."

Spin me right round, baby

To play the music, Spin uses xwax, an open-source digital vinyl system for Linux. This software

enables DJs to control the playback of music files using a normal turntable and a time-coded vinyl record. "It gives them the ability to scratch any music," says Arvind. "Instead of having music in the grooves, it has timestamps. If you listen to it, it sounds like beeps or a sine wave."

The signal is sent as audio to a Behringer audio interface, which converts it to digital for Raspberry Pi. Xwax decodes the incoming sound into the timestamps to control the music.

One challenge was that xwax uses a graphical user interface and can't be controlled from the command line. Arvind used a keyboard emulator to simulate the keyboard shortcuts required to load the new track and play it.

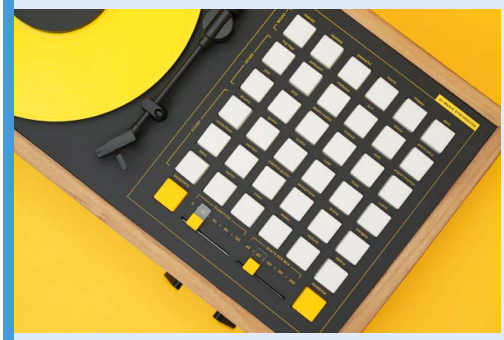
The project didn't run entirely smoothly. "It failed at the last point, when everything was in the enclosure, even though I'd been testing in stages," said Arvind. "I thought it was a software glitch, or it had something to do with the needle not being sensitive enough now because it had been running a long time. I took everything apart, piece by piece, and tested it. There was a loose contact within the audio jack from the record player that I had to resolder."

> "I took everything apart, piece by piece, and tested it"

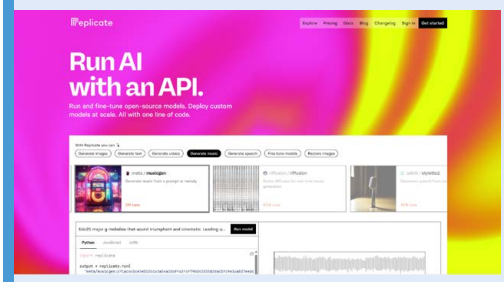
Arvind's had queries from DJs asking if he's selling it, and he's hoping to collaborate with artists in the Bay Area when he relocates to San Francisco shortly. He has no plans to start manufacturing it, though, preferring to do more experiments. "I would be happy to see someone creating their own commercial version," he says. "That would be a nice thing to see in the world."

What's his favourite combination? "I love lo-fi tracks," says Arvind, "so I always start with a combination of peaceful, hip hop, lo-fi and some piano. But death metal orchestra and death metal disco are really fun to try."

Taking AI for a spin



01 The buttons are connected to the Arduino Mega using a keyboard matrix. The Arduino receives your button choices, and turns them into a text prompt for AI.



02 Raspberry Pi sends the prompt to the MusicGen AI model, running on **replicate.com**. Raspberry Pi converts the audio from WAV to an MP3, which is played using the xwax digital vinyl system.



03 The signal from the time-coded vinyl is sent as audio, through a Behringer audio interface to the Raspberry Pi. Xwax converts this audio to timecodes and controls the playback.

Puttr

Getting good at golf without the green fees with a bit of help from Raspberry Pi? **Rosie Hattersley** wants to know more



MAKER

Matthew Allard

Puttr CEO Matthew has worked on mobile software and for AOL on smart home development. This is his first Raspberry Pi project.

puttr.co

Executive boardrooms up and down the land are (according to urban myth or business tropes) stuffed to their expensive gills with bag after bag of golf clubs; their owners while away the working week so they can head off to the fairway and execute some impressive swings and putts.

What joy to learn of a miniature putting mat that puts those otherwise idle clubs to good use mid-week too. Puttr (**puttr.co**) makes excellent use of Raspberry Pi 4 and an HQ Camera to determine whether a putt is made or missed, logging results on a linked app.

Like many great ideas, Puttr came about because of some enforced downtime during lockdown. Entrepreneur and founder of several successful start-ups Matthew Allard had been on the golf team at university, and lockdown had him contemplating an at-home putting game that he and his son could both enjoy. Matthew had a personal interest in how software and computers can interact with the real world, and having taken post-graduate courses in embedded systems was keen to make use of what he'd learned.

One thing Matthew knew already was that "putting practice is boring and lonely" (don't they have crazy golf courses in the US?) yet it accounts for 42% of time golfers put in. Creating a means to connect fellow golfers and 'gamify' putting could transform this rote activity and allow members of the golfing community to challenge each other with online tournaments.

Hits and misses

Matthew originally aimed to track made and missed putts via an app using sensors in the hole of an at-home putting mat hooked up to GPIO pins. However,



▶ The 3D printed and injection moulded case doubles as a storage case



Quick **FACTS**

- The hole in a golf course is only 2.5x the diameter of the ball
- Off-course golfing exceeds on-course golfing
- Adjustable legs help ensure the playmat is fully flat
- While Raspberry Pi's camera provides a visual confirmation...
- ...then automatically connects putting mat to phone via Bluetooth

A perfectly flat putting mat is vital: the camera comes in useful again here, lighting up an LED when alignment is just right

Puttr uses Raspberry Pi 4 and a wide-angle camera to detect 'made and missed' putts, gamifying an otherwise repetitive aspect of golf practice

Shots can be taken from different places on the 11-foot putting mat, with results logged to the Puttr app and optionally shared with followers

he soon discovered this approach was limited: "I could detect when a ball went in the hole, [but] I couldn't detect missed putts." Next, Matthew tried break-beam IR sensors to get more precision and measure missed putts, as well as 'makes', but "quickly realised that any sun exposure would cause false positives in the break-beam".

A friend tipped him off about Raspberry Pi, and Matthew soon saw he could use computer vision and a wide-angle lens to detect the location of the physical hole, then track any golf ball that passed its field of view. Once a ball has entered or exited, it sends the full ball path data over Bluetooth to a connected app on an iOS or Android device, he explains. Details of each putt are logged, with the user able to access stats on their performance and optionally share it with other Puttr users.

Raspberry Pi quickly proved a great choice, since it offered an operating system with all the tools he needed for the software along with good value hardware that worked well together. "Many suppliers tried to talk me into creating my own board [but] there were many reasons to use Raspberry Pi." The camera connection, Bluetooth, Wi-Fi, and processor were all included. Matthew was also encouraged by the strong community keen to help with any troubleshooting he might need, given this was his first ever Raspberry Pi project.

▼ Putts can be attempted from multiple distances with balls returned down a chute



Embrace the light

At first, Matthew stuck with his infrared break-beam idea, testing it in his garage in the evenings after long days at his day job. There were "a ton of tweaks" to get the computer vision to work well under different lighting conditions. Eventually, it seemed as though the beams were working just as he expected. "I would get a break when the ball enters the ramp, and another one when and if it entered the hole. Perfect!"

Replicating results when demonstrating the embryonic Puttr game to his son was less successful. In fact, it didn't work at all in daylight. Matthew eventually realised that sunlight hitting the beam's receiver was preventing the circuit being broken even when a ball passed through



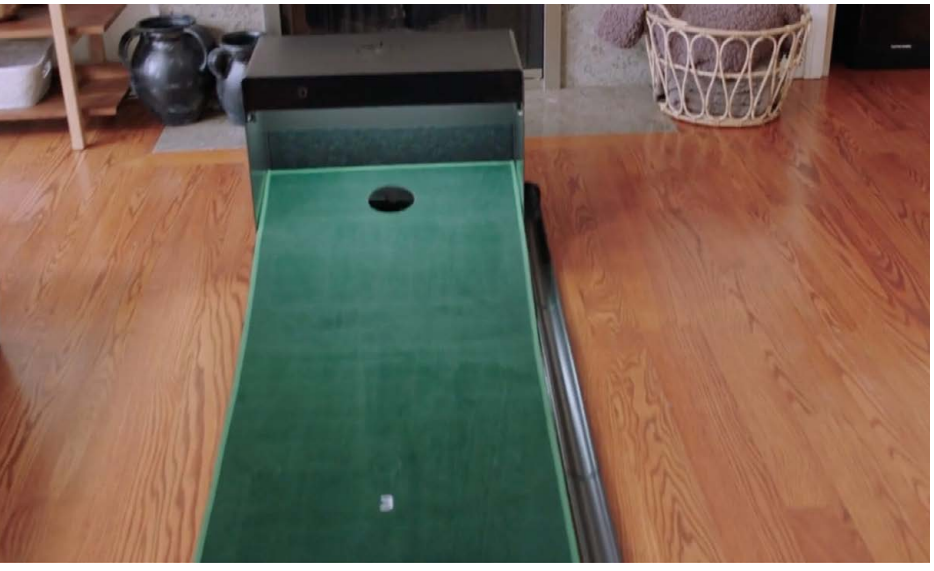
▶ Putting mat and chute roll up and are storage in the self-contained Puttr box

it because it emits infrared rays of its own: "Apparently I missed that in school!" Connecting Raspberry Pi 4 to a GATT server (for Apple devices) as a headless Bluetooth peripheral meant code pairing was not an option. Instead, Matthew created a Bluetooth Write Characteristic that can receive a Wi-Fi SSID and password specifically for the task. He then wrote all the computer vision code and app software to make Puttr work.

> The Puttr app has logged more than a million putts

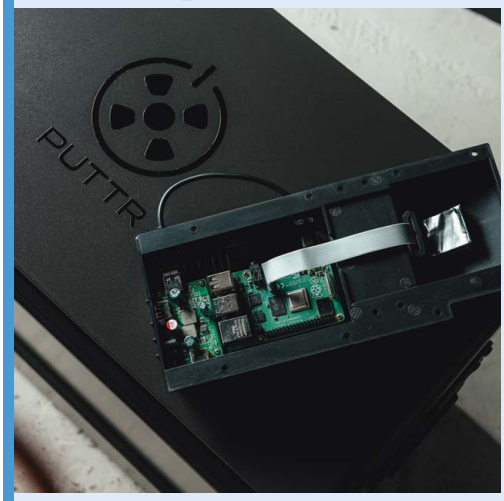
Prototyping involved laser-cutting Baltic birchwood, and Matthew's first foray into 3D design and printing using CraftCloud to create the box used as both ball tracker and holdall, the ramp, and ball return chute. The clever design is portable, with the mat rolling up inside.

Matthew praises the "stable, tested OS, camera interface, Bluetooth and Wi-Fi, and says choosing Raspberry Pi meant R&D took at least a year less than choosing a different setup with costs that would have been much higher. New versions and applications are already planned. Since launching 18 months ago (after a successful Indigogo crowdfunder), the Puttr app has logged more than a million putts. The clever take on pitch and putt now has worldwide league tables, games and challenges, with a subscription model for golfers keen to pit their skills against others.

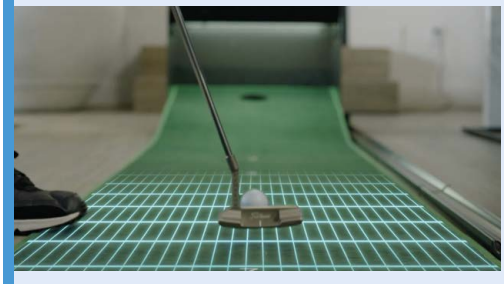


▼ The Raspberry Pi camera tracks the golf ball as it approaches the hole, logging whether it is putted

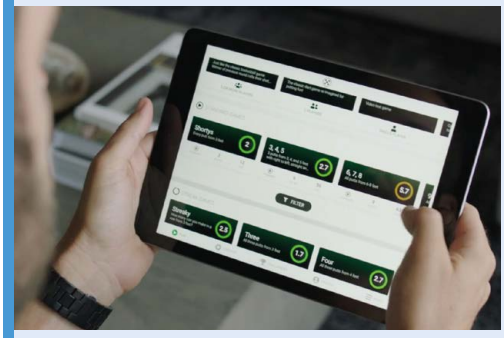
Pitch for perfection



01 Creating a putt-tracker involves mounting Raspberry Pi 4, an infrared lens and wide-angle camera lens in a case (Puttr's was injection-moulded). Custom computer vision code for Raspbian Buster Lite OS discerns successful putts.



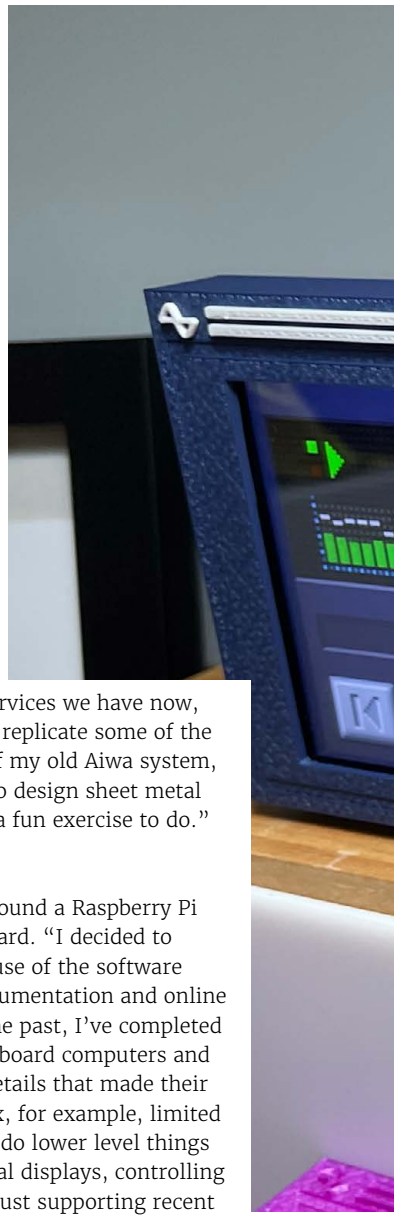
02 The box also contains a printed circuit board and a USB LED light placed above the golf hole, plus a break-beam laser mechanism triggered by the golf ball rolling into the hole or running wide.



03 The Puttr app automatically connects the mat to the phone or tablet via Bluetooth and records statistics for each player's putting average.

Linamp

Adore music from the 1980s and 1990s? Then wind back time and play your tracks on this Winamp/hi-fi-inspired set-up. **David Crookes** gets into the groove





MAKER

Rodrigo Méndez

Rodrigo is a software engineer, hardware hobbyist and industrial design aficionado from Mexico. He's been tinkering with hardware since 2010.

magpi.cc/linamp

When looking to play MP3 music files for a good while from the late-'90s onwards, Microsoft Windows users would tend to migrate towards the Winamp media player. Originally released in 1997 and developed by Justin Frankel and Dmitry Boldyrev, Winamp's skeuomorphic user interface soon resembled a compact stereo system. It was instantly accessible and it certainly caught the attention of a young Rodrigo Méndez – so much so, he's based a cool Raspberry Pi project on it.

"I remember when I first got my own PC – an 800Mhz Athlon with Windows 98," he recalls. "My cousin installed Winamp in it and gave me some MP3s to play. At that time, seeing music coming from a PC, and having the visualisations move in real time to the music was unbelievable to me because my previous experience with computers had been an old MS-DOS PC that my dad had at work."

For his project, Rodrigo wanted to bring Winamp's early days back to life in a more physical form so he decided to produce a music player that could easily be part of a hi-fi mini system. Specifically, he took inspiration from a Aiwa mini setup from around 1983, figuring he could create a case and have all of the functions available on a front touchscreen display.

One thing he noticed was the simplicity of design of the old devices. "Old electronics, especially audio devices, managed to look high-tech and yet elegant," he explains. "They managed to fit in well with people's home décor while using relatively simple construction techniques such as sheet metal or wood. I thought that, with all the new manufacturing services we have now, It wouldn't be too hard to replicate some of the construction techniques of my old Aiwa system, so I set out to learn how to design sheet metal parts, which was in itself a fun exercise to do."

Physical

Rodrigo based his build around a Raspberry Pi 4B with a 32GB microSD card. "I decided to use the Raspberry Pi because of the software support and extensive documentation and online resources," he said. "In the past, I've completed projects with other single board computers and I've always found small details that made their usage much more complex, for example, limited documentation on how to do lower level things like interfacing with special displays, controlling the boot process, or even just supporting recent Linux kernels.

"Since this was a hobby project, I didn't want to spend too much time figuring out those details on other SBCs. Also I chose Raspberry Pi 4 because it was the latest model at the time I started the project. Raspberry Pi 5 was announced after I'd begun and I figured I didn't really need that device's performance anyway."

At first, Rodrigo toyed with the idea of making the front face physical. "I wanted to add real-life buttons using a 3D printer and I was going to design a custom PCB for the interface," he says. But he couldn't find screens with the correct size and dimensions for the spectrum analyser and song information displays that needed to be included to remain faithful to Winamp without making the build too complex.

The intention was always to create a standalone appliance. The casing was designed with a square hole so that a custom back panel could be created to host the connections

Rodrigo had considered a front cover 3D printed on Nylon but he opted for a multi-colour 3D print created on his Bambulab P1S 3D printer instead

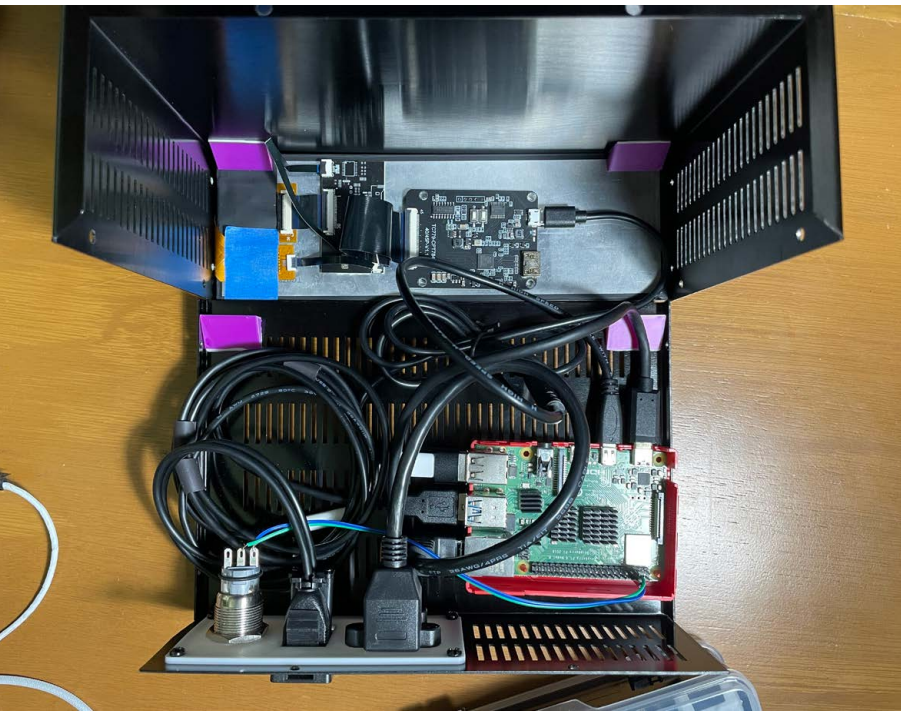
The touchscreen display has been based on Winamp 2.0's Base Skin. This version was released in 1998 – two years before Rodrigo got his own PC

Quick **FACTS**

- It's a music player inspired by the Winamp app
- All of the functions are on a touchscreen
- The software has been written from scratch
- The case design is based on retro hi-fi systems
- It cost around $700 to make



This is the Aiwa stereo tuner and amplifier which inspired Rodrigo to create his own retro hi-fi device



▲ A Raspberry Pi 4 forms the heart of this build. It is connected to a generic 7.9-inch touchscreen display. Extension cables allow for rear ports

"Making it physical would have made it less flexible as well," he adds. For example, I would not be able to have the playlist view in the same display, which would make the device bigger and clunkier so I decided to go with a touchscreen." This, he figured, would stretch across the entire front of the device and include all of the buttons as part of the UI. He reckoned his background as a software engineer meant this would prove to be relatively straightforward.

A little more love

Rodrigo opted for a 7.9-inch extra-wide screen and he created the case using sheet metal, sending his Onshape designs to PCBWay so they could be produced using 1mm anodised aluminium. He'd closely analysed his Aiwa system so he could figure the correct dimensions and overall look and, for convenience, he placed a power button, Ethernet port, USB-A and USB-ports and 3.5mm stereo jack at the back.

The majority of his time was spent on the software, however. He created a custom Qt 6 app which he wrote in C++. "Replicating the layout itself wasn't that hard, it was just a matter of getting rough dimensions at first and drafting the UI in Qt Creator using the graphical Qt



▶ Rodrigo is looking to create Linamp devices for sale and wants the community to help him figure the logistics by filling in survey at **magpi.cc/linampsurvey**



▲ Linmp can play MP3, M4A, FLAC files and more. You can control the output volume and balance too

Widget designer interface, and then fine tuning dimensions by comparing screenshots in GIMP," he explains. "The complex part was replicating the spectrum analyser and getting the raw audio data to feed it. I did a lot of research and looked into other open-source projects' code to get ideas and code to base my solution on."

It's proven to be a very vivid, eye-catching solution and it doesn't feel as if any compromises have been made. Above all, it has the intended nostalgic flavour thanks in the main to the spectrum analyser and the way the name of the song and artist scroll across the top. It also retains the intuitive UI in full, so songs can be selected and played in no time. "Linamp supports playing music CDs from a CD/DVD drive connected via USB as well, but you need to use a powered USB hub in order for the drive to work, otherwise Raspberry Pi may not have enough power for the external drive," Rodrigo adds.

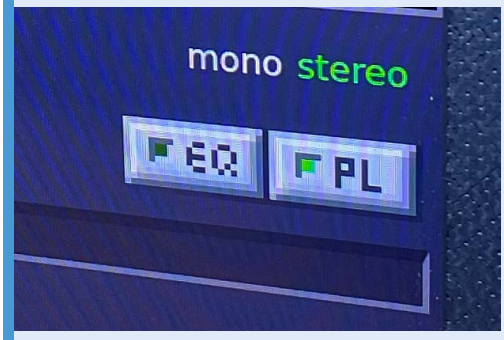
> "I looked into other open-source projects' code to get ideas and code"

Yet despite being feature packed, Rodrigo wants more. He's also been overwhelmed by the positive reaction from people who have seen the project and he is working on adding Spotify playback and Bluetooth. "It had an amazing response," Rodrigo says. "I never imagined it would have been that popular, especially on YouTube, where I uploaded a quick video of how the UI works as an afterthought." With more than 100,000 views, we don't think we've heard the last of this project.

Pump up the volume



01 First of all, press the power button on the back of the device to turn it on. The screen will remain blank while Raspberry Pi boots directly into the Linamp UI. Once done, it's ready for the selection and playing of music.



02 Touch the PL or Eject button in the UI and you'll go to the Playlist view. A file browser lets you navigate the Raspberry Pi filesystem, starting at the **~/Music** folder by default. Songs can be stored on a home server or USB drive.



03 Select music files and click a button to add them to the playlist then start playing your fabulous tracks. The track information is displayed along with the bitrate and sample rate and there's a real-time bar spectrum analyser.

Gehn Imager
Andotrope

Replicating a beloved display from a favourite game yielded amazing results for one Raspberry Pi maker, discovers **Rosie Hattersley**



MAKER

Mike Ando

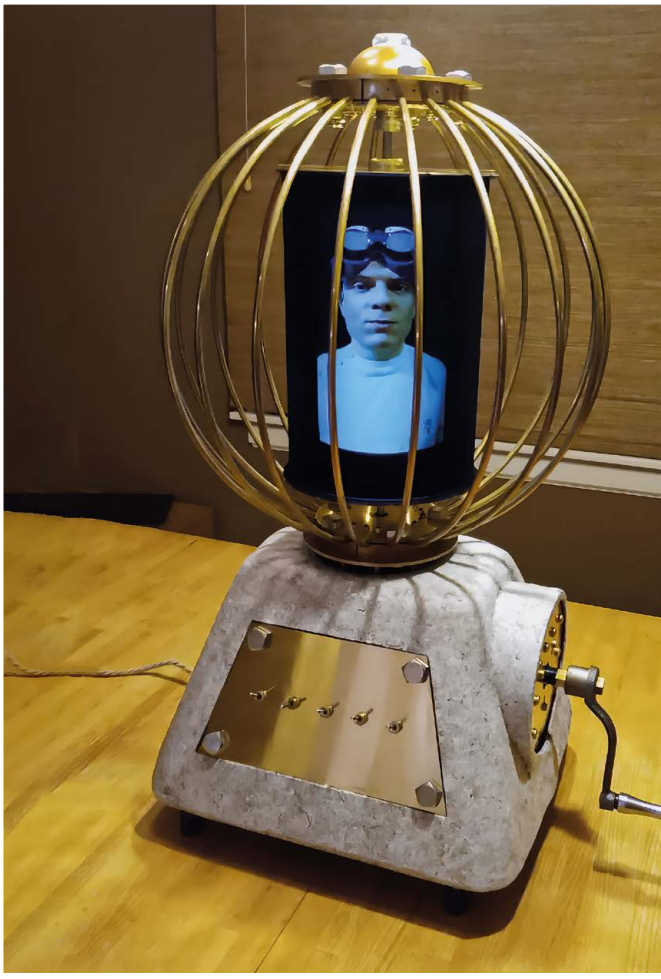
DeLorean driver Mike looks after IT for a small business and says others describe him as a time-travelling mad scientist

magpi.cc/andotrope

Mike Ando loves making things in his spare time, and uses a Raspberry Pi "because they're so easy and save me time implementing things". Even so, he's just spent eight months designing his own take on Gehn's holographic imager from the game *Riven*, the sequel to puzzle adventure *Myst*. As well as displaying images and playing video clips, it can be used for video calls and games. "Basically, I've brought a 150-year-old children's toy into the 21st century." Actually, the Australian systems administrator has created two such 'andotropes'. The second version uses Pico W which is much smaller and cheaper and doesn't use so much expensive and heavy brass, but The MagPi was especially taken with his original, Raspberry Pi 3 model which requires no CGI or other visual trickery and uses two back to back 10in tablets: **magpi.cc/andotropeyt**.

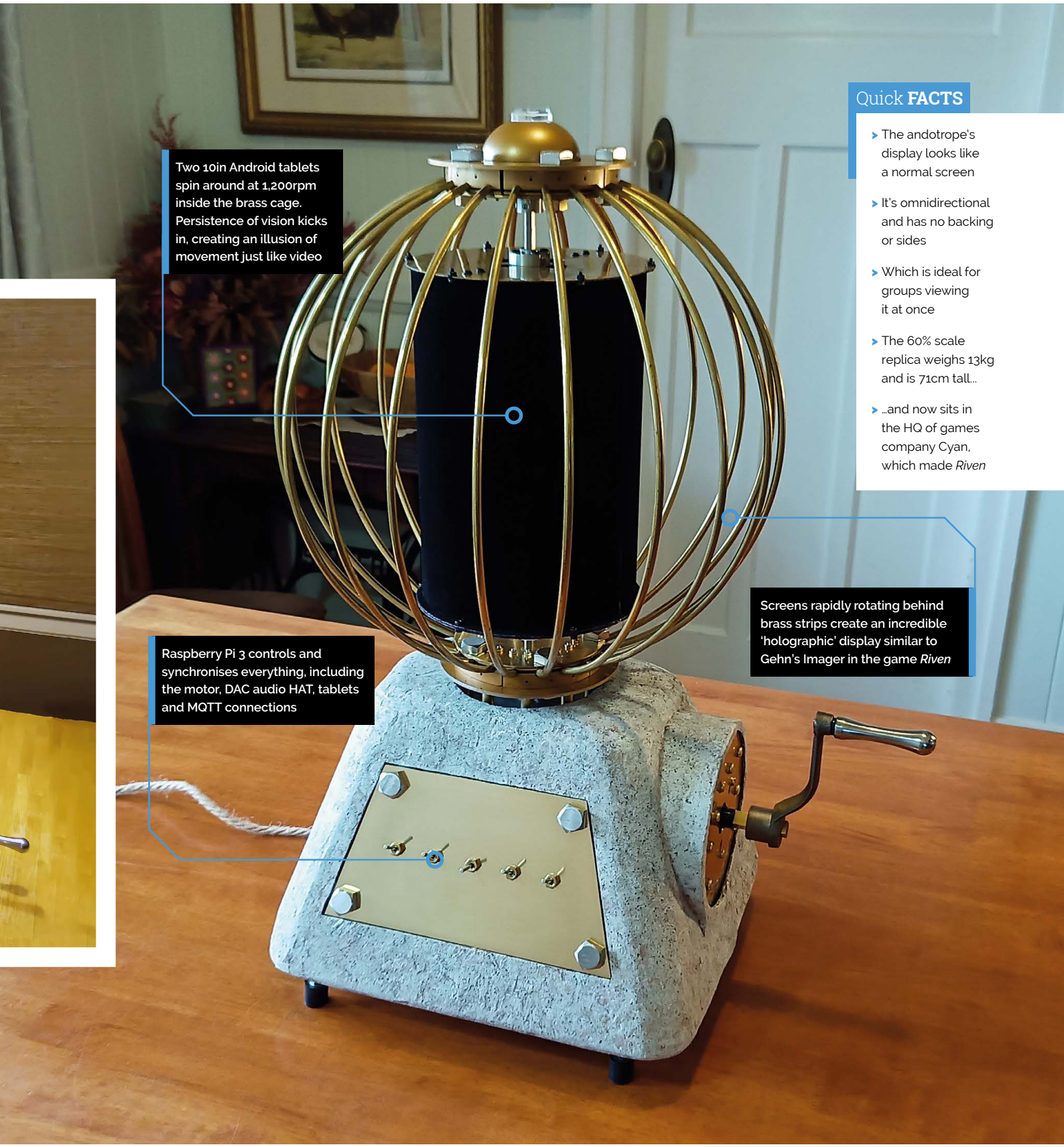
New tricks

If 'andotrope' sounds unfamiliar, that's because it is a word Mike coined, having almost by chance ended up creating a new form of display. His hologram-like display sits inside a spherical cage constructed from around 12m (40ft) of 6mm brass tube. "It doesn't quite meet the definition of a zoetrope, and because I couldn't find anyone else who successfully pulled this off before, I'm calling any display you could build that's similar to this by the generic term 'andotrope'".



▶ Mike managed to display his own image in the andotrope

The whole imager is actually 60% scale of the original in-game one. "The original was just impractically large and everyone who has seen it in-person (including the game's creators) thinks my one is the right size and big enough," explains Mike. His confident stance is not easily merited:



Quick **FACTS**

- The andotrope's display looks like a normal screen
- It's omnidirectional and has no backing or sides
- Which is ideal for groups viewing it at once
- The 60% scale replica weighs 13kg and is 71cm tall...
- ...and now sits in the HQ of games company Cyan, which made *Riven*

> At 1,200rpm, persistence of vision kicks in, creating an illusion of movement just like video



▲ Construction was a lengthy process



▶ A still from *Riven* showing the Gehn's Imager Mike has replicated

Mike is a self-taught maker and IT specialist who drives a DeLorean to maker events where his take on *Myst*'s linking book has gone down a storm: **magpi.cc/mystbook**.

Mike had not made anything with Raspberry Pi before, but it seemed ideal for the andotrope because he "needed a small, powerful computer with a lot of capabilities. Something that can blink lights on and off very well wouldn't cut it for this project. An Arduino or ESP32 microcontroller just isn't powerful enough, and a full desktop x86 computer would be such a hassle". Raspberry Pi is used as a central computer to act as the master control device – the main hub that controls and synchronises everything. It handles the user input and the local Wi-Fi network, it communicates to the tablets via MQTT, it manages the Arduino Pro Mini motor controller and DFRobot DRI0042 motor driver, and it plays back the audio. "I'm quite impressed with how much it can manage simultaneously!" says Mike.

Mike used ChatGPT as the starting point for his code, manually editing it, "fixing the edge cases" and expanding its scope. He then focused on finessing the displays so the two tablets were synchronised and phone photos and videos looked good. There were also tweaks to the andotrope's rotational speed and adjustments to the width of the viewing slit to improve the illusion of movement.

Brassed off

"Brass is a beautiful metal but I find it a pain to work with," says Mike. Designing and creating a means to securely hold all the brass rods in place was "a major headache", and the andotrope mechanism was also a challenge. "It's not that hard to get one of those displays working, but it's a lot of effort to get it working well."

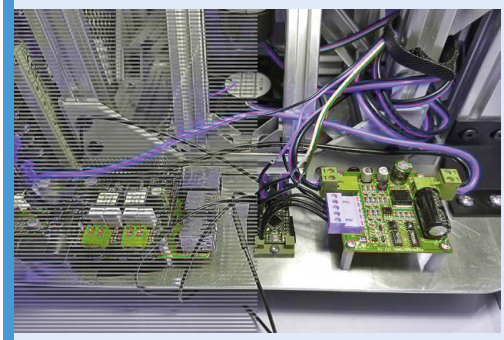
The andotrope project ended up "pretty expensive thanks to all that brass!" Mike notes that the brass sphere alone was around $700. The 10in Android tablets he chose were also pricey, but use very little power when sitting idle and "happily last a full nine hours of constant playing at a convention with battery life to spare," which he finds pretty amazing.

There are a lot of different uses for the Andotrope display – everything from a personal digital assistant (Siri/Alexa) display to a teleconferencing system to playing board games with friends. Anyone trying to create their own should use a phone or a tablet with zero flicker to its video, as any flicker at all will show up at high rotational speeds.

Use your illusion



01 The back-to-back Android tablets, motor and stepper controller, plus wireless access are all Raspberry Pi 3B-controlled.



02 Toggles on the outside of the case trigger the content to play, while Raspberry Pi tells the Arduino motor controller to spin the screens at a rate that ensures only one animation (length unimportant) is shown at once.



03 Mike designed a 3D printed case and spent hours fitting all the components and brass struts in place. A Python script runs on startup to control everything, with the two screens rotating at 1200rpm to simulate movement and be viewable from any angle.

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



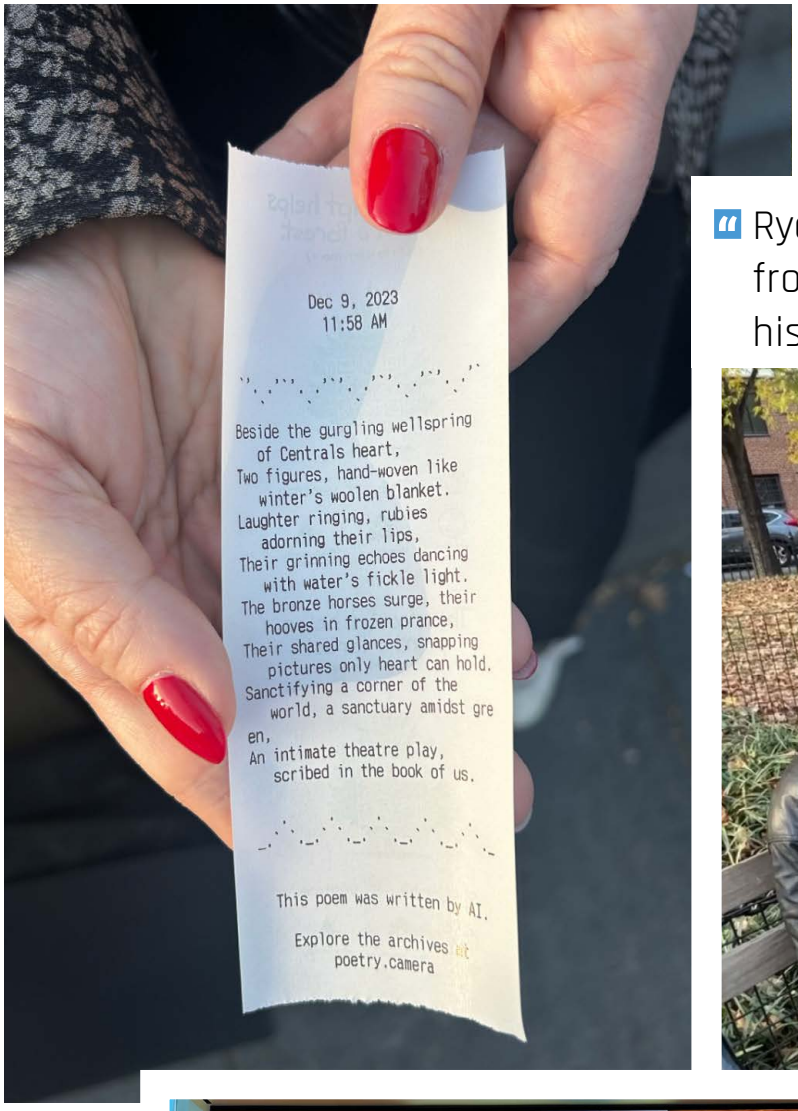
A fresh focus

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."

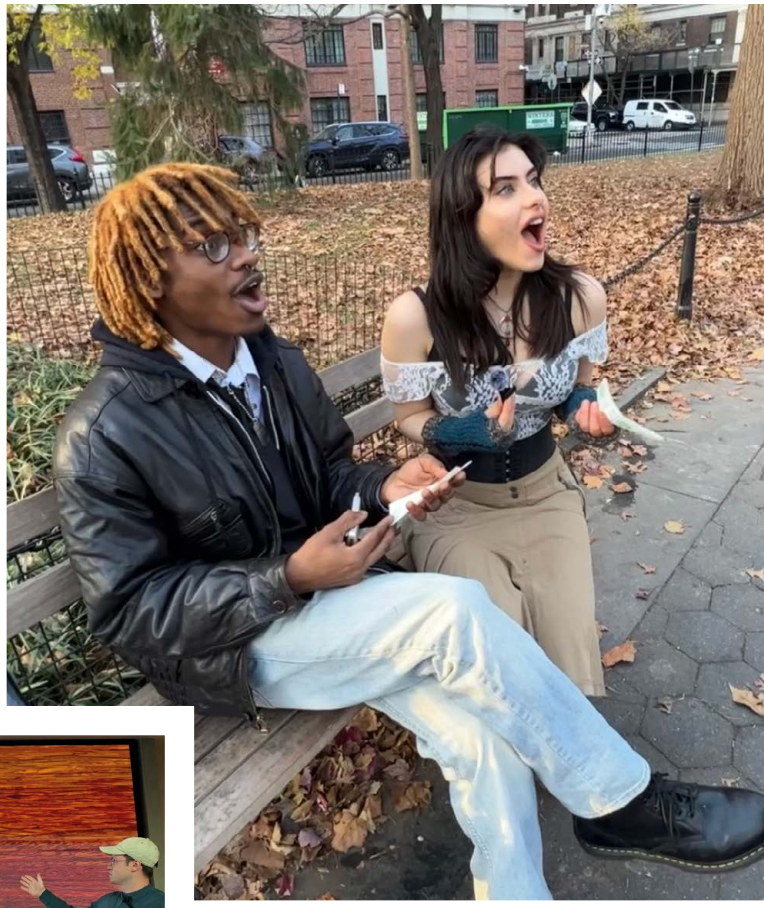


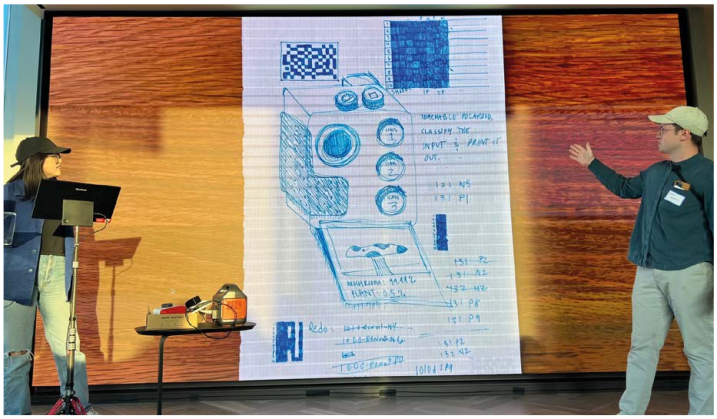
Quick **FACTS**

- 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.

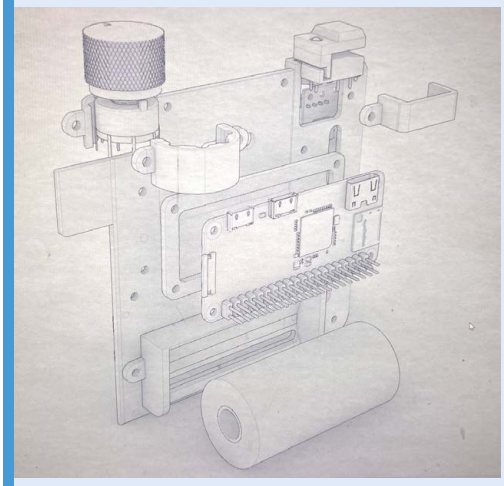
He was "ecstatic to create something from scratch, and prototype it on his home 3D printer". Having started out as pen and paper sketches, Poetry Camera's form was created and iterated on in Rhino.

Power play

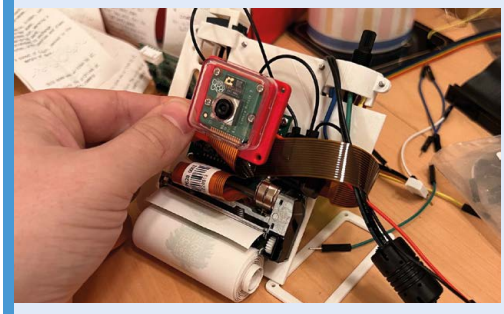
As "the brain of the whole device," Raspberry Pi Zero 2 W connects to a Camera Module 3 and a thermal printer via UART. It calls on remote AI models via an API for pointers on poem writing. The idea was that they'd get faster responses this way, but this approach necessitates connecting to Wi-Fi hotspots, 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



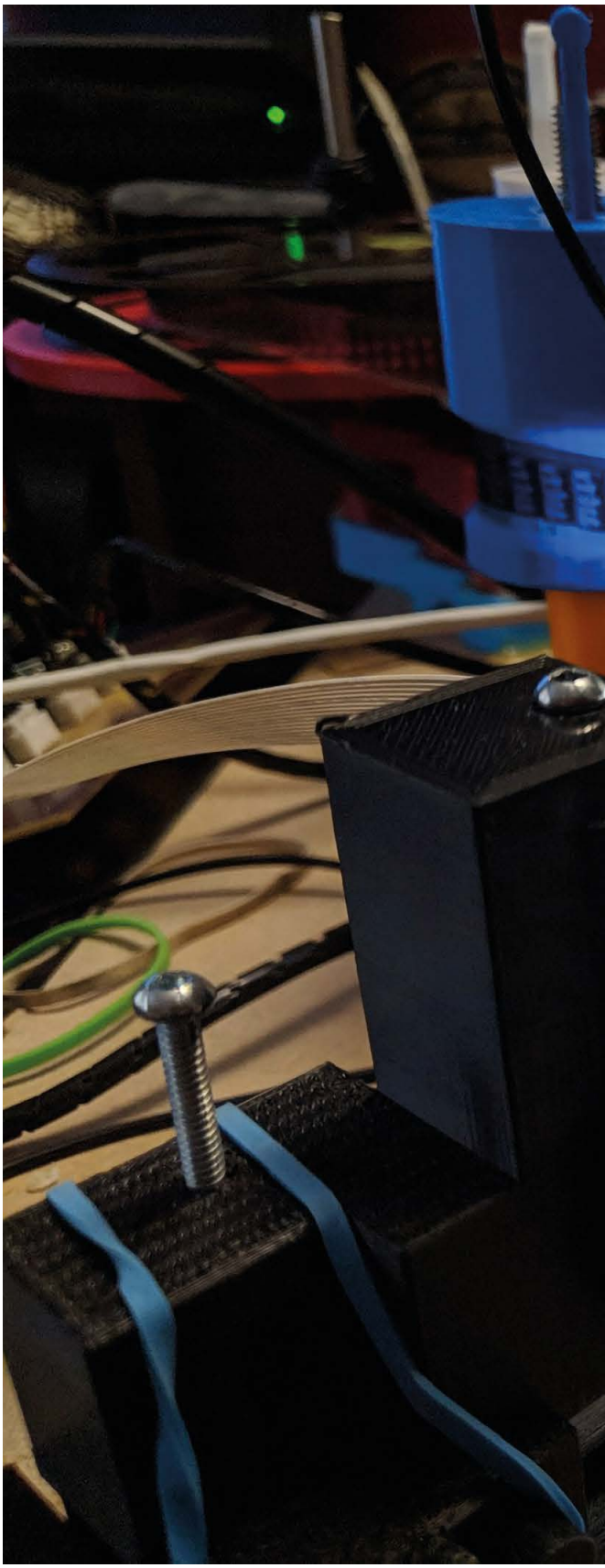
01 Poetry Camera contains Raspberry Pi Zero 2 W and uses Camera Module 3 to capture an initial image.



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 **magpi.cc/poetrycamgit**.



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**).

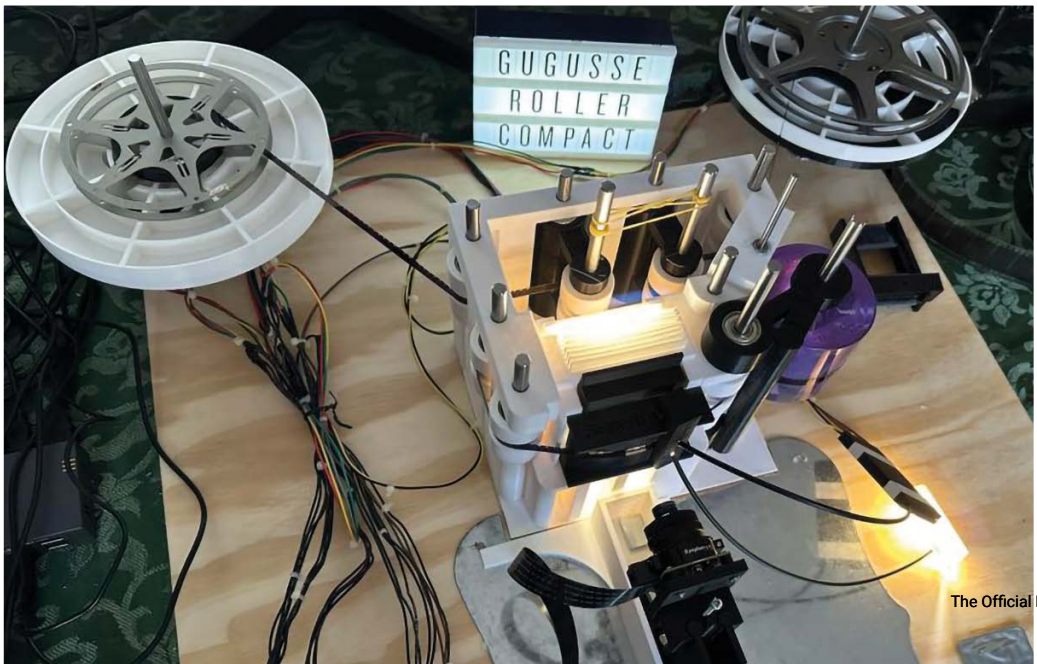
The Gugusse roller uses Raspberry Pi HQ camera and Raspberry Pi 4 to import and digitise analogue film footage

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

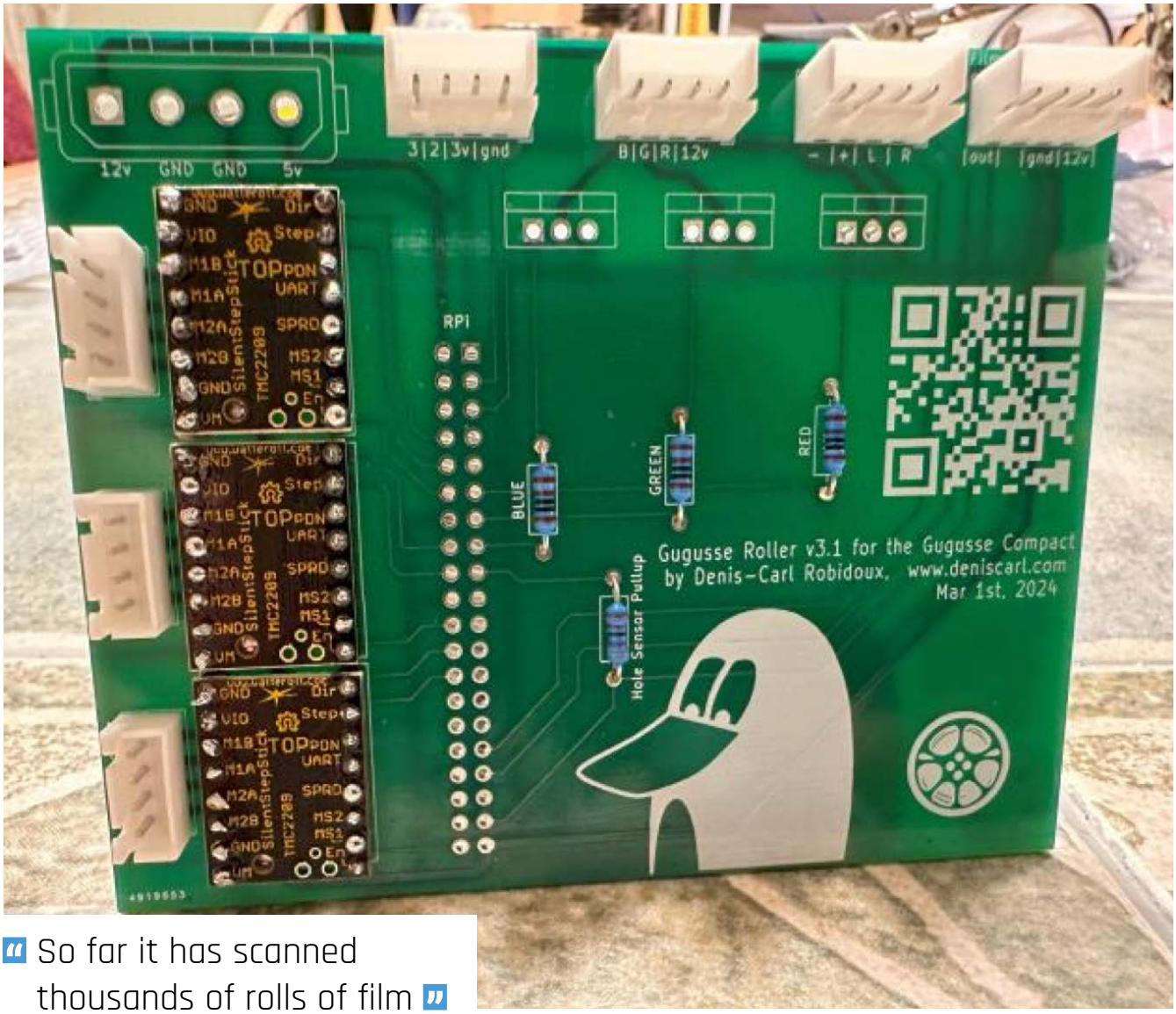
Quick **FACTS**

- 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)**

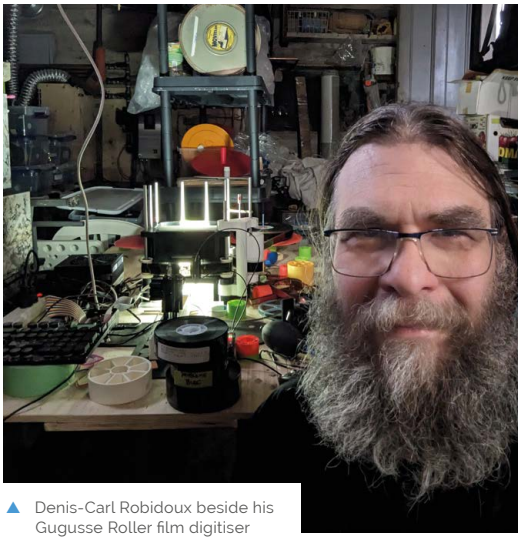
▼ Version 3.1 of Denis-Carl's Gugusse Roller PCB



> 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**).

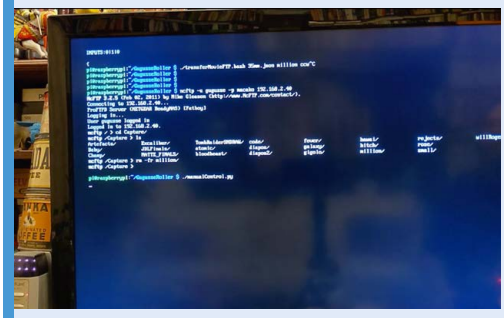
Roll VT



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**.

Portable Pi 84

With a mechanical keyboard powered by Raspberry Pi Pico and with Raspberry Pi 4 at its heart, **David Crookes** has fallen in love



MAKER

Michael Mayer

Born in Austria, Michael was 12 years-old when he began programming in BASIC on a pocket computer. Today he works as a software engineer.

magpi.cc/pi84portable

As impressive looking as modern laptops are with their heights usually measured in millimetres, the chunkier devices of yesteryear still have the power to turn heads. Their solid builds gave the impression that you could drop them off a cliff and still manage to use them to write about the incident later. There was also something rather attractive about their no-frills, plasticky nature.

It is to those bygone laptops that Michael Mayer has turned when creating his own portable classic. Named the Portable Pi 84 – by virtue of being driven by a Raspberry Pi 4 computer – it takes inspiration from the machines that had very clear central hinges. It also sports a fun, red colouring and has a widescreen display that is more than large enough to be productive.

This little device includes a mechanical keyboard that, Michael says: was his primary motivation for making his retro marvel. Having first cut his teeth learning BASIC on a Sharp PC-1260, he quickly became a fan of portable computers and snapped up many more. But when, in recent years, he sought to revive his interest in such machines, he said he's been left disappointed.

"I have tried Raspberry Pi and Linux-compatible portables and laptops but I've never been really satisfied with their keyboards," he says, name-checking the Pocket C.H.I.P, Devterm and uConsole projects. "Even at work I used a mechanical keyboard with the company laptop so I started to search for smaller keyboards and portable Raspberry Pi projects. I then found ZeroWriter."

Key to success

ZeroWriter is an open e-ink typewriter with a Raspberry Pi Zero 2 W board at its heart. Michael decided to create one for himself, and ordered the Vortex Core 40% keyboard while swapping out the WaveShare 4.2-inch e-paper display with a Waveshare five-inch monitor. "As there was still space, I added a speaker to the side," he adds. "But the project was limited in terms of the Python audio effects development I wanted to pursue."

Michael decided to take the project to another level, hence the use of Raspberry Pi 4. "With the experience of my first build, it was clear that I should go bigger and I also searched for another keyboard," he says. Looking on **pcbway.com**, he found the Happy Keyboard, a 47-key, 40% ortholinear mechanical keyboard that uses a Raspberry Pi Pico development board running KMK firmware. It formed the basis of the design for the entire project.

"I started with the keyboard because it was the single largest part of the build," he explains, adding that the next step was to find a display. "I searched for a screen with vertical resolution bigger than 400 or 480, and found a 9.3-inch display by Waveshare with a funky resolution of 1600×600 which fitted perfectly to the 40% keyboard." This setup dictated the design of the project's case, and it helped that every Waveshare screen comes with a CAD file and audio amplifier.

"It was all natural and fell into place because of



▶ Michael originally sought to create his own version of the ZeroWriter project incorporating a Raspberry Pi Zero 2 but felt it was too limited for what he wanted to do

The 3D-printed case was designed in FreeCAD to the fit the keyboard but, happily, the screen was almost the same size too

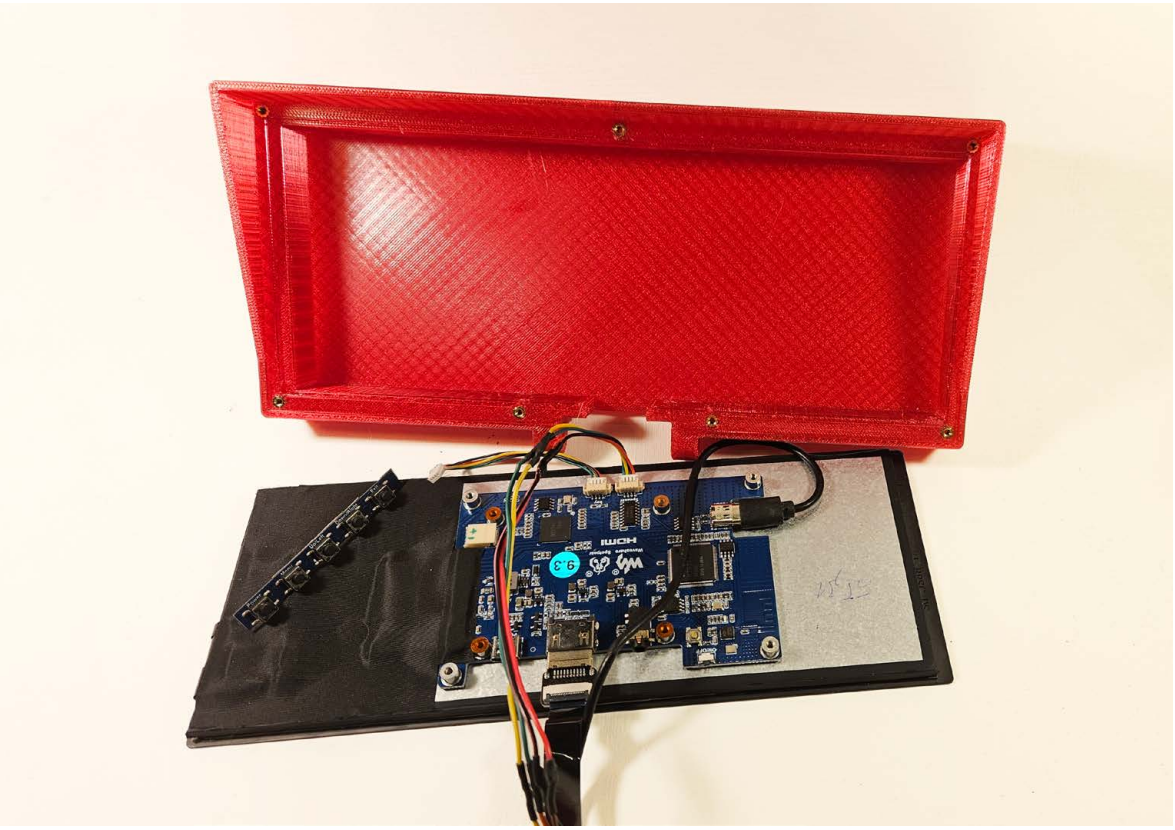


The project's 9.3-inch Waveshare touchscreen is actually inserted upside down so that the HDMI cable can run from the bottom of the screen

The mechanical keyboard is wired to the underside of the Raspberry Pi 4 computer

Quick **FACTS**

- The computer is based around Raspberry Pi 4
- It uses a hand-wired mechanical 40% keyboard
- There's a button for checking the battery life
- The device can be charged via USB when turned on
- The case files are available on Printables



The screen makes use of the touch input to deliver power. The real power USB port is not used. This allows the screen to fit into the case

the size of the components and the requirement that the keyboard should be as low as possible," Michael says. "Somehow I loved the wide display more than a normal 16:9 display, so this may be the reason for the centred screen."

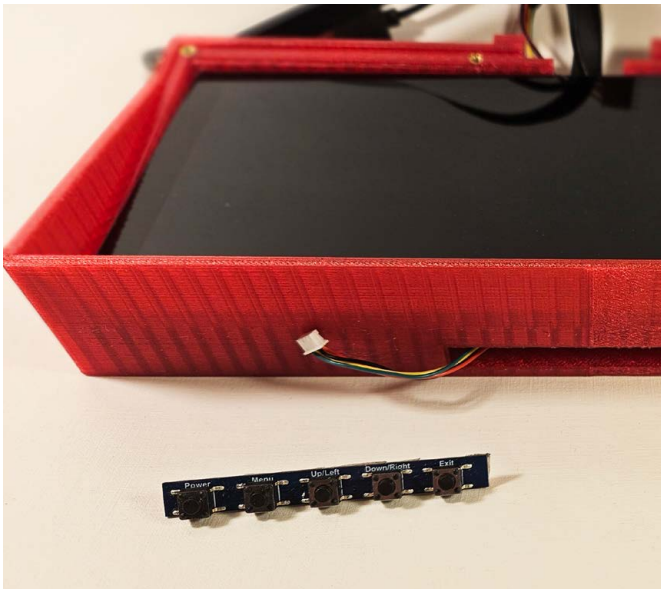
A great case

Other design considerations needed to be considered. "It was clear in the beginning that the Raspberry Pi 4 and the battery would have to sit behind the keyboard," Michael says, having decided to place them in a sizable rear compartment. The Raspberry Pi Pico development board also needed to be moved because there wasn't sufficient room on the main keyboard PCB.

In extending the back section by up to two centimetres and increasing its height to match that of the screen and keyboard, Michael found space to fit audio speakers. He worked on ways of being able to use the USB ports, too, by creating insert panels on the back of the case for flexibility. "Instead of having to print an entire case, taking tens of hours, every time I decided I'd want to reconfigure the ports, I could just print new panels, which takes about an hour," he explains.

Even so, there were other issues to contend with. Michael had trouble with the HDMI connection being on top of the screen. "I had to rotate it, and it took me some time to figure out how to flip the screen," he says. "The display's on-screen menu is still the wrong way around and this can't be fixed, but I think that's a Waveshare issue."

The biggest headache, however, was power – the system draws juice from a pair of 21700 batteries connected to a UPS HAT. "I tried several battery boards but I was getting random reboots and other issues," he says. "I then recognised that the cables I used to connect to the Raspberry Pi 4 computer were too thin. After I used better cables it worked fine. There were still some power warnings after two hours but it's not bad."



The screen buttons are fixed to the top of the case allowing for very easy access. They are recessed to prevent accidental pressing



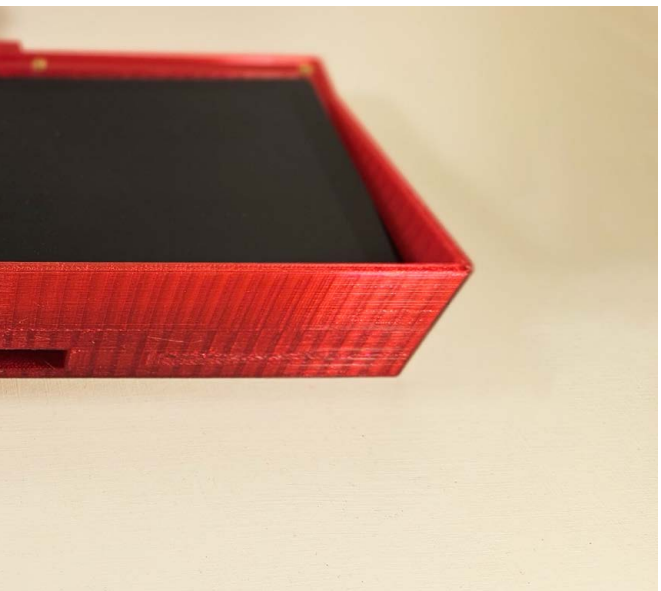
▲ The hinges are fastened using M4 screws. Although Michael is seeking to improve the hinge design, it allows the display to rest nicely against the machine's trunk

Powering up

Battery issues are why he decided against using a Raspberry Pi 5 board, for now at least. "If I could find a battery able to power it, I'd use Raspberry Pi 5," he says. Michael also wants to be able to move the Raspberry Pi computer away from the side and make a side panel. "This would make it possible to use more single-board computers in the future, and help to connect the screen and keyboard to Raspberry Pi internally," he says.

> "If I could find a battery able to power it, I'd use Raspberry Pi 5"

But he's more than happy with the result so far and he says it's a build that has fulfilled his requirements. "It's also been a good way to learn FreeCAD which was fun most of the time – there was a lot of cursing before understanding, though." He uses the device for programming and watching streams and finds it to be very convenient. "It's easy to fetch and can be placed on the couch or kitchen table without taking up much room," he says. And that, in a nutshell, is what a portable computer should be like.



Creating a classic



01 Unlike the laptops that were available in the 1980s and 1990s, Michael's contemporary version packs a real punch thanks to the use of a Raspberry Pi 4 Model B computer. He is considering making use of Raspberry Pi 5 in the future for greater power.



02 The ortholinear mechanical keyboard has 47 keys and it uses the Raspberry Pi Pico W running KMK firmware powered by CircuitPython. It's possible to fit any keycap or switch to this keyboard, but Michael bought an inexpensive set of blanks from Amazon.



03 Removable panels at the back of the device allow the ports to be easily reconfigured without the need for a whole new case. The ports include a power button, an audio stereo jack, a battery charging port and a second HDMI-out, all within perfect reach of the user.

VespAI

AI models are adept at distinguishing one winged creature from another. **Rosie Hattersley** goes beyond the buzz



MAKERS

Exeter University VespAI team

The research team from University of Exeter's Environment and Sustainability Institute field-tested the Asian hornet detector in Jersey and Cornwall.

magpi.cc/vespaigit

Fun fact that might get you a point in the local pub quiz: Vespa, Piaggio's iconic scooter, is Italian for wasp, which its buzzing engine sounds a bit like. Less fun fact: nature's counterpart to the speedy two-wheeler has an aggressive variant that has been seen in increasing numbers across western Europe and which is a direct threat to bees (**magpi.cc/beeshornet**) which are one of their key food sources. Bees are great for biodiversity; Asian hornets (the largest type of eusocial wasp) are not. But it's only particular hornet species that pose such a threat. Most citizen reports of Asian hornets are native species and a key issue is ensuring that existing hornet species are not being destroyed on this mistaken assumption. To combat misinformation and alarm at the so-called 'killer' hornet (itself a subset of wasp), academics at the University of Exeter have developed a VespAI detector that presents a positive identification system showing where new colonies of the invasive hornet *Vespa velutina nigrithorax* have begun to spread. The system works by drawing the insects to a pad that is impregnated with tasty (to wasps) smelling foodstuffs.

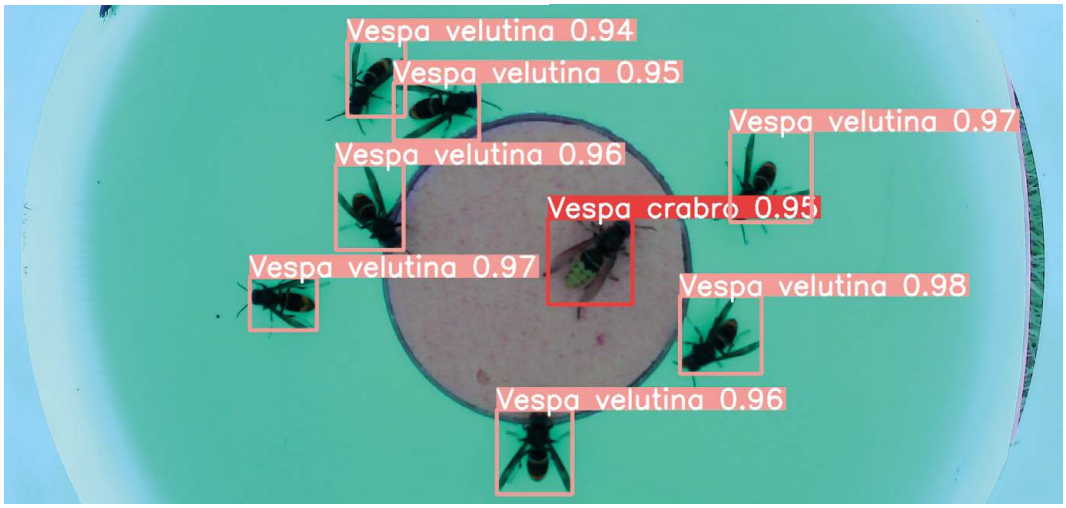
Considerate response

VespAI provides a nonharmful alternative to traditional trapping surveys and can also be used for monitoring hornet behaviour and mapping distributions of both the Asian hornet (*Vespa velutina*) and European hornet (*Vespa crabro*) which is protected in some countries. "Live hornets can be caught and tracked back to the nest, which is the only effective way to destroy them," explains the team's research paper: **magpi.cc/vespaihornet**.

Creepy feeling

VespAI features a camera positioned above a bait station that detects insects as they land to feed and gets to work establishing whether the curious mite is, in fact, an Asian hornet. The Exeter team developed the AI algorithm in Python, using YOLO image detection models: **magpi.cc/vespaigit**. These identify whether Asian hornets are present and, if so, send an alert to users. Raspberry Pi proved

▼ Non-Asian hornets are discounted, meaning non-invasive native species are not destroyed in a bid to eradicate the destructive newcomers





VespAI can be fitted with solar panels so it can operate in remote locations and alert researchers of new Asian hornet populations

Raspberry Pi 4 provides connectivity and powers the AI algorithm that crosschecks a potential hornet against its 33,000-strong image database

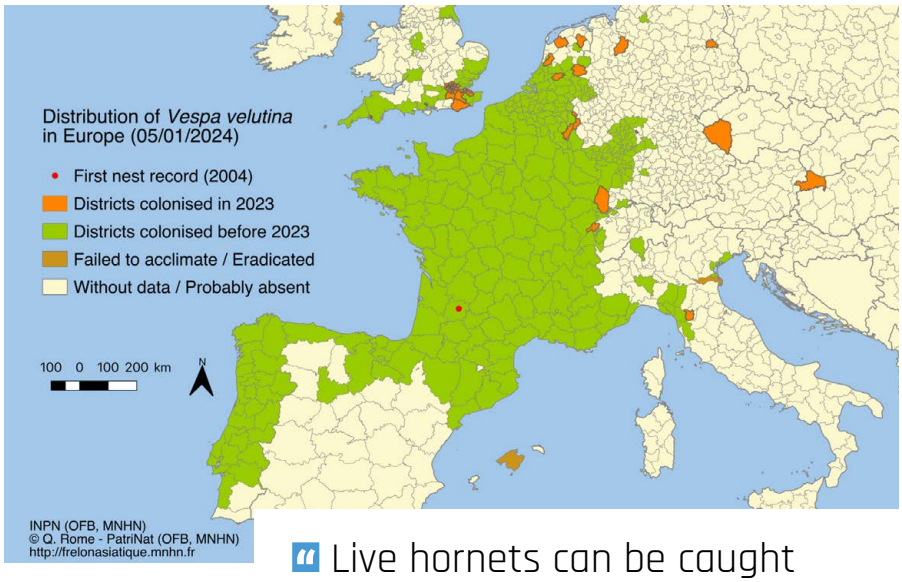
VespAI provides a non-harmful alternative to traditional trapping surveys, identifying Asian hornets using AI and a 16Mp camera. A plastic baffle deters squirrels attracted by its bait

Quick **FACTS**

- VespAI was trained on more than 3300 hornet images
- The detection unit is protected from raiders with a squirrel baffle
- The team has handled thousands of Asian hornets...
- ...and no one has ever been stung
- European hornets are protected in many countries

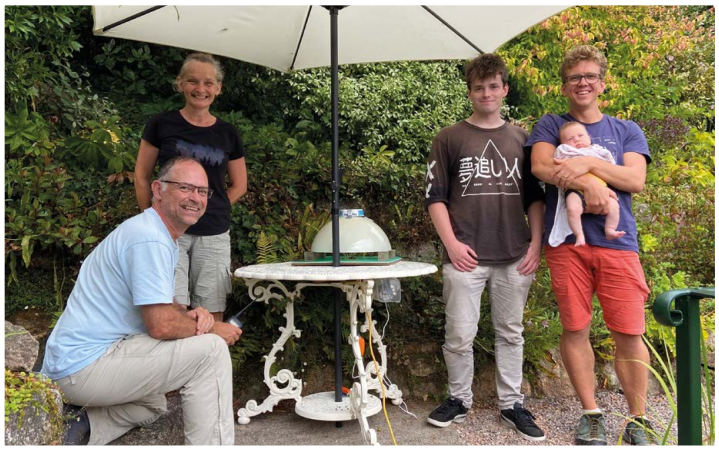
Warning!
Sharp sting

Wasps and hornets do not relish being prodded and poked, and may sting you if you seem to be a threat. If you create your own Asian hornet detector, inform a specialist to trace them back to their nest.
magpi.cc/insectbites



▶ Asian hornets have rapidly spread from southern Europe and are now increasing in numbers in the UK

> "Live hornets can be caught and tracked back to the nest, which is the only effective way to destroy them"



▲ Dr Thomas O'Shea-Weller, Juliet Osborne, and Peter Kennedy



▶ Once attracted to liquid in a Petri dish, VespAI identifies any Asian hornets and automatically alerts researchers who trace them back to their nest

a great choice because of its compact size, ability to run the hornet recognition algorithm, real-time clock and support for peripherals such as an external battery. The prototype bait station design was made with items that the team had at hand in their lab, including a squirrel baffle for the weather shield, Petri dishes and sponges to hold hornet attractant, and a beehive stand for the monitor to rest on.

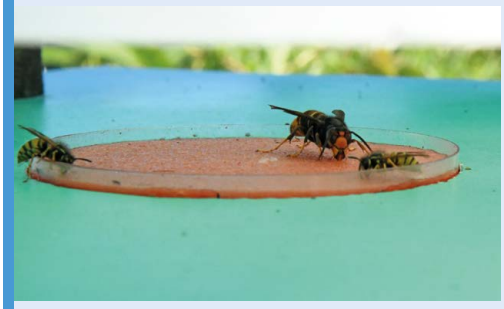
Design challenges included optimising the hornet detection algorithm for use on Raspberry Pi. "An AI algorithm may work well during training or when validated in the lab. However, field deployment is essential to expose it to potentially unforeseen scenarios that may return errors", they note. The project also involved developing a monitor with an integrated camera, processor, and peripherals while minimising power consumption. To this end the VespAI team is currently optimising their software to run on Raspberry Pi Zero having watched footage of the AntVideoRecord device monitoring leafcutter ant (*Acromyrmex lundi*) foraging trails (**magpi.cc/antvideo**) and been impressed by its ability to run for extended periods remotely due to its low power consumption.

As this interactive map shows, Asian hornets have quickly made inroads across Western Europe: **magpi.cc/vespamap**.

The Raspberry Pi-enabled setup is "intended to support national surveillance efforts, thus limiting hornet incursions into new regions," explains Dr Thomas O'Shea-Wheller, a research fellow in the university's Environment and Sustainability Institute. He and his colleagues have been working on the AI project since 2022, conducting additional fieldwork this summer with the National Bee Unit and the Government of Jersey (Channel Islands) mapping new locations and fine-tuning its accessibility to potential users ahead of a planned commercial version.

Given Raspberry Pi's extensive and enthusiastic users, they hope sharing their code on GitHub will help expand the number of VespAI detection stations and improve surveillance and reporting of hornet species.

Wasp watch



01 The system is inactive unless an insect of the correct size is detected, in which case the 16Mp camera takes a photo and the YOLO algorithm begins its analysis, comparing it against its existing image database.



02 VespAI runs on Python and uses TensorFlow to facilitate hornet detection through the YOLO architecture. Should an Asian hornet be detected, researchers receive a smartphone or email alert.



03 A rugged external battery powers the wireless Raspberry Pi 4-based VespAI setup, making it suitable for use in remote locations. The team plans to launch a consumer version soon.

Automatic pressure cleaner

A robotic pressure washer can analyse and clean areas of grime with thanks to a Raspberry Pi. **Rob Zwetsloot** takes a splash



MAKER

Connor

A Miami high-schooler and YouTuber, Connor competes in robotics competitions and also runs cross country.

magpi.cc/garagerobots



▲ The APC pulls the trigger on the pressure washer wand in a very simple solution to activating it

We've all been there. You see a tough dirty spot and think 'ah, if only a robot could do it for me'. Or is that just us? Well, the thought did occur to Connor at least:

"I first thought of [my project] because of a dirt patch on the concrete in my backyard," Connor tells us. "Initially, I wanted to just use a regular old pressure cleaner, but then I thought how much easier and less time-consuming it would be if I could relax and watch a robot do the job for me."

Over the course of a few months, Connor built that robot, a device to automatically clean a space measuring two feet by three feet (about 610mm × 915mm in new money).

"I almost ran out of dirt to clean by the end of it and realised it may have been less effort to just go ahead and clean it," admits Connor.

Dirt vision

The system works by comparing before and after images of the spot it's trying to clean.

"The APC has a slot for the pressure cleaner, and a camera lies atop this slot," Connor explains. "The machine uses a Raspberry Pi camera module operated by Raspberry Pi to take pictures and convert them to greyscale. The program takes an average of the brightness of all the pixels. Then, under Raspberry Pi's command, the VEX motors move the pressure nozzle in a grid-like fashion while engaging the pressure cleaner's trigger. The whole cleaning process takes about a minute and a half to complete. After that, the camera and nozzle are reset to their original position, and another picture is taken and converted to greyscale. Raspberry Pi calculates the subsequent average pixel brightness. If there is a significant enough increase in brightness, the APC moves on to the next section."

Connor chose a Raspberry Pi and a camera module for this project because the image analysis was a lot simpler than some more advanced neural network implementations.



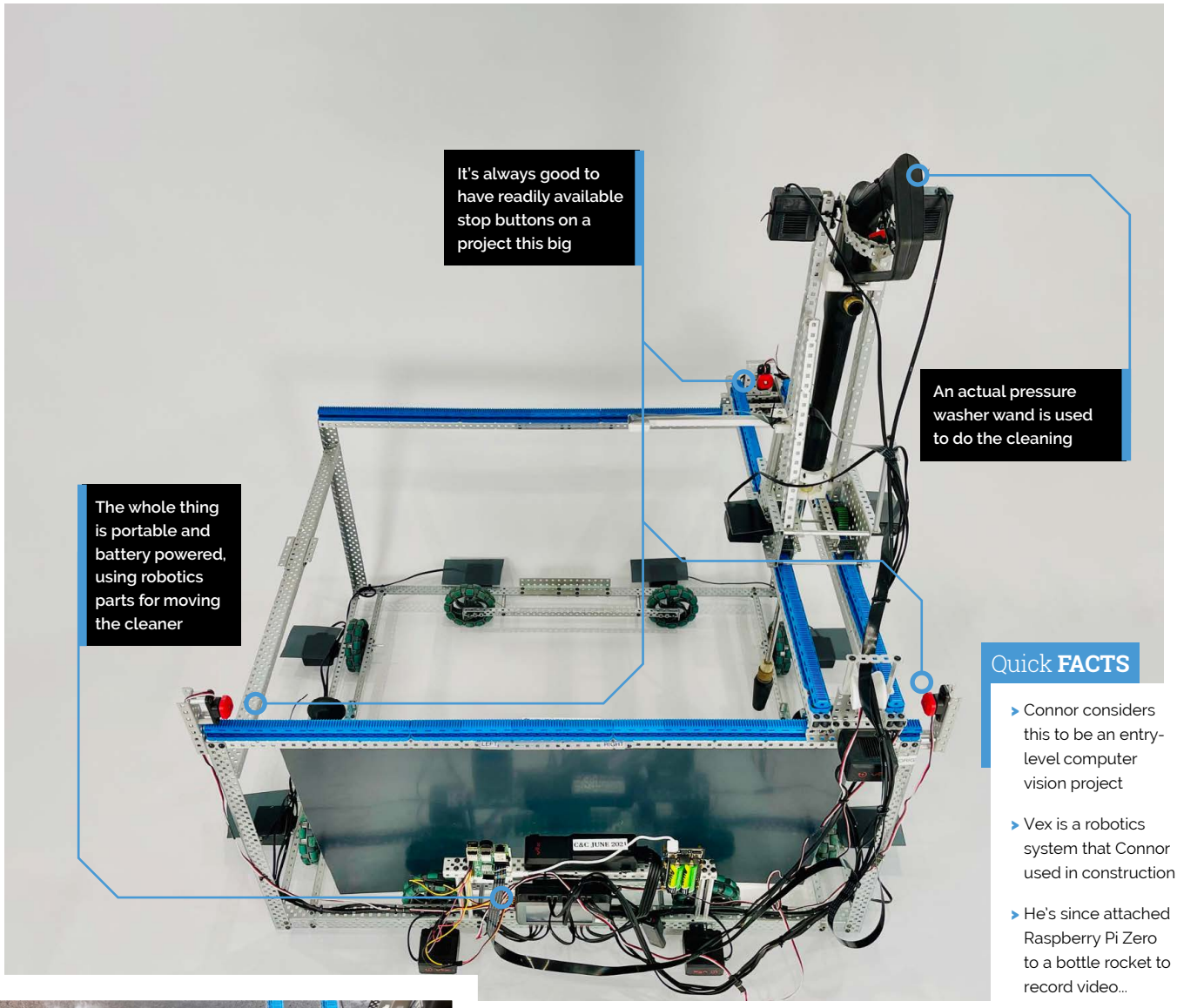
▲ No dirt can escape the roving eye of a Raspberry Pi camera module

All's well

Getting it completed was a bit of a challenge though. "The build process was … a learning experience," Connor says. "The most straightforward part was obtaining and analysing the image. The physical construct proved more challenging. The wheels slipped on the wet surface, so weights needed to be spread along the base judiciously. The moving gantry ripped off the wires, so [cable] ties, tape, and rubber bands kept the many moving wires clear of snagging."

In a spot of good luck, Connors school had a 'Shark Tank Pitch Competition' a month after he finished it. *Shark Tank* is the US name for the TV show *Dragon's Den*, and he was able to use it as his presentation.

"Moving the entire machine to the school required a bit of deconstruction and reconstruction, but the effort was worth it," Connor tells us. "The reaction was both praise for its uniqueness and an acknowledgment that more progress was needed for viable commercialisation."



Quick **FACTS**

- Connor considers this to be an entry-level computer vision project
- Vex is a robotics system that Connor used in construction
- He's since attached Raspberry Pi Zero to a bottle rocket to record video...
- ...in which an Einstein LEGO minifig went up to the Karman line and back
- His next project involves identifying buildings on radiographs with neural networks



> The most straightforward part was obtaining and analysing the image. The physical construct proved more challenging

◀ Despite how far-fetched it seems, it completely works

Pixie clock

It's not a Nixie clock, it's a Pixie clock. By **Louis Wood**



MAKER

Louis Wood

Maker In Residence intern, Louis, spent the summer making all sorts of cool Raspberry Pi builds.

magpi.cc/louiswood

This project was inspired by Nixie tubes, an old technology used for displaying digits. The trouble with Nixie tubes is that they are quite dangerous, requiring 170 volts to produce their characteristic glow, and very expensive, since they are no longer mass produced. A safer, more modern approach is using LEDs to light the edges of engraved acrylic.

Electronics

The electrical design of this project is simple and uses a single 300-LED-long strip of NeoPixels, a Raspberry Pi 4, and a 5V power supply. To provide ample current to the Raspberry Pi and the pixels, I went with an 8A supply.

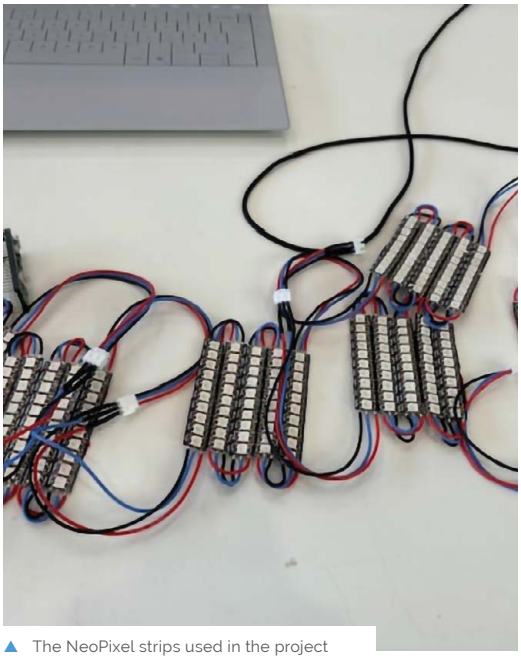
While there are only a few electrical components a lot of soldering was required. The LED strip needed to be cut into 30 segments, which I then soldered back together with short wires to allow the strip to snake. Between sets of strips, I soldered longer wires with crimped connectors for easy linking of tubes.

Tubes, base, and programming

Each tube needs to display digits from 0 to 9, so each contains ten laser-cut and engraved rectangles of acrylic. To provide more of a tubular appearance, I surrounded the digits with a transparent cylindrical enclosure. All this acrylic is housed between two 3D-printed discs. The LEDs sit below this assembly in their own 3D-printed enclosure, and the two parts come together with recessed magnets for a clean look.

Since I was building a clock to display hours, minutes and seconds, six tubes were required. To hold these in position, together with the Raspberry Pi, I laser-cut a base from more acrylic, with 3D-printed standoffs between the top and bottom.

I loaded the Raspberry Pi with a simple program, using `datetime` to fetch time information and then display it on the clock by lighting up the appropriate LEDs. Each digit has five LEDs associated with it, so I created arrays to make it easy to address the pixels for a particular digit.



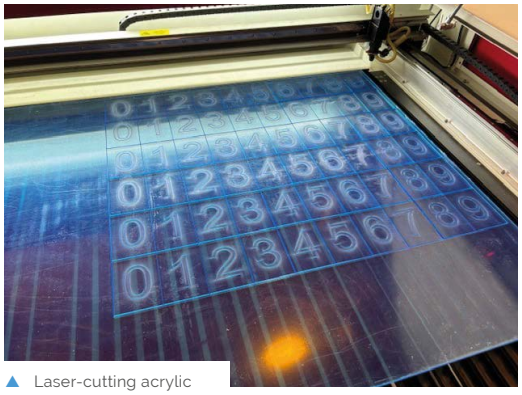
▲ The NeoPixel strips used in the project





◀ Pixie Clock displaying LED numbers

> The clock is currently doing its regular job in the Maker Lab at Pi Towers



▲ Laser-cutting acrylic

For example, one of these arrays looks like this:

```
h1 = [
    [0, 19, 20, 39, 40],
    [1, 18, 21, 38, 41],
    [2, 17, 22, 37, 42],
    [3, 16, 23, 36, 43],
    [4, 15, 24, 35, 44],
    [5, 14, 25, 34, 45],
    [6, 13, 26, 33, 46],
    [7, 12, 27, 32, 47],
    [8, 11, 28, 31, 48],
    [9, 10, 29, 30, 49]
]
```

`h1` means the array is for the first of the two hour digits. To light up the digit 7 for the first hour digit, you would turn on all the pixels in the list `h1[7]` [*I don't want to think about why you might need to show that it's 70-something hundred hours – Ed*]. The slightly strange pixel order is due to the way the NeoPixels snake their way through the clock design.

The clock is currently doing its regular job in the Maker Lab at Pi Towers, but our Head of Social asked if I could tweak the code to turn it into a likes counter for our TikTok account (**magpi.cc/rpi-tiktok**), so once I've managed to do that, it'll have a whole new purpose.

Quick **FACTS**

- Nixie tubes were usually filled with neon…
- …which require a high voltage (around 170w)
- Pixie uses 300 NeoPixels instead
- The LED lights are a lot safer
- It's being adapted as a TikTok likes counter

Smart Pill Dispenser

Judges at the Coolest Projects challenge were hugely impressed by a pragmatic teenager's Raspberry Pi-based approach to age-related forgetfulness. By **Rosie Hattersley**



MAKER

Andrew Zhang

High school student Andrew Zhang has been programming since 6th grade, and has a passion for creating cool software and using hardware to bring it to life.

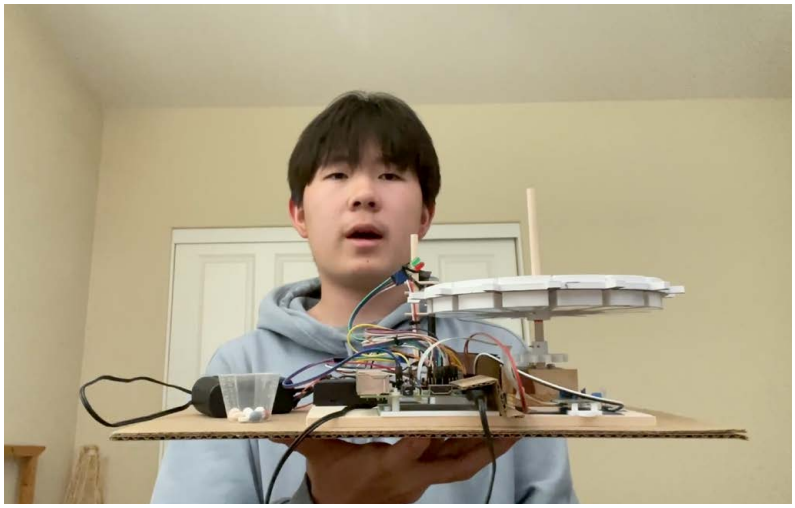
magpi.cc/smartpillvid

▼ Andrew with his smart pill dispenser project, which won a Coolest Projects award

Every year, the Raspberry Pi Foundation runs and helps judge Coolest Projects, a competition in which young coders and makers from around the world are encouraged to use technology in innovative ways. Among the hundreds of entries to Coolest Projects 2024 challenge, 15-year-old Andrew Zhang's Smart Pill Dispenser stood out for the considered approach to solving a problem he'd encountered first-hand – his grandmother sometimes forgets to take important medications, and Andrew's informal research among her peers indicated it was a fairly common scenario – as well as the way he went about designing a means of solving it, using Raspberry Pi Zero, and documenting everything in superb detail.

Aiming high

Aspiring software developer engineer Andrew is still a junior high-school student but, given the quality of his Smart Pill Dispenser project, it came as little surprise when he told us his technical chops have already been recognised. He also helps out with web development as part of a backend team for various nonprofits that have competed in (and won) seven hackathons.





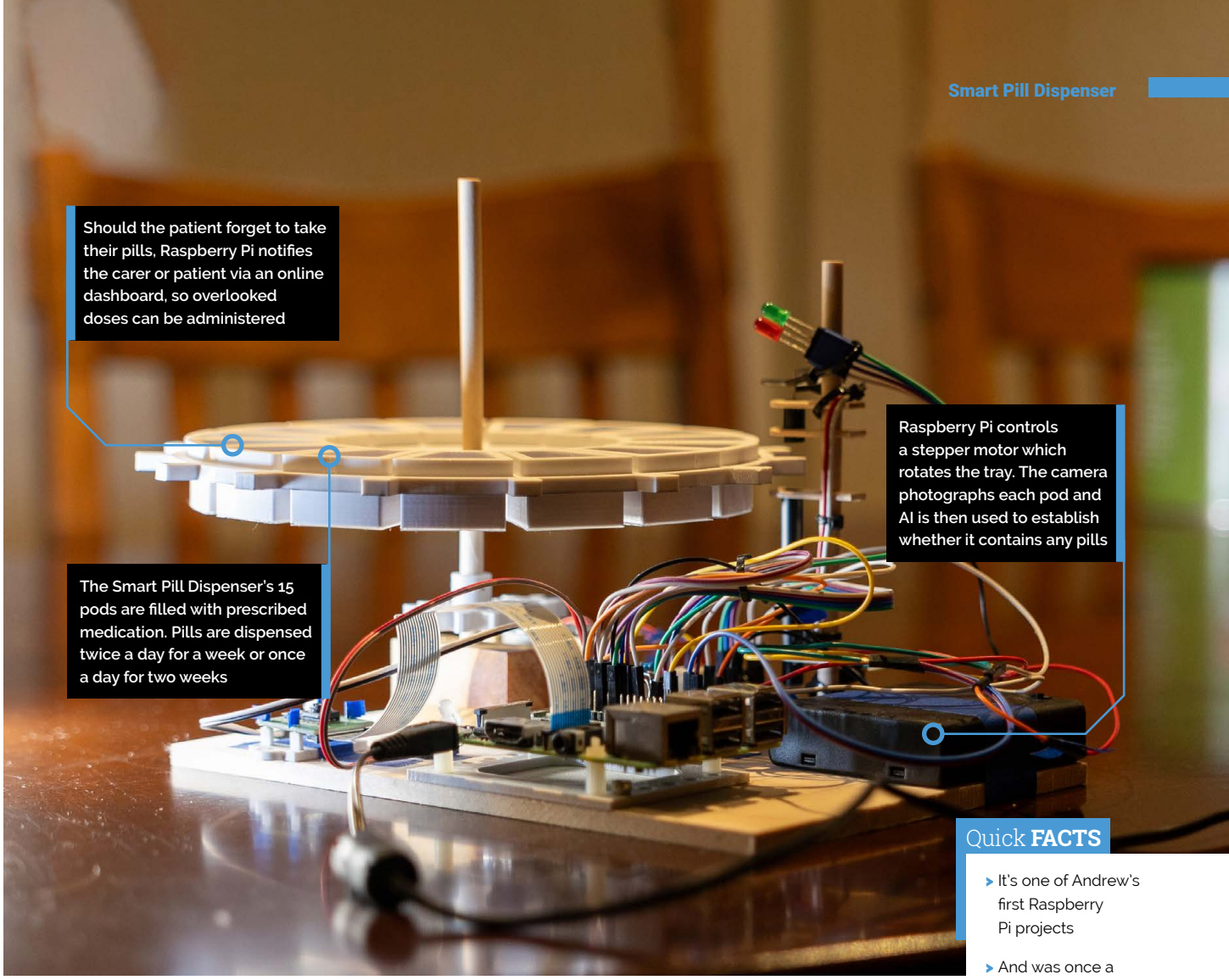
▲ Pills sorted into doses and stored in their smart pill dispenser pods

His Coolest Projects entry aimed to "leverage AI and internet technology to solve the problem in a way that is reliable, convenient, and affordable. Keen photographer Andrew realised that training a camera on a pill box to check whether it was still empty long after medication time could provide an invaluable failsafe for patients and their carers.

Andrew's motivation for the Smart Pill Dispenser stemmed from his grandmother's "occasional forgetfulness" around conventional medication containers. He designed a prototype smart dispenser that can automatically verify whether a patient has taken their medication, thus helping his grandmother and her elderly friends. Carers can monitor remotely and provide prompt intervention when necessary.

Ongoing refinements

The smart pill dispenser consists of Raspberry Pi 3B, stepper motor and driver board, a Raspberry Pi Camera Module and a 3D-printed dispensing tray on a spindle. The prototype version has a cardboard base and scrap wood supporting tray. However, a 3D-printed baseboard to replace these is in the works. The stepper motor turns the pill container tray so the camera can take pictures through each container's clear bottom. A photoresistor and several LEDs form a photogate which acts as a

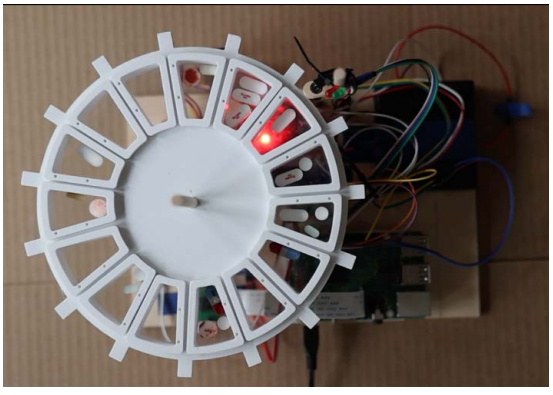


fill light and shows the device's status. Four AA batteries power the motor, but Andrew is looking into ways to power both this and Raspberry Pi from a single DC-DC power supply. He also wants to replace the existing photogate with a better-trained AI to create a more compact unit.

Raspberry Pi was the ideal choice for this project, says Andrew. Its GPIO interface allows communication with essential hardware components such as the stepper motor, LEDs and photogate as well the Raspberry Pi camera. Raspberry Pi is also used to run TensorFlow Lite and the Django framework. "Its small size and low power consumption are also essential for making this project practical. Most importantly, the vast amount of widely available online tutorials from the Raspberry Pi maker community significantly shortened my project development time and helped to make it a reality", said Andrew. The system cost $90 to build and $4 a year to run and proved reliable, accurate, cost-effective and easy to use. In fact, Andrew believes, "with improvements, it has the potential to be a widely used medical device serving large groups of patients".

Andrew explains his project in methodical detail on Vimeo: **magpi.cc/smartpillvid**.

> Andrew's motivation for the Smart Pill Dispenser stemmed from his grandmother's occasional forgetfulness around conventional medication containers



A Raspberry Pi Camera Module photographs each pill pod to check its contents

Quick **FACTS**

- It's one of Andrew's first Raspberry Pi projects
- And was once a sweetie dispenser...
- ...that wouldn't pay out if you were greedy
- Andrew recently made a Raspberry Pi-powered FM radio with built-in AI
- And an AI-powered personal FM radio station too

CatBot

Feed the cats without poisoning the birds, thanks to an open-source AI stack. By **Andrew Gregory**



MAKER

Michael Suguitan

An engineer and researcher interested in human-robot and -computer interaction, machine learning, and creative programming.

michaelsuguitan.com/catbot

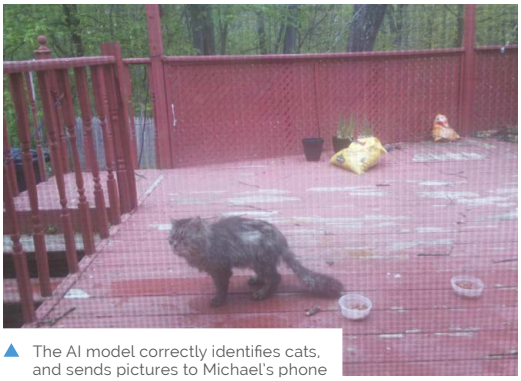
▼ Because Raspberry Pi Zero is too underpowered to deploy a computer vision model, a separate Raspberry Pi 5 requests images from the Zero and performs object detection with a small Faster R-CNN MobileNet model

If you like cats, and you want to be alerted whenever a cat wanders into your garden, then we have the project for you. CatBot is a notification system for stray cat sightings. It's a brilliant example of a project that takes a minimal amount of hardware, adds open-source services, and just works.

CatBot is built using two Raspberry Pi boards: the first, a Raspberry Pi Zero, hosts a Raspberry Pi Camera Module 2 and a Flask server, which sends images to a Raspberry Pi 5 for processing. Raspberry Pi 5 is a much more powerful machine, and so that's where the clever stuff happens: it runs a computer vision model, which determines whether the cat-shaped collection of pixels is a cat. If it's a cat, the Raspberry Pi 5 can send photos to Michael's phone via a Twillo client (as an MMS message, sent to Michael's phone number, not an email).

"I used Raspberry Pi because I was recently working with Raspberry Pi and cameras for another project, a digital sensor for a film camera," says Michael. "Although there are definitely simpler solutions with cheaper microcontrollers, I find it valuable to start with techniques I know rather than going down rabbit holes of learning new tools. I used two separate boards because Raspberry Pi 5 is my home server and NAS, which I did not want to mount on the kitchen window."



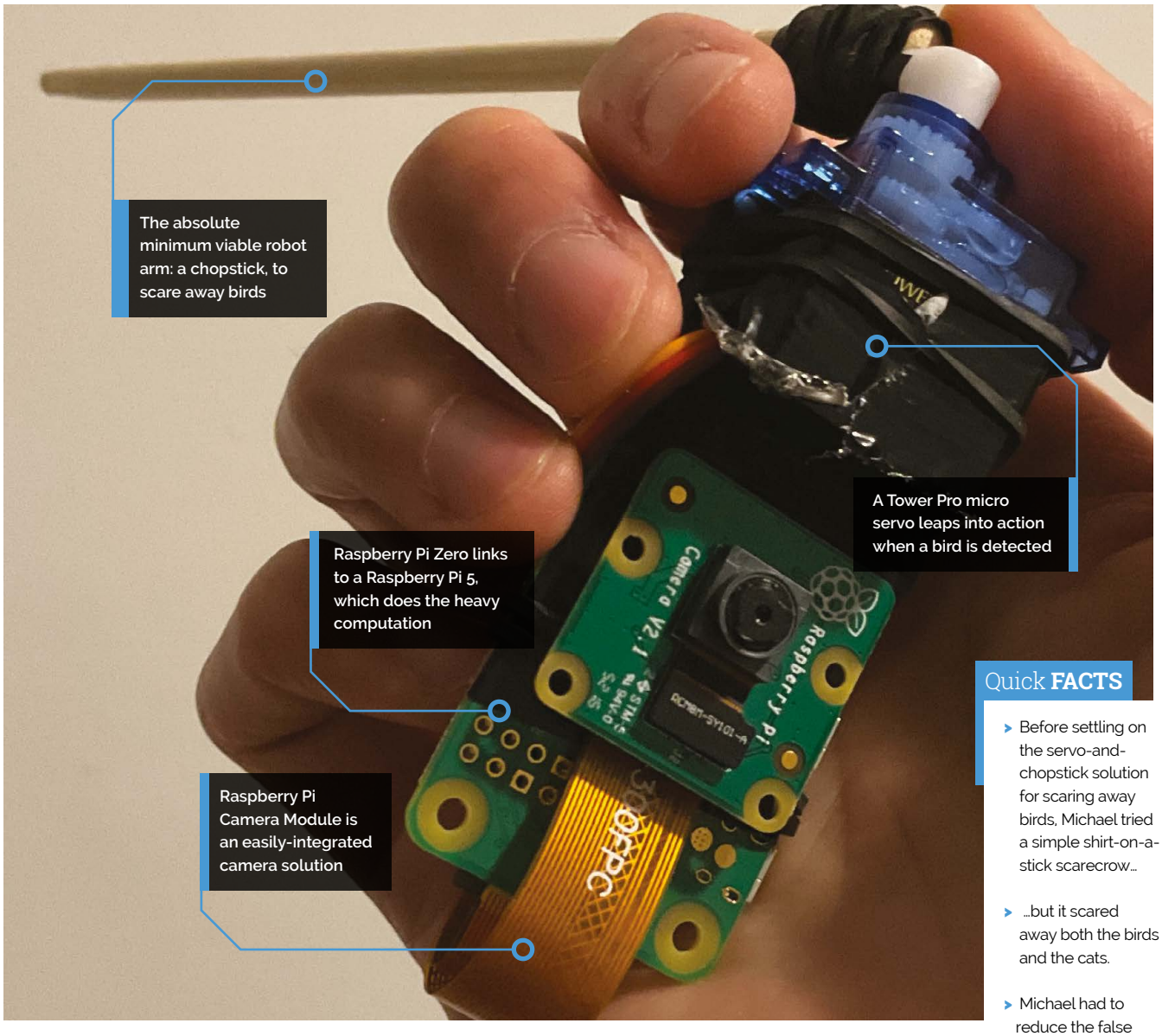


▲ The AI model correctly identifies cats, and sends pictures to Michael's phone

But there's a catch: the food that Michael was leaving out for the cats was also attracting birds, for which cat food is potentially unhealthy, so he needed to find a way of identifying birds and scaring them away. He eventually settled on a minimal solution that just – only just – qualifies for the label of 'robot': an actuator (a Tower Pro micro servo) connected to a chopstick that taps on the window to scare the birds away. If Raspberry Pi 5 detects a bird, it sends a request to Raspberry Pi Zero to activate the servo.

> "I find it valuable to start with techniques I know rather than going down rabbit holes of learning new tools"

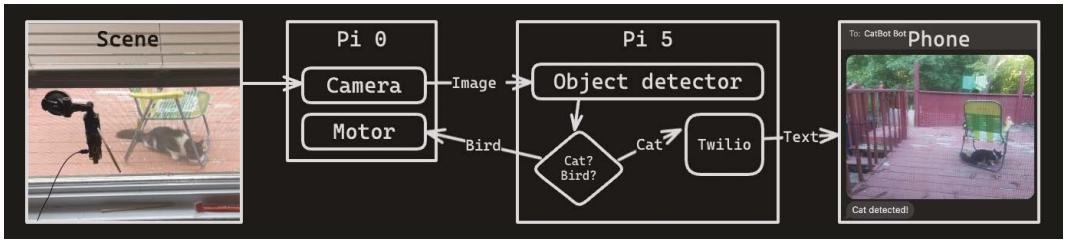
"Defining 'robot' is hard to pin down and frequently leads to disagreement among roboticists," says Michael. "I believe that a robot is any physical thing with sensors and actuators. While some definitions require autonomy, that excludes arguably robotic things like human-piloted mecha or heavy industrial equipment. Relaxing the requirement of autonomy frames



robots as tools that complement rather than supplant our abilities, which I find valuable in the current hype wave of AI and ML.

"There are commercial products that do similar things, like the Bird Buddy or pet-oriented indoor security cameras. By the time that I could hack those to get the functionality I wanted, I might as well have started with open-source tools."

"My favorite projects include Blossom, an open-source robot platform that I developed during my PhD, and the Leica MPi, a swappable digital sensor for a Leica film camera. I'm currently taking a sabbatical at the Recurse Center, a programming retreat in New York, where I am exploring alternative HCI hardware and brushing up on AIML for robotics."



Quick FACTS

- Before settling on the servo-and-chopstick solution for scaring away birds, Michael tried a simple shirt-on-a-stick scarecrow…
- …but it scared away both the birds and the cats.
- Michael had to reduce the false positive rate by raising the detection threshold for the bird class.
- You can buy similar devices off the shelf, but they're not as cool as this is.
- Cats, birds and raccoons all like free food.

The work of building this project was mostly integrating the various subsystems

Bumpin' Sticker

When Guy Dupont spotted a bumper sticker expressing love for experimental jazz, he decided to 'sax' it up by creating a changeable digital version, as **David Crookes** discovers



MAKER

Guy Dupont

Guy is a software developer, audio engineer, and hardware hacker from Cambridge, MA. He likes to build things that make people say: "That's ridiculous, but I would buy one anyways!"

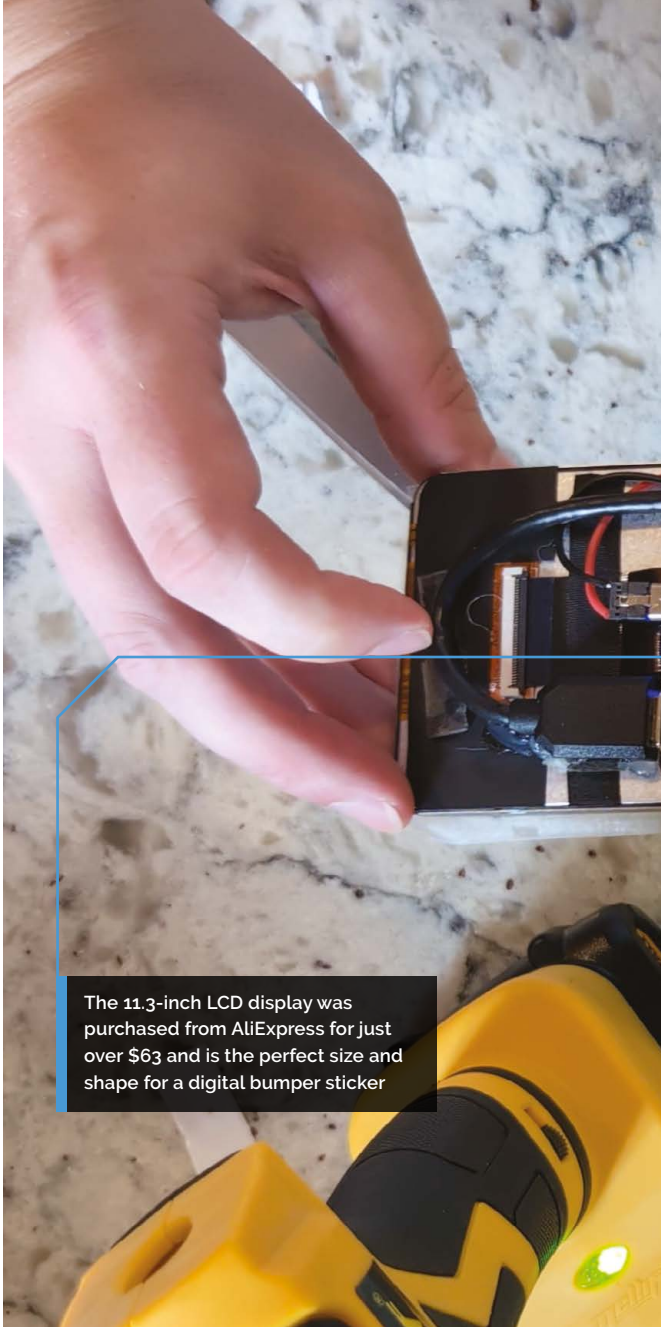
magpi.cc/bumpinstick

Bumper stickers have been around since 1946 when an American silkscreen printer called Forest P Gill spotted the popularity of attaching advertising messages to the rear of vehicles and combined adhesive-backed paper with fluorescent paint – significantly upgrading the old practice of printing messages on a piece of cardboard or metal and attaching them with wire.

They weren't great – they'd often become soggy in wet weather – but they became widely used, particularly in the US. Still popular today, they enable drivers to promote goods and services, express humour, highlight political and religious affiliations, and share their love of sports teams. But what if someone wanted to change their message depending on their mood or the time of year? Is it really practical to keep peeling and replacing?

During a long morning walk, Guy Dupont began thinking along those lines. He'd spotted a car in his neighbourhood with a sticker that read, "Keep Honking! I'm listening to Alice Coltrane's meteoric sensation 'Universal Consciousness'!" (a sticker which appeared on countless vehicles) and he believed the concept could be vastly improved.

"I love the idea of using bumper stickers as a form of self-expression, but I got to thinking about how 'permanent' they are, and how my own style, mood and taste tends to change relatively quickly," he says. "I wanted to see how I could resolve those things – could I make a bumper sticker that was always up to date? Would it still be interesting if it wasn't permanent?"



The 11.3-inch LCD display was purchased from AliExpress for just over $63 and is the perfect size and shape for a digital bumper sticker

On track

Figuring a changeable bumper sticker would be both practical and fun, he initially decided to experiment by connecting a Raspberry Pi Zero 2 W computer to a 5-volt HDMI display before working out a way to gather and share information about the song he was currently listening to in near real-time. He figured the best method would be to connect the Raspberry Pi device to the internet and make use of the online music service Last.fm. "It's a 'scrobbling' tool that you can use to keep track of everything you listen to, regardless of where you're listening from," Guy explains.

By connecting Spotify to his Last.fm account, Guy had a way of grabbing details about his most recently played tune. Raspberry Pi could then pull that information and send it to the display for others to view. Since he wanted his project to look like a bumper sticker, this entailed creating an easily updated graphic – one with black text on a

A Raspberry Pi Zero 2 W computer is mounted on the back of the display. It was chosen for its small size, BLE/WiFi capabilities and ability to drive a high-definition HDMI display

Electrical tape is used on the back of the display because the electrical connections on the back of Raspberry Pi can short out when they come into contact with metal

Quick **FACTS**

- It's a realistic-looking digital bumper sticker
- It'll display the last song you listened to
- Data is automatically scraped from last.fm
- A PNG image is created using Val Town
- Power is obtained from the car battery



From a distance, you wouldn't be able to tell that the bumper sticker is a digital display



▲ The project is open source with the code available at **magpi.cc/bumpinstickgh**

yellow background – that could be easily updated with new details – and Guy came up with the idea of using an image file that could be produced and rendered just before it was shown.

To enable this, Guy turned to a social website called Val Town which allows developers to code in the cloud. He wrote a small chunk of code – referred to as a val – that would access and fetch his Last.fm profile to gather details of the last song he was listening to. He then, with the assistance of Val Town's AI, wrote another val to use a Javascript HTML5 canvas library to lay out the bumper sticker using the information gathered. This involved a lot of trial and error to make the text fit correctly, but he was able to successfully create, export and display a PNG image without any manual intervention.

Driving forward

With the nuts and bolts of the project in place, it was time to start refining. "I always start with components I already have or already know how to use," Guy says. "I then quickly get as close as I can to a finished version, and then I see if there are any deal-breakers or cheap and obvious ways to improve the design. I find that momentum, as well as the ability to see and feel a project early on, really helps me stay on track, even if I know I'm going to have to revise things.

Given the idea was to create a device that looked as much like a real bumper sticker as possible, Dupont swapped out the display for an 11.3-inch strip LCD. "Size, shape, and readability came before anything else," he explained. Figuring he'd be drawing power from a 12-volt car battery, he also grabbed a couple of breakout connectors and a buck converter to knock the power down to five volts.

Initial plans to connect the Raspberry Pi computer to the internet using a hotspot on his phone were revised as well. Dupont realised that he'd need to manually connect Raspberry Pi to the hotspot every time he got into his car and he knew, in his heart of hearts, that he would eventually tire of doing this, causing him to eventually consign the project to a drawer. To avoid this situation, he utilised a Particle Baron IoT development board which he also happened to have lying around.

> "I always start with components I already have or already know how to use"

"The main advantage of the board versus using the phone as a hotspot is that I never have to



▶ The heat-shrunk, weatherproofed device also comes with a warning to potential thieves on the back, telling them they won't be able to get it to work if they steal it.



touch it or remember to turn it on," he says. The board connects to Raspberry Pi and uses cellular data, the bonus being there are no monthly fees. The data is limited in quantity, but there's more than enough for Guy's intended use which makes for a perfect fit. With everything working, it was then a case of installing it, which required a spot of in-car wiring – and some dismantling of the vehicle's interior panels.

▲ The bumper sticker is wired to the car's battery and, for a neat finish, you would need to gain access to various parts of the vehicle's innards

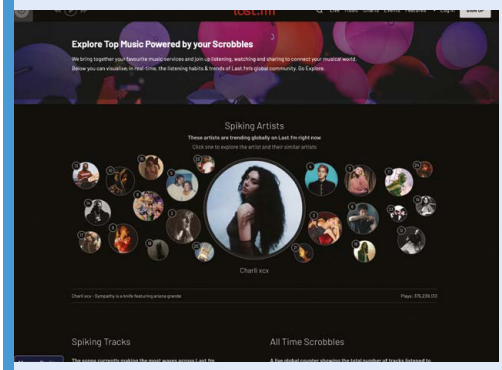
The right path

The Raspberry Pi and other components were affixed to the back of the display panel which was also fitted with magnets to allow the device to be easily secured to the back of the car. For a neat finish, the device was placed in a heat-shrink sleeve that happened to be the perfect size. A bit of cutting was then required to allow the screen to show through, and Guy used some glue around the cuts for weatherproofing.

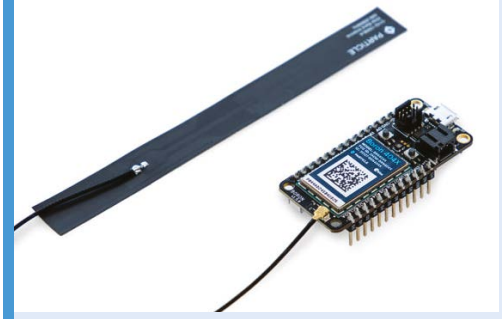
It works well. Powered by the car battery as soon as the vehicle is turned on, it immediately connects to the internet, grabs the required information and displays it. "Honestly, everything went pretty smoothly with this build," Guy said. "It's funny, but the thing that held me up the most was trying to figure out which HDMI settings would make this oddball display show what I wanted it to!"

Guy particularly likes the fact that it's entirely automated so he always knows that it'll be displaying his songs when he tootling down the road. "It lives with the car, which also means the sticker continues to work even if my wife is driving," he laughs. "I'm afraid to ask whether she thinks that's a bug or feature!"

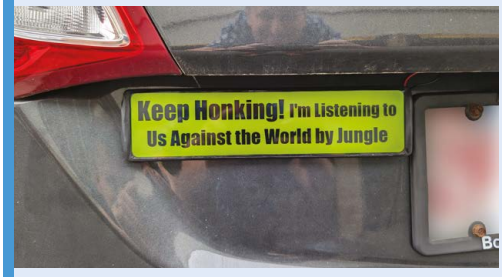
Road to success



01 A function written in Typescript and deployed on val.town periodically fetches Guy's profile from last.fm and scrapes his most recently played item from the web page. When the car is turned on, Raspberry Pi receives power from the battery and connects to the internet.



02 From inside the car, the Particle Boron IoT board uses its cellular connection to fetch the scraped data from **val.town** via Particle's webhook system. It then rebroadcasts that data as a JSON string using a Bluetooth Low Energy GATT Characteristic.



03 The Raspberry Pi has a loop that reads the latest data from the Boron's BLE Characteristic. It generates a bumper sticker image and displays it via HDMI. The image generation script was also written in Typescript and can be run either locally on Raspberry Pi or in the cloud, on **val.town**.

Adventure Time Self-Playing Guitar

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



MAKER

Allie Katz

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

katzcreates.com

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

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



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

Sensible but silly

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



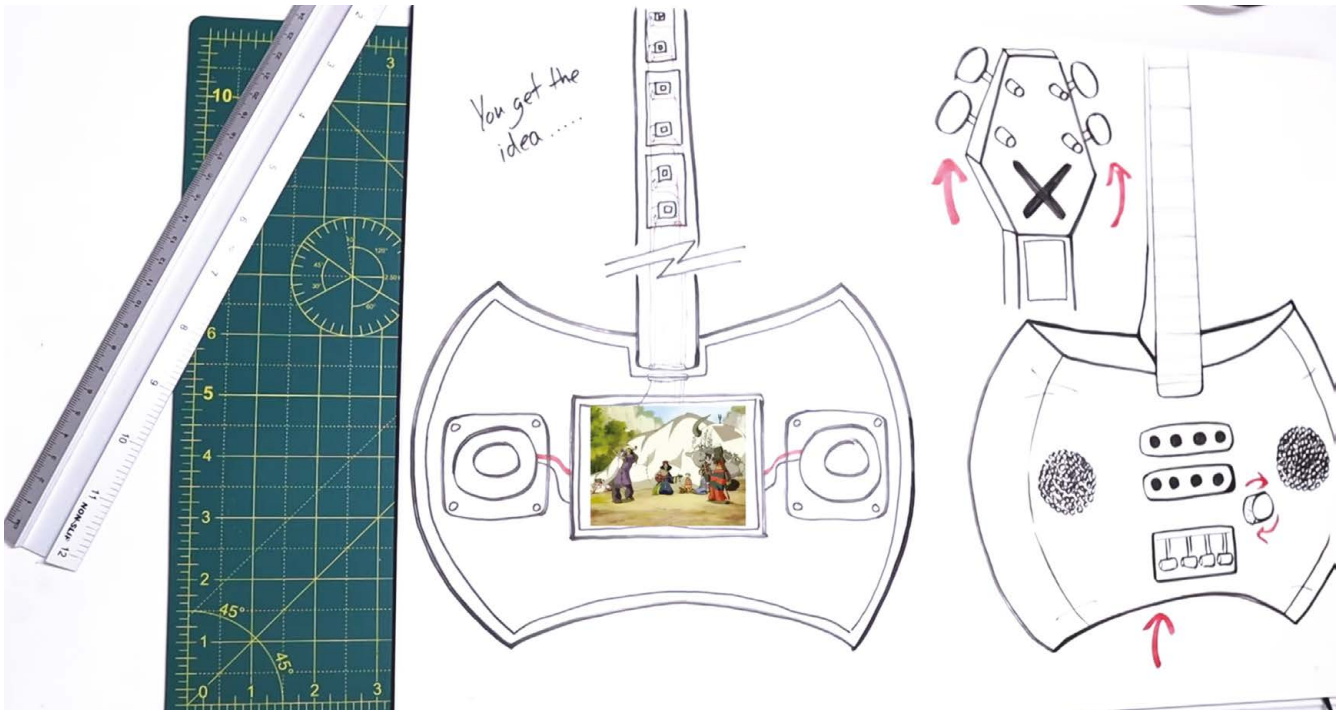
A Raspberry Pi 5-controlled self-playing guitar is the focal point of creative technologist Allie Katz's Adventure Time Marceline cosplay outfit

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

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

Quick **FACTS**

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



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



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

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



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

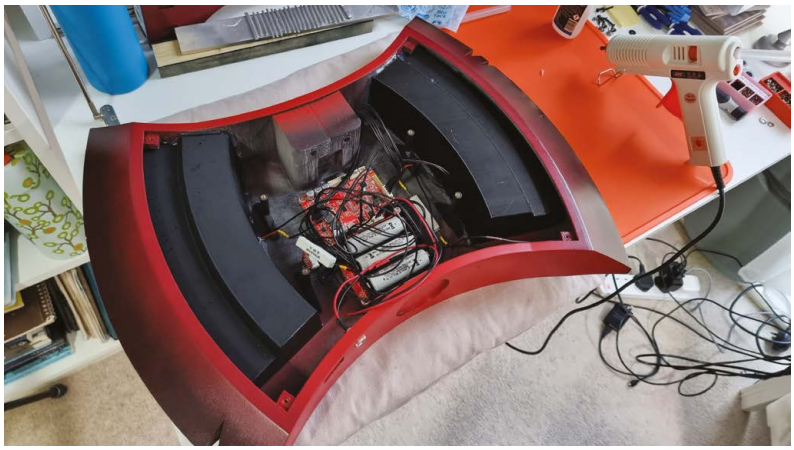
"My technical background is incredibly diverse, but when it comes to electronics I am completely self-taught," reveals Allie. "I got interested in the Raspberry Pi because of how incredibly powerful it was (at a really good price point!) and the community behind it."

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

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

Time trial

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



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

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

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

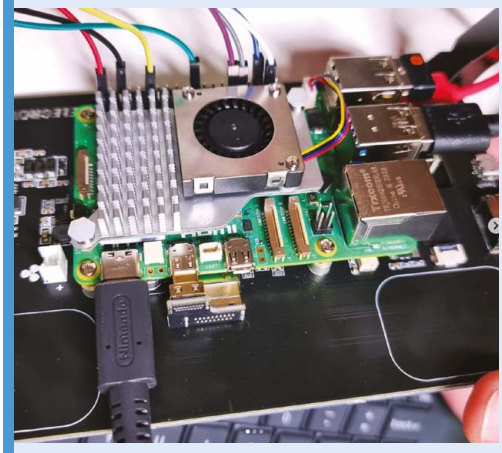
> "What project would be complete with a couple of iterations?"

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

Strike a chord



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



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



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

Floppy Disk Archiver

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



MAKER

Graham Hooley

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

youtube.com/c/grahamtinkers

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

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

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



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

Grease is the word

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

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

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

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



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

Quick **FACTS**

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



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

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

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



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

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

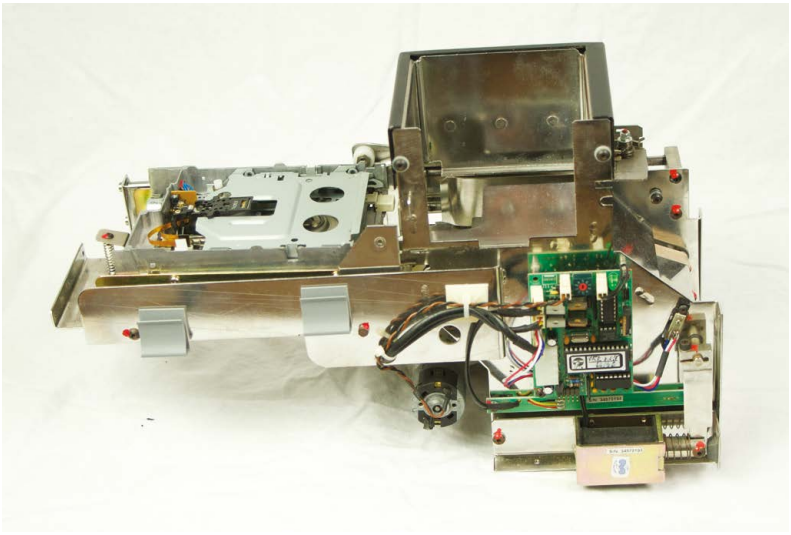
Flux capacity

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

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

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

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



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

Wide scope

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

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

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

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

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



Warning!
Moving parts

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

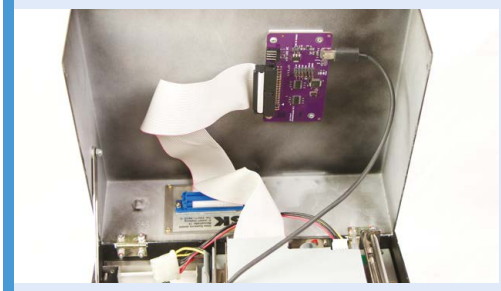
Floppy Disk Archiver



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



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



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

Lawny

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



MAKER

Eugene Tkachenko

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

magpi.cc/lawnygit

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

Makers gonna make

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



▲ Lawny tackles an overgrown lawn



Warning!
Sharp blades

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

magpi.cc/mowersafety

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

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

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

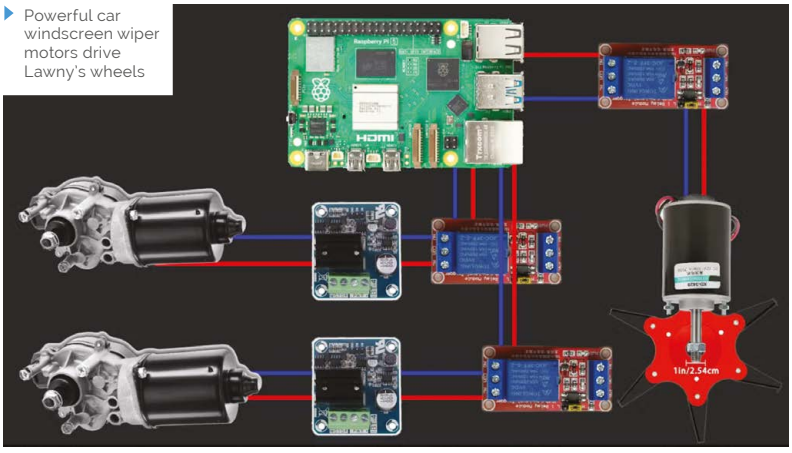
Quick **FACTS**

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

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

Get the motor running

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



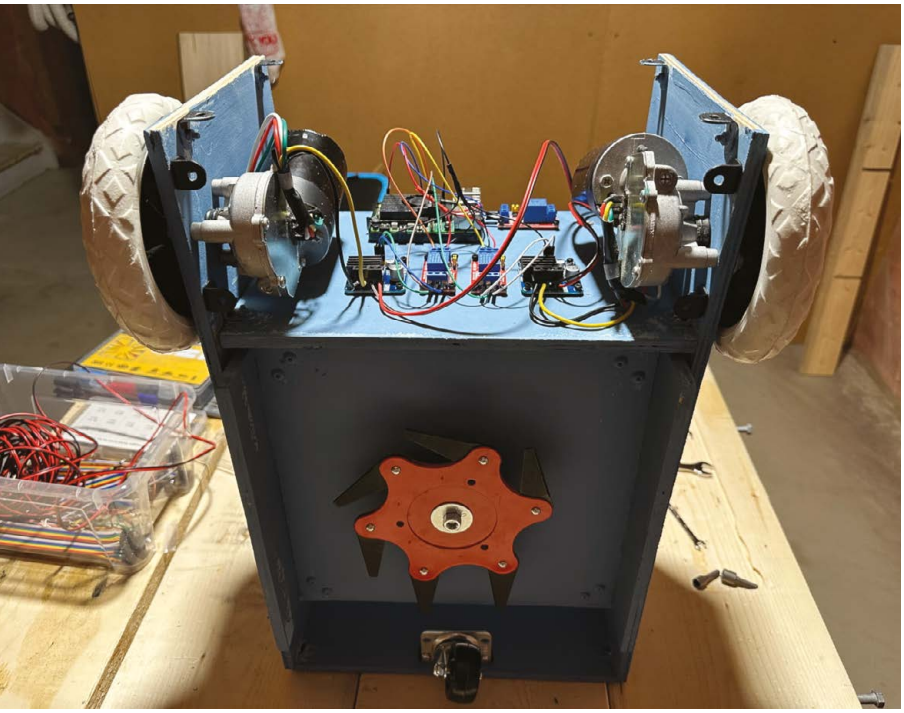
Powerful car windscreen wiper motors drive Lawny's wheels

A smartphone view of the grass Lawny is about to mow



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

Lawny being built. Blades are attached to the razor motor

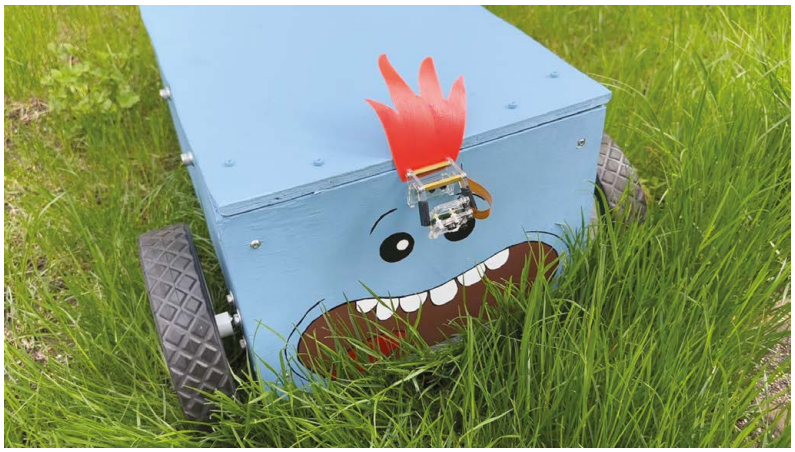


Having got the grass-cutting action working, Eugene set about making Lawny mobile, since a static lawnmower would be of limited use! Two additional motors and H-bridges allowed for movement from left to right so Lawny could be manoeuvred. Power rather than speed was required, so he used car windscreen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

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

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

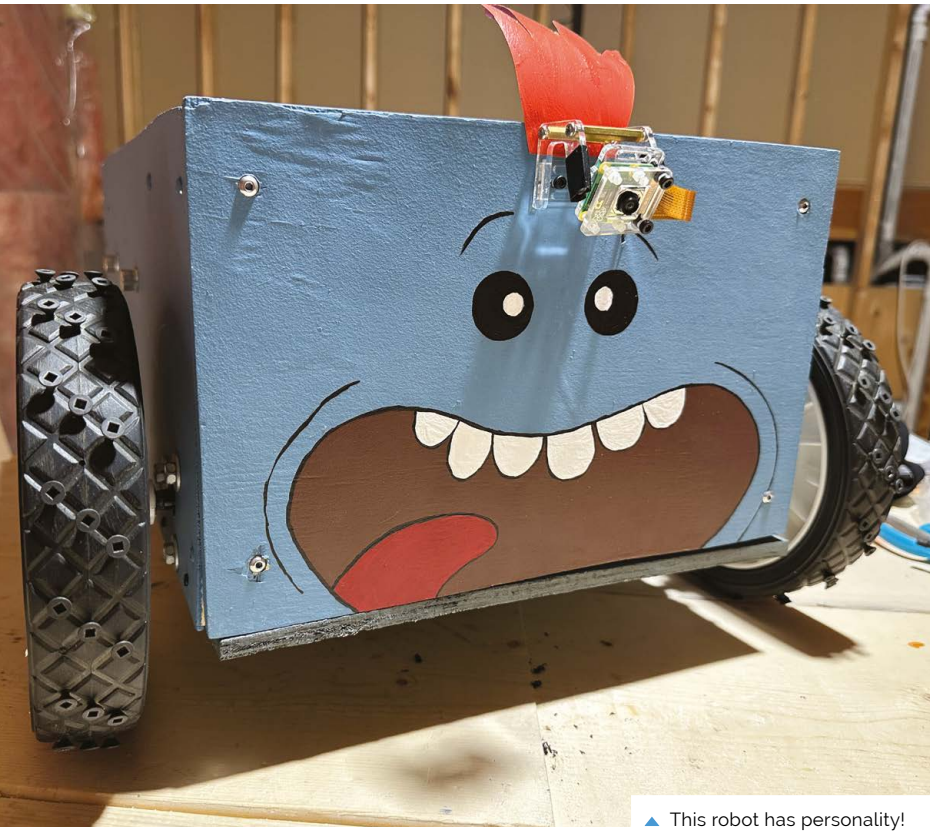




While the project itself required many iterations along the way, the wheels were the main bugbear. "I eventually ended up screwing a bunch of screws into a plastic wheel. Also, I replaced and sharpened the blades because it was hard to go through tall grass," Eugene reveals.

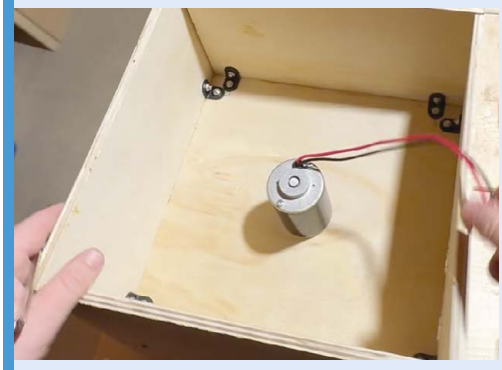
These powerful blades soon made Eugene realise that although the original aim was to create a remote-control lawnmower, doing so was a challenge if he was to rely on a video stream from the camera. From a safety point of view, Lawny should always remain in sight given the power of the blades, he cautions.

▲ With its grippy wheels, Lawny can handle rough terrain

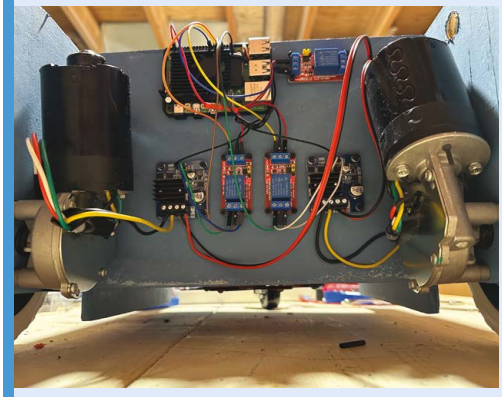


▲ This robot has personality!

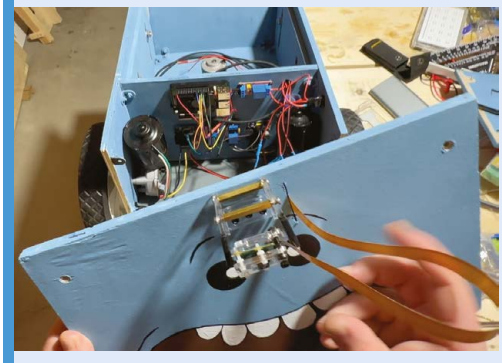
Go on, Mo!



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



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



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

Cave mapping with Raspberry Shake

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



MAKER

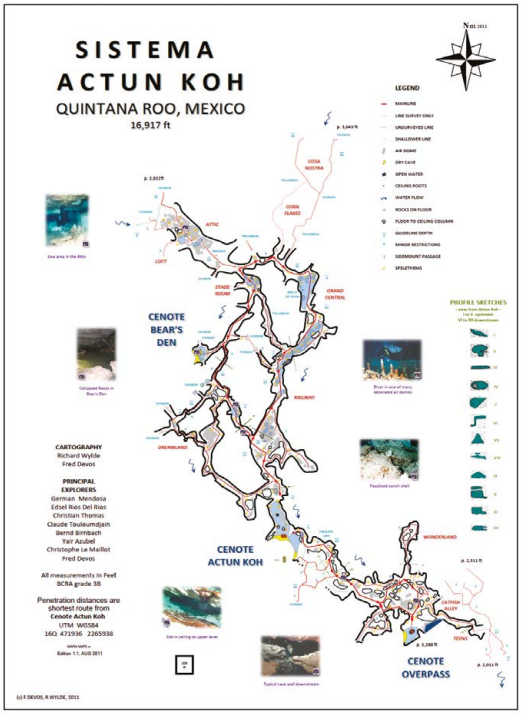
Richard Wylde

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

terahertz.co.uk

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

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



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

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

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

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

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

Distinguished company

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

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

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



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

Quick **FACTS**

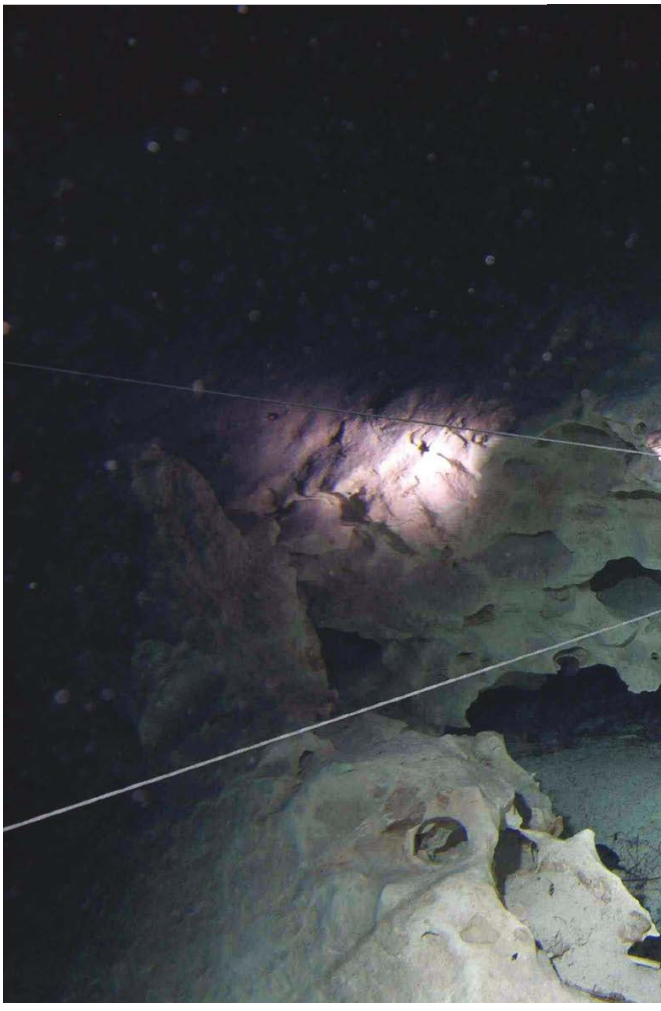
- Divers' photos reveal the caves' stark beauty…
- And lay bare the effects of nitrate run-off from nearby golf courses
- The pristine cenote waters are home to Remapedia crustaceans…
- And translucent fish that live in the dark
- But now have massive algae blooms from chemical pollution



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

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

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



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

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

Instrumental improvements

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

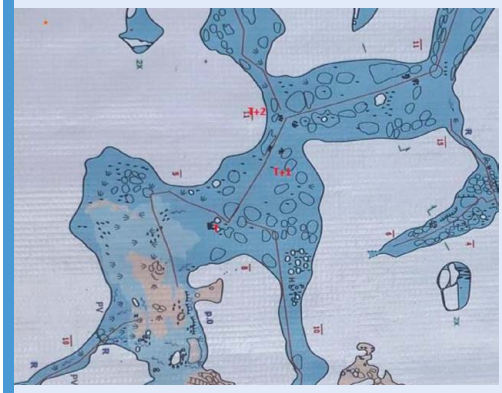
at the Sagitario cenote. In the summer of 2024, Richard and his cave-mapping colleagues trialled new means of confirming their findings, using both the Raspberry Shake 1D vertical motion seismometer and a far more sensitive acoustic magnetometer. Getting to the site after hacking through the jungle,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

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



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

Mapping the underworld



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



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

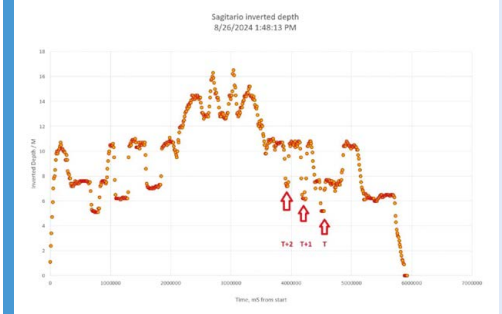


Fig 5: Plot of the depth of during the dive: Arrow point to the T+2, T+1 and T as the dives exited the cave

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

Maker Guides

116 Build a Raspberry Pi 5 media player
Power up your HTPC with a Raspberry Pi 5

122 Raspberry Pi 5 case group test
The very best enclosures, tested thoroughly

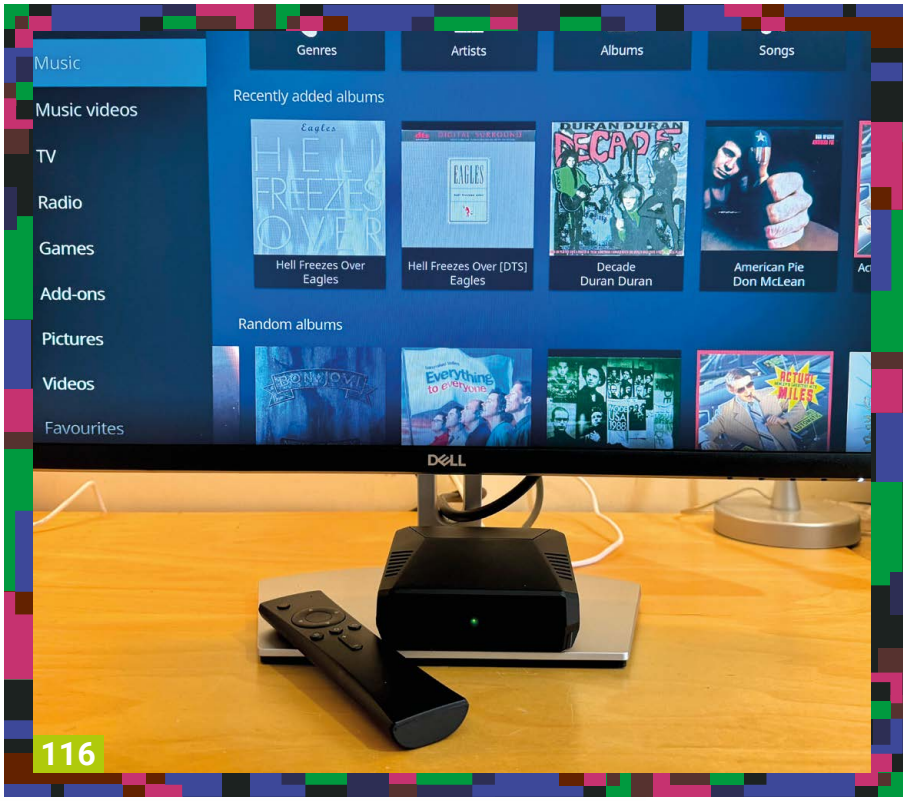
130 Make a private cloud server
Save on subs and improve your privacy

148 Essential Electronics
Basic components and simple circuits

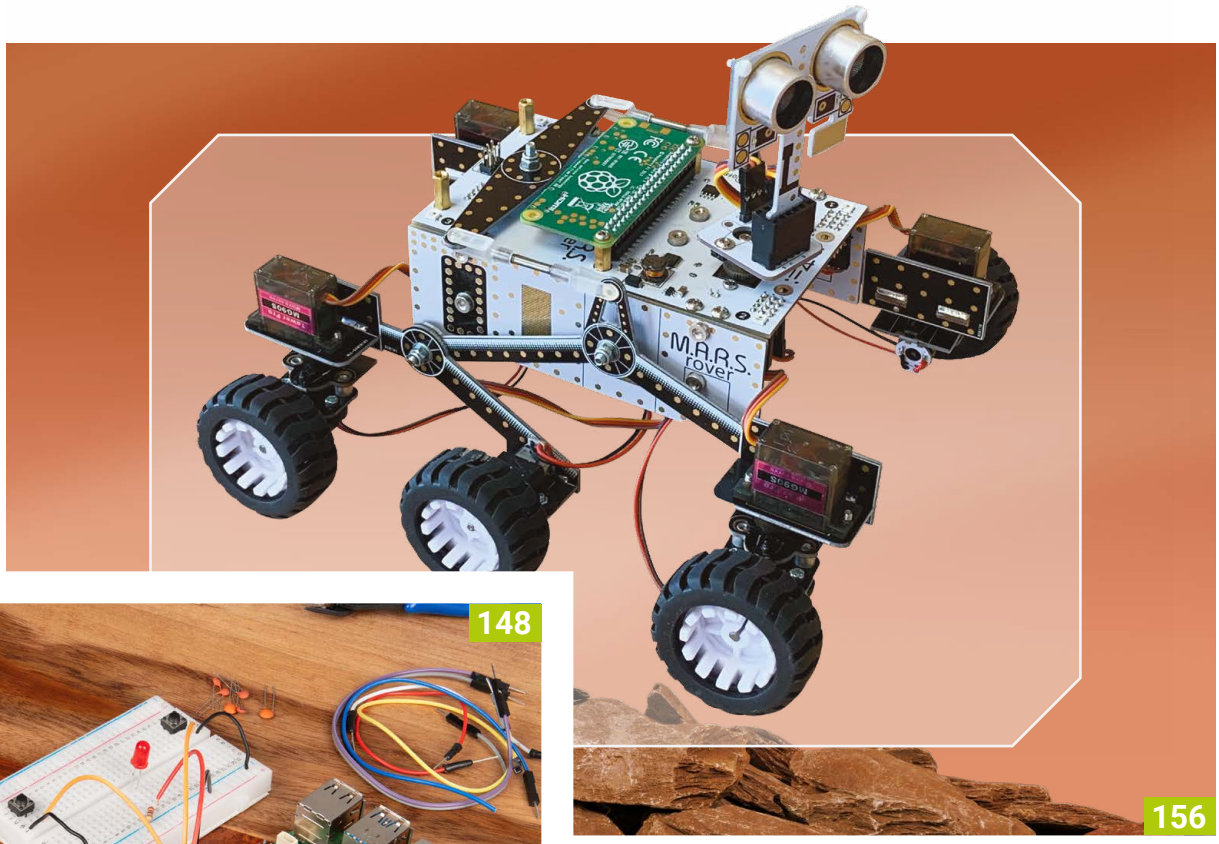
156 Robot explorers
Get out in the world with these automatons

164 Play retro horror classics on Raspberry Pi 5
How to play scary games on Raspberry Pi

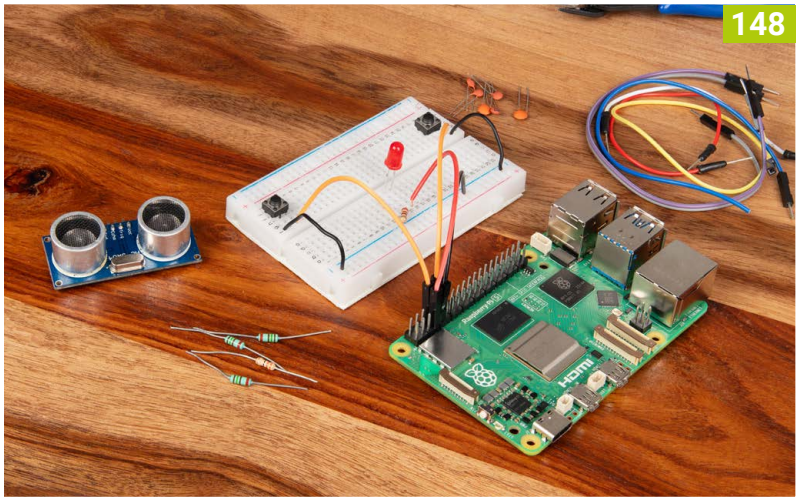
175 Handheld gaming with Raspberry Pi
How to play on the go, and make your own



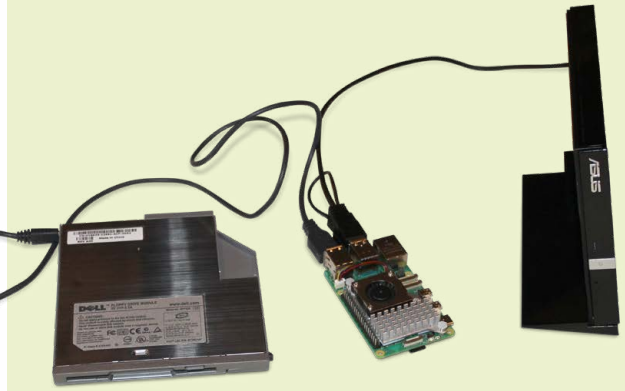




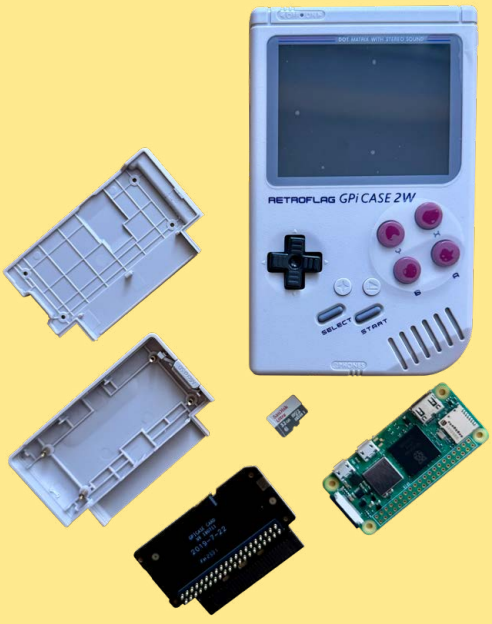
156



148



164



175



BUILD A RASPBERRY PI 5 MEDIA PLAYER

Free your films, videos and music from your computer with our complete guide

PJ Evans brings the popcorn

Since its inception, Raspberry Pi has always been a favourite choice for those wanting to build their own media centre. But why bother when so many off-the-shelf options are available? There are many reasons: Control over your data, avoiding subscription costs, accessing more obscure services like public domain films and homebrew games. The biggest reason of all is because it's fun. Over the next few pages we'll take a look at the hardware and software available to you, and run through a powerful setup using the popular Kodi platform. Soon you'll be on the sofa watching all your favourites.

HARDWARE

There are a few things you can do to really make your media centre shine



Raspberry Pi 5

Yes, it sounds obvious but the latest iteration of Raspberry Pi is perfect for video performance up to 4K.

magpi.cc/raspberrypi5

£58

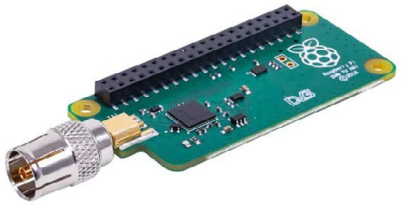


Argon IR Remote

Pair your Argon case with this elegant IR controller and you don't have to leave the sofa.

magpi.cc/argonremote

£9



Raspberry Pi TV HAT

Did you know you can watch over-the-air digital broadcasts? Just add this HAT!

magpi.cc/tvhat

£21

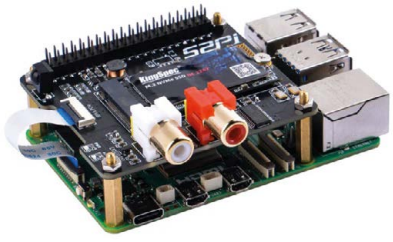


Argon ONE V3 M.2 NVME Case

Argon's latest for the Raspberry Pi 5 features M.2 SSD support, active cooling and an IR receiver.

magpi.cc/argononev3m2

£46



52Pi NVDAC

Audio quality your priority? This two-in-one HAT gives you an M.2 SSD and a high-quality DAC.

magpi.cc/52pinvdac

£29



Mini Bluetooth Keyboard

If you fancy browsing the web or chatting from your chair, get a wire-free mini keyboard.

magpi.cc/minikeyb

£13

SOFTWARE CHOICES

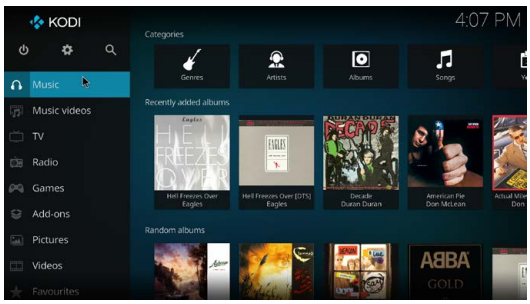
Now you have your hardware, what to run on it? Luckily there's no shortage of options

LibreELEC & Kodi

libreelec.tv

- Dedicated image, so easy to install
- Handles videos, audio and more
- Community supported with hundreds of plug-ins

LibreELEC is a dedicated operating system designed to only run Kodi, which is one of the most popular media players available. A solid all-rounder that handles hundreds of different audio and video formats, it's designed for the big screen and works brilliantly with a remote control. Access to streaming comes through the huge repository of plug-ins.

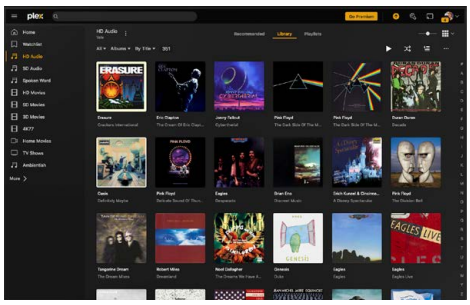


Plex

plex.tv

- Perfect for streaming both home and away
- Lots of free content
- Superb library management

Where Kodi is for consuming media on a dedicated device, Plex is a server that gives you access to your media anywhere. Install the server and add your media using the excellent web interface then you can use the Plex client app on your computer, phone or even Kodi. You can also access your media when you're outside your home network.

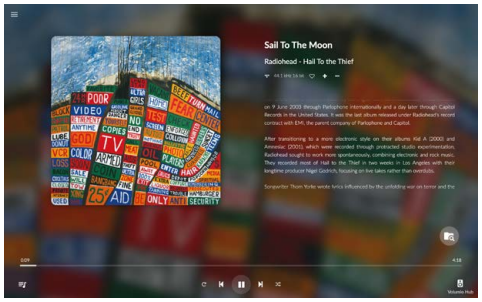


Volumio

volumio.com

- Audiophile-grade solution
- Beautiful interface
- Wide range of remote control apps

If you're looking for a high-quality audio-only solution, Volumio have spent years developing their audiophile solutions for Raspberry Pi. Paired with a good DAC, you have a music player with impressive library management that rivals devices that cost several times more. It's also available as an OS image for simple installation.

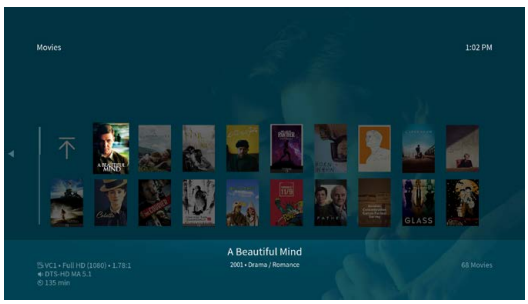


OSMC

osmc.tv

- Elegant interface
- Highly customisable
- Lots of plug-ins

One of the joys of open-source software is that anyone is free to 'fork' an existing codebase and build their own version. OSMC forked Kodi so they could add new features. The result is an elegant design which suits those of a minimalist persuasion. Like LibreELEC, it's available as an OS image. Choose this if you want a calm, refined experience from your media centre.



FILL UP THAT SSD

There's no point having a state-of-the-art media player with nothing to play. Here's where you can find great content

YouTube — Videos

The most popular video service in the world is obviously going to be a must-have for your media server. YouTube on Chromium works out of the box if you're using Raspberry Pi Desktop. If you want to use it with Kodi, the good news is a plug-in is available directly from the Kodi interface. Just head over to the Add-ons menu and search for 'YouTube'.

Netflix (also Disney+ etc) — Movies & TV

Many on-line streaming services use Widevine, which is a browser-based anti-piracy system. This is not installed by default on Raspberry Pi, so services such as Netflix won't work. Luckily it can be installed simply, just follow this guide: **magpi.cc/widevine**. If you're using Kodi, try the unofficial plugin: **magpi.cc/netflixkodi**

Qobuz — Music

Over the recent years, music file size has stayed the same, but storage has got bigger and cheaper. There's no longer the need to crush the quality, instead you can use FLAC which is a 'lossless' format that loses no music quality in its compression. The strangely named Qobuz is a leading online retailer of FLAC-encoded music.

DON'T MANGLE YOUR MEDIA

Keep on top of some basic housekeeping, and you'll always be able to find what you want

Tag all the things

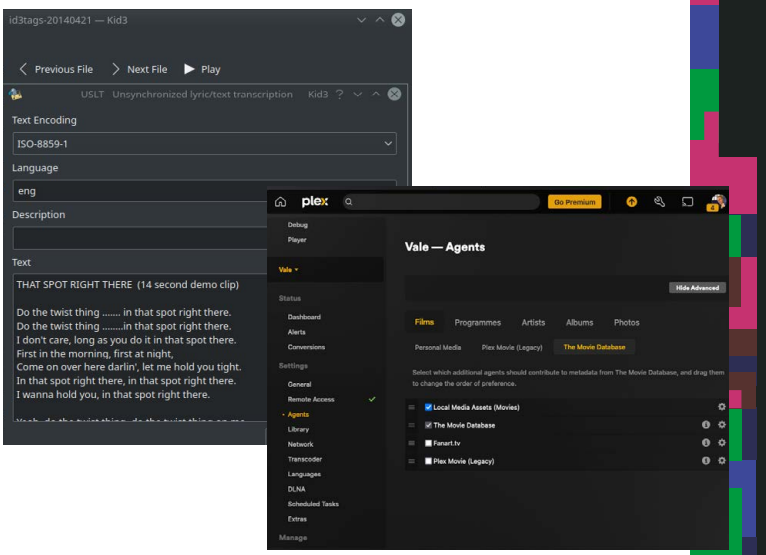
The key to a neat media library is to tag everything. Tags are metadata encoded in the media file itself that tells the media library things like titles, artists, genres and track numbers. Without properly tagged files, you may find things hard to find and out of order. Try **magpi.cc/kid3**.

What's in a name?

Quite a lot, as it turns out. Many media libraries will make assumptions based on the filename of your media. For example, Plex likes music files to start with the track number (e.g. "01 Help.flac") and will correctly order them. TV Show filenames should contain the season and episode in the format "s01e02".

Use the scraper

Platforms such as Kodi and Plex have built in 'scrapers' or 'agents' that will look at your media filename and try to tag it for you (although they don't always write the tags to the file, only their database). This can be great for automatically getting artwork and extra fields like actors, directors or lyrics.



BUILD A KODI MEDIA CENTRE

If you're not sure where to start, this tutorial will help you build a powerhouse Kodi media centre perfect for the living room

You'll Need

- SD Card
- Argon ONE V3 M.2
- rgon remote control
- M.2 NVMe SSD (We used a 1TB)

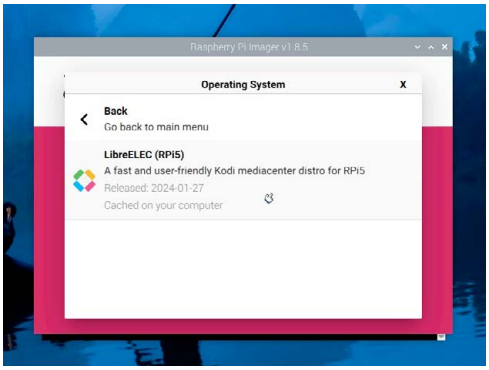
01 Assemble your hardware

Following the provided instructions, mount your Raspberry Pi 5 into the Argon ONE case. Prepare a microSD card with a copy of Raspberry Pi OS with Desktop and insert it into the Raspberry Pi. Carefully connect the NVMe ribbon cable. Connect a monitor, keyboard and mouse then boot up. To enable the NVMe SSD, run `sudo raspi-config`, select Advanced Options, Bootloader Version then Latest. Save and reboot.



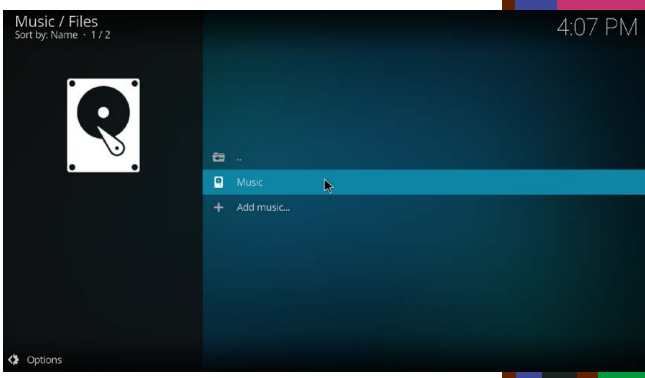
02 Install LibreELEC

Once rebooted, In the Desktop, run the Imager (you'll find it under Accessories) and select 'Raspberry Pi 5' as the device, 'LibreELEC' as the OS (under 'Media Player OS') and select your SSD as the storage. Once the image is written, shut down and remove the microSD card. Put everything back together and boot the Raspberry Pi. Make sure you've got a keyboard connected for the next bit.



03 Initial configuration and file transfer

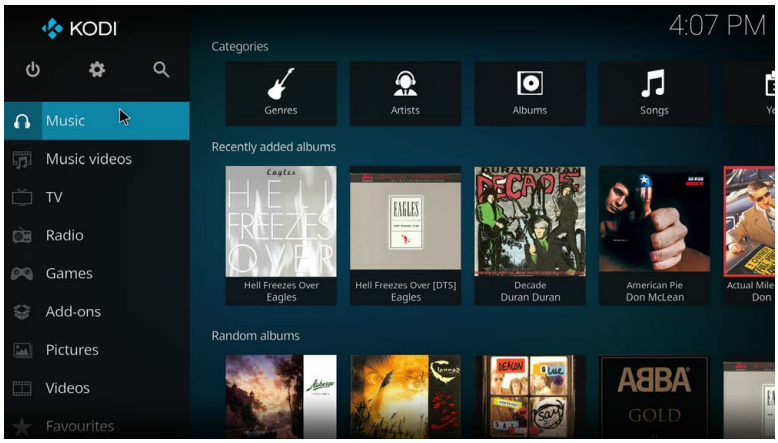
On first boot Kodi will start a setup wizard where you can configure things like Wi-Fi and ssh access. Now it's time to load up some local media or configure network connections. For local storage you can map the content folder to a local mapping using Samba or use `scp` to copy files across on the command line (hostname: libreelec.local). Kodi has already created some folders for you in the root directory for movies and music. Start by uploading some tunes into the 'music' directory.



> A great money-saving way to watch classic films is to investigate the world of the public domain

04 Configure libraries

The default folders are already 'mapped' to the different categories in Kodi, but you need to initiate the first scan. Select 'Music' then 'Enter Files Section'. You'll see 'Music' next to a disc drive icon. Right-click on the icon and select 'Scan item to library'. Your music will now be indexed by Kodi and within a few seconds you'll be able to return to the Music library and see all your cover art. Repeat this process for your movies and videos.



05 Add remote control

So you can get all cosy on the sofa and enjoy your media, the Argon ONE case has an infrared receiver. With the Argon remote, you can control Kodi from across the room. Instructions are provided on how to configure the remote here: **magpi.cc/argonremoteconfig**. Once installed, you'll no longer need your keyboard and mouse and your new device will be ready to take pride of place in your media setup.



Public domain content

A great money-saving way to watch classic films is to investigate the world of the public domain. These are films that have lapsed out of copyright so are free to view and download. You may have to wallow through some stinkers but there are some genuinely brilliant movies out there. Popular repositories are:

- **archive.org**
- **magpi.cc/pubdomfilms**
- **publicdomaincinema.net**
- **magpi.cc/retroflix**

Gaming

Many media streaming services now include gaming. Raspberry Pi is no different. Kodi offers a range of gaming plug-ins including many popular retro computer emulators. Plus, thanks to Microsoft's Xbox Cloud Gaming service, you can play the latest AAA console games in your living room using a Raspberry Pi. For a full tutorial have a look at issue #136 (**magpi.cc/136**).

Raspberry Pi 5 Cases

Group Test

Phil King tests some of the best cases available for Raspberry Pi 5

Raspberry Pi 5 is one cool single-board computer, but it can look even cooler inside a smart case. More importantly, a case can also help it to keep the board cool under a heavy workload, by using thermal pads, a heatsink, fan, or a combination of all three. To test the cooling effectiveness, we performed a stress test using all four of the CPU cores at the default maximum of 2400GHz. We also checked the Wi-Fi signal to see if the case interfered with it. In addition, we assessed each case's capacity – for mounting a HAT etc – and the access to Raspberry Pi 5's ports. It's a best case scenario!



Official Raspberry Pi 5 Case

Raspberry Pi | magpi.cc/case
£10 / $10

Coming in red/white or black, the official case comprises three plastic sections that snap-fit together, so assembly is a cinch. The middle section includes a clear insert with a fan that connects to Raspberry Pi 5's Fan port. A small SoC heatsink is also included.

Capacity: By removing the clear insert and fan from the middle section, you can mount a HAT. Or you could use a booster header to lift it above the fan.

Port access: All side ports are accessible via cutaways, along with the power button. The middle section features a wide slot to enable access to the GPIO pins when the lid is removed; it could also be used for routing cables for a camera or other accessories.

Cooling: The variable-speed fan's cooling is aided by vents in the bottom of the case, plus the SoC heatsink. It works even with the lid on, due to a circular gap. In our tests, it prevented throttling even under a heavy workload, but some other cases performed better.

Wi-Fi signal: As you'd expect, the plastic case has very little effect on the signal, which remained strong.

Verdict
A well-thought-out, versatile design that covers most uses.



ICE Tower CPU Cooler

The Pi Hut | magpi.cc/icetower
£16 / $17

Its cool-looking tower design is enhanced by RGB LEDs making it glow in various colours. Is it really a case? Well, it does have a plastic base, connected via screws and bolts to two metal mounting brackets and the main fan/heatsink section on top. Assembly is a little fiddly (especially the brackets), but not too tricky. The heatsink it connected to the SoC via a thermal pad.

Capacity: You won't be mounting any HATs with that large fan and heatsink sitting atop Raspberry Pi!

Port access: The open design means access to all the ports and GPIO pins is unhindered.

Cooling: The vertically mounted fan blows air onto the aluminium fins of the large heatsink, whose base is connected to Raspberry Pi 5's SoC via a thermal pad. This results in excellent cooling performance. By default, the fan doesn't even kick in until the temperature reaches 60°C (which didn't happen during our tests), but it could prove more useful if you're overclocking Raspberry Pi 5.

Wi-Fi signal: The presence of that metal heatsink does have an effect on the signal, but not too much.

Verdict
With its unusual design and lighting, it looks very cool… and delivers great cooling.



Argon NEO 5

Argon 40 | magpi.cc/argonneo5
£18 / $19

A three-piece design – with two aluminium sections and a plastic base – the NEO 5 oozes style and quality with its red/black colour scheme and solid feel. The middle section is especially impressive, with a fan next to curved fins to aid cooling. Assembly is aided by a guide in a small booklet.

Capacity: With the top part removed, you could mount a HAT with a booster header to lift it over the fan. A special NVMe version of the case is also available.

Port access: The middle section has cutouts for the main ports, camera/display, PCIe, UART, RTC, and the GPIO pins (with a helpful labelled strip on the side).

Cooling: The fan's effect is aided by vents in the middle section and base, plus a couple of thermal pads for the SoC and PMIC. This results in very good cooling performance.

Wi-Fi signal: The mainly metal case does result in a noticeable reduction in signal strength and quality.

Verdict
A stylish, quality case with great cooling performance.



KKSB HAT Case

The Pi Hut | magpi.cc/kksbhat
£16 / $16

The tallest case in the group, it's 56mm high, and is designed to accommodate a Raspberry Pi 5 with a HAT mounted on top. The anodised aluminium case has no built-in cooling, but you could add an Active Cooler or heatsink. There's plenty of room, and a GPIO booster header is supplied if needed to lift a HAT up slightly. Assembly is tricky, as you need to remove both side panels and slide in Raspberry Pi, screw it in place with tiny screws, and then add a HAT afterwards.

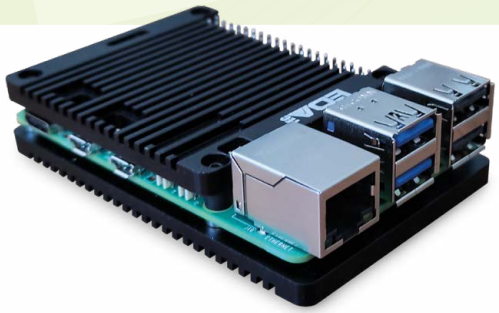
Capacity: The high headroom means there's plenty of room to mount HATs on top of Raspberry Pi. Getting things in and out of the case and securing them in place is fiddly, though. We'd have preferred a removable lid.

Port access: The main ports are accessible via cutouts. There are slots for camera connections and PCIe ribbon cables. You'll need to remove one or both side panels to access the other ports.

Cooling: There's no built-in cooling, but the KKSB can be used with an Active Cooler, or most other coolers and heatsinks. Lots of slots in the case aid ventilation.

Wi-Fi signal: Maybe it's all those ventilation slots, but the signal is hardly affected.

Verdict
Not the most user-friendly design and no built-in cooling, but good capacity.



Passive Cooling Open CNC Case

EDATEC | magpi.cc/opencnccase
£7 / $8

Raspberry Pi 5 is sandwiched between the two case sections, with no side pieces. Each grooved aluminium piece is fitted with several thermal pads to aid passive cooling, including for Raspberry Pi 5's SoC, PMIC, and wireless module. The two case sections are secured with long bolts.

Capacity: With the open design and GPIO header access, you can mount a HAT just above the top section.

Port access: With no side pieces, access to ports is unfettered, with cutouts for the GPIO pins, PoE header, PCIe and camera/display ports, plus UART and RTC battery connectors.

Cooling: Highly effective passive cooling is provided by the numerous thermal pads and grooved aluminium case pieces. It keeps Raspberry Pi 5 cool (37.8°C) even under a heavy workload.

Wi-Fi signal: The metal case does result in a noticeable reduction in signal strength and quality.

Verdict
Great port access and some impressive passive cooling performance.



ABS Fan Case

The Pi Hut | magpi.cc/absfancase
£15 / $16

While it doesn't feel the most solid or weighty case, its two main sections have plentiful vents and you get a choice of coloured stripes to stick on the lid! An Armour Lite V5 fan-equipped heatsink sits on top of Raspberry Pi 5 via five thermal pads.

Capacity: The heatsink takes up a fair amount of space in the case. You could still mount a HAT with a GPIO header booster and the lid off.

Port access: The main side ports are accessible via cutouts. With the lid removed, you can access all the others.

Cooling: Five thermal pads connect the SoC, PMIC, RP1, RAM, and wireless module to the heatsink with built-in fan. Considering this, cooling performance was not quite as good as we expected, but decent.

Wi-Fi signal: There's some effect on the strength and quality, possibly due to the metal heatsink.

Verdict
Middling cooling performance in a lightweight case.



Pibow Coupe 5

Pimoroni | magpi.cc/pibowcoupe5
£10 / $10

Like previous editions of the classic Pibow, this case comprises multiple acrylic layers that need to be assembled to surround Raspberry Pi and then secured with four long bolts. It's like doing a 3D jigsaw puzzle. The top of Raspberry Pi is left open, which will suit some use cases better than others.

Capacity: The case's open top design means you can mount any HAT you like.

Port access: The USB and Ethernet ports sit on top of the case, while cutouts enable access to the rest. GPIO pins are fully accessible.

Cooling: There's no built-in cooling, but the Pibow can be used with an Active Cooler or standard heatsink.

Wi-Fi signal: As you'd expect from an open-top case, the signal strength and quality are very good.

Verdict
A multi-part, open-top case with no built-in cooling, but very versatile.



FLIRC Raspberry Pi 5 Case

The Pi Hut | magpi.cc/flircrpi5
£14 / $15

Like previous models, this smart-looking FLIRC case is designed for use with a media centre setup. The main aluminium section also acts as a heatsink via a thermal pad stuck to Raspberry Pi's SoC. There's also a mini power button.

Capacity: There's no room for a HAT inside the case.

Port access: The regular side ports are all accessible via cutouts, but the internal ones – including PCIe and GPIO pins – are not.

Cooling: The metal case acts as one large heatsink via a thermal pad on the SoC, providing effective passive cooling.

Wi-Fi signal: The metal case does reduce the signal strength and quality somewhat.

Verdict
A smart and robust case for a media centre.



Passive Cooling CNC Case

EDATEC | magpi.cc/cnccase
£15 / $19

As with the Open CNC Case, the two case pieces are aluminium; here they lack grooves, but retain the thermal pads. The bottom part also has sides with cutouts for the ports. The result is a sleek-looking case with a snug fit.

Capacity: The GPIO header cutout enables the mounting of a HAT above the top of the case.

Port Access: Cutouts enable full access to the main side ports, along with GPIO pins, PoE header, PCIe and camera/display ports, and UART and RTC battery connectors.

Cooling: As with the Open version of the case, the numerous thermal pads (for SoC, PMIC, wireless, and underside) provide highly effective passive cooling.

Wi-Fi Signal: Fully enclosing Raspberry Pi 5 in a metal box has an adverse effect on the wireless signal.

Verdict
A metal case with great cooling, but Wi-Fi signal isn't great.



Argon ONE v3

Argon 40 | magpi.cc/argononev3
£25 / $30

The biggest case of the bunch, it features a daughterboard that plugs into the side of Raspberry Pi 5. As well as rerouting video and power to full-size HDMI and USB-C ports, its RP2040 chip handles cooling and power management. There's also an IR receiver to use with a remote (supplied separately). A removable magnetic flap in the case top reveals the GPIO pins and labelled strip. An NVMe version of the case is also available.

Capacity: Despite the size, it's not possible to mount a standard HAT inside the case.

Port Access: USB and Ethernet are accessible, along with power and two full-size HDMI ports.

Cooling: An angled fan in the top case section is aided by two thermal pads. You need to install a script for fan control. Cooling performance wasn't the best, especially under stress.

Wi-Fi Signal: Strength and quality were only slightly lower than with the official case.

Verdict
A feature-packed case that's ideal for a media centre or desktop system.

Cooling comparison

We checked the typical CPU temperature when idling and under stress (with all four cores running at 2400MHz).

Case	Idling (°C)	Stressed (°C)
Official Raspberry Pi 5 Case	47.2	65.9
ICE Tower CPU Cooler	31.2	48.8
Argon NEO 5	28.5	42.2
KKSB HAT Case*	–	–
EDATEC Passive Cooling Open CNC Case	25.7	37.8
ABS Fan Case	45.5	65.3
Pibow Coupe 5*	–	–
FLIRC	33.4	49.9
EDATEC Passive Cooling CNC Case	27.0	40.0
Argon ONE v3	39.5	67.5

* No built-in cooling.

Wi-Fi signal

We tested the average strength and quality of Raspberry Pi 5's Wi-Fi signal for each case.

Case	Strength (dBm)	Quality (%)
Official Raspberry Pi 5 Case	-43	96
ICE Tower CPU Cooler	-59	73
Argon NEO 5	-59	73
KKSB HAT Case	-48	90
EDATEC Passive Cooling Open CNC Case	-59	73
ABS Fan Case	-57	76
Pibow Coupe 5	-46	93
FLIRC	-59	71
EDATEC Passive Cooling CNC Case	-65	64
Argon ONE v3	-50	86

Sixfab

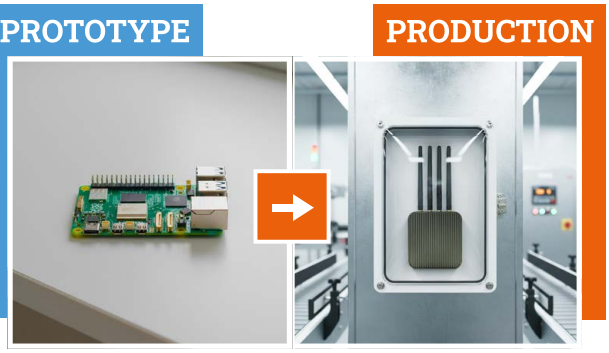
From Project to Real-World AI:

Powered by Raspberry Pi, Delivered by Sixfab

Sixfab is a Raspberry Pi Design Partner delivering ALPON Edge Computers, global connectivity, and ALPON Cloud — all in one stack from prototype to production. From proof-of-concept to thousands of always-on devices — scaling made simple.



Keep the flexibility you love, add the reliability you need.



Deploy in days, not months
Developer-friendly guides & resources
Scale from 1 → 1000+ devices without redesign

SPECS

On-Device AI
Run AI models right on your device — faster, safer, smarter.

Built to Last
Fanless enclosures, industrial power, certified global connectivity.

Secure & Manageable
OTA updates, hardware cryptography, and fleet cloud management.

Raspberry Pi
Design Partner

Ready to scale your Raspberry Pi project without the headaches?

sixfab.com/scale

Part 01

Build a private cloud server

Fed up with service subscriptions? Want to do things yourself and protect your privacy? This new series shows you how



MAKER

PJ Evans

PJ is a writer, software engineer and home automation enthusiast. He is guaranteed 100% AI-free, even if his home server isn't.

@mrpjevans

We live in a golden age of free open-source software. We also live in an age of megacorps offering 'free' services that routinely sell your data via arcane terms and conditions. Luckily there is a new appetite for running your own services and regaining control thanks to fast and affordable bandwidth and the growth of small yet powerful computers to do the work (sound familiar?). In this new series, we're going to go step-by-step through the process of building a reliable cloud server that you own and control. We'll cover file sharing, email, social media and other collaboration tools. Let's start by choosing and building our base server.

You'll Need

- Argon EON NAS enclosure (or similar) **magpi.cc/eonnas**
- At least two HDD drives
- Additional OS drive (ideally SSD)
- Fast internet in both directions
- SATA to USB3 cable (optional)

01 Is this a good idea?

We're setting out to build a server that can replicate many of the popular 'SaaS' (software as a service) solutions out there, from email to collaborative spreadsheeting. This is only practical if you have the time to devote to keeping it updated (security especially) and are happy to deal with the inevitable glitches. You'll also need a decent internet connection if you want to run things like an email server or a Mastodon instance. There are many reasons to undertake this project, some political, some practical, but we're mainly doing it because it's a fun learning experience.

02 Choose your storage

We're making file storage an integral part of the server. As such, we want lots of space and some form of backup strategy. Although you can always upgrade your storage as you go, it's best to think ahead and get as large a solution as you can afford. Our project is using 2 × 4TB SATA hard drives as file storage, plus a 250GB SSD SATA drive for the operating system. We'd happily go SSD all the way, but the costs are prohibitive. Separating the OS from the file storage allows us to use a fast SSD and makes it easier to upgrade in future. You could also use a microSD card for the OS.

03 Prepare the operating system

We'll refer to our choice of hardware from now on, so alter the process as needed for your setup. We're using a small but fast SSD for our operating system. This means we need to copy the image directly onto the SSD. The easiest way to do this is to use a cheap SATA to USB3 cable on your main computer or other Raspberry Pi and use Raspberry Pi Imager (**magpi.cc/imager**), selecting 'Raspberry Pi Lite (64-bit)'. If you don't have a cable, install the drive in the NAS and boot off a microSD card and use that to burn the OS onto the SSD. Either way, use the customisation feature to choose a good network name and enable SSH for remote access.

04 Assemble your NAS

This will vary depending on what type of disk setup and enclosure you are using, but either way now is the time to install your disks. The Argon EON requires some initial disassembly to access the space for a 4GB Raspberry Pi 4. For our setup we have 4 SATA slots available. The first (left from the front-on view) will host our SSD drive (a quirk of the EON, due to its shape, is that slots 1 and 4 must be smaller drives). Next we install our main file storage drives in slots 2 and 3. All drives must be secured to the backplate with the supplied screws. Finally the EON has a USB 3 coupler to connect the disks to the Raspberry Pi.

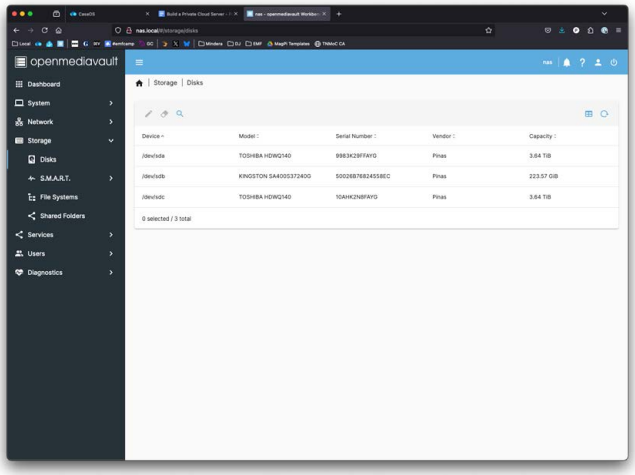


> File sharing, email, social media and other tools

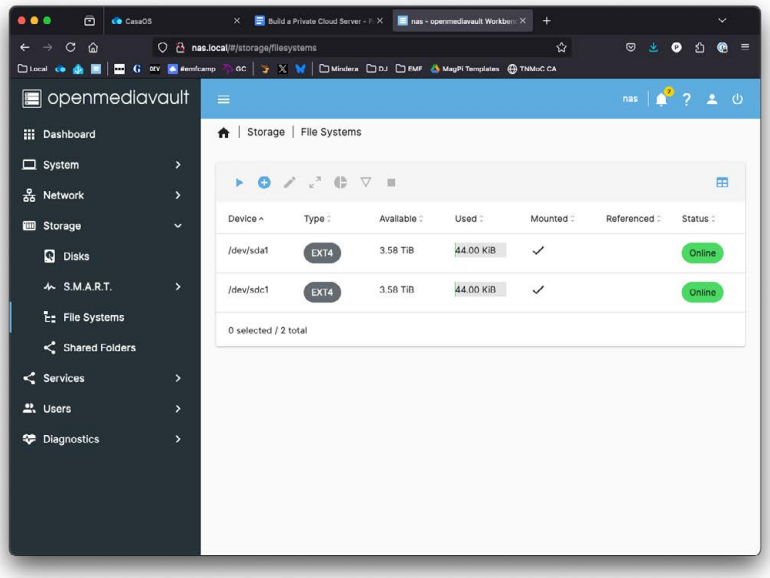
Top Tip

Choosing disks

If using hard disk drives, consider buying dedicated NAS drives. These tend to be slower than desktop drives but much more efficient and quieter.



When you first log in to OpenMediaVault you'll see your disks listed as devices



You can create, view and manage file systems on this page

05 Test booting

Time to fire up the server for the first time and check everything is in order. It's worth connecting a monitor and keyboard just in case something is out of place. If you find the SSD doesn't boot, it may be because the Raspberry Pi isn't checking for it and you need to change the bootloader. Open Raspberry Pi Imager. Under operating systems choose 'Misc utility images' > 'Bootloader' > 'SD Card Boot', burn that to a microSD card and boot your NAS from it. When a green screen appears, power off and remove the card. Your SSD should now boot normally.

06 Wire up and update

We strongly recommend using a wired connection for this project as it may become essential for reliable performance, especially if you're using email or social media services. You'll also need to check in on the server from time to time, so make sure you can use SSH to log in remotely. You should be able to reach the NAS using your choice of name plus '.local'. So, if you set the hostname to 'nas' in Raspberry Pi Imager, you can SSH in using 'nas.local' (note: not all routers support this feature). Once logged in make sure everything is up-to-date by running the following from the command-line:

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

If you're using the Argon EON, you should also install its config scripts at this point. See the manual for details.

07 Install OpenMediaVault

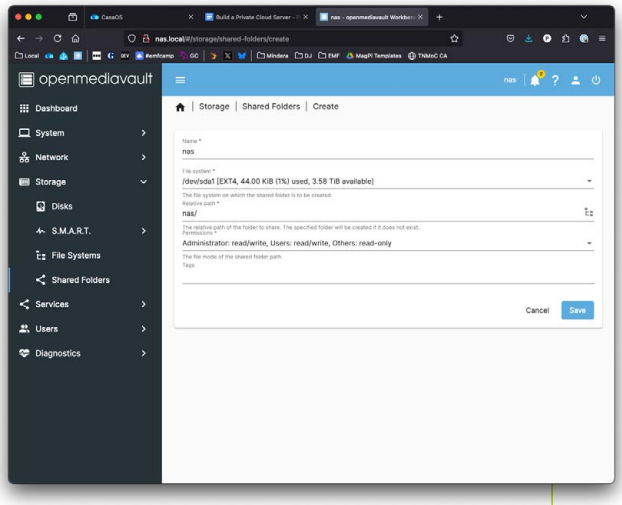
OpenMediaVault (or OMV) is a robust, well-featured framework for creating our own home storage. It's excellent for avoiding some of the more scary command line utilities for handling disk storage and setting up sharing. OMV's job is to help you prepare your disks and share them securely with the other computers on your network. The OMV team have provided a custom setup script at and you can run it directly by entering:

```
wget -O - https://raw.githubusercontent.
com/OpenMediaVault-Plugin-Developers/
installScript/master/install | sudo bash
```

There will be a lot of text and the process will go on for several minutes. At the end the server will reboot. Once complete you should be able to access OMV in a web browser at **http://nas.local/** (or your equivalent). You can login with username 'admin' and password 'openmediavault'. Remember to change that password!

08 Configure your storage

You can now see the OMV web interface for the first time. Feel free to have an exploration. Assuming you're starting with new disks, you need to partition and format them. Luckily OMV makes this a much easier process than using the command line. Click on 'Storage' then 'Disks'. You'll see your disks, including the OS disk, listed. If not starting afresh you can wipe them here. To actually use the disks, click on 'File Systems' and



The final step is to create share points on each disk (in reality each is a root folder on the disk) and then share using SMB

the plus sign on the toolbar. Select 'EXT4' and choose your first disk. It may take a few minutes to complete. Repeat for each disk.

09 Mounting and sharing

Once each disk has formatted you are presented with a screen to mount the drive. Select the disk you just formatted and click 'Mount'. The file system is now available to OMV. You'll see a yellow 'Pending' prompt. This is a feature of OMV. Wherever you make changes, they will not take effect until you acknowledge that prompt. Now click 'Shared Folders' and the plus button. Give your share a meaningful name (we used 'nas') and choose your first disk. Click 'Save' and apply the changes. Now click 'Services', 'SMB/CIFS' then 'Settings' and enabled the service. Now go to 'Shares' then the plus button and select your shared folder. Save and apply.

10 Connect to your new share

In the previous steps you formatted your disks, created a shared folder on one of them and then allowed access using the popular SMB protocol, which is supported by a wide range of operating systems. You can now connect to your new storage! In each case, use your Raspberry Pi OS username and password as credentials. In Windows right-click on 'This PC' and select 'Map network drive'. Enter the details in format **\\nas.local\nas** (change for your setup) and select 'use different credentials'. In macOS, select Finder then 'Go' from the menu and 'Connect to server'. Enter the address as '**smb://nas.local/nas**' and connect.

11 Nightly backup

So what about the other disk? We're going to use that to back up our precious data. Under 'Storage', 'Shared Folders' create a share for the second disk (e.g. '**nas-backup**'). Then under 'Services' select 'Rsync' then 'Tasks'. Select your first share as the source and the second share as the target. Change 'minute' to 0 and 'hour' to 0, leaving all other options unchanged. Save and apply. Now, every night at midnight, the contents of the primary disk will be backed up to the secondary disk. Although there is a small window where a file does not have an instant backup (we'll address this, and off-site backups, in the future) a deleted file will be instantly recoverable.

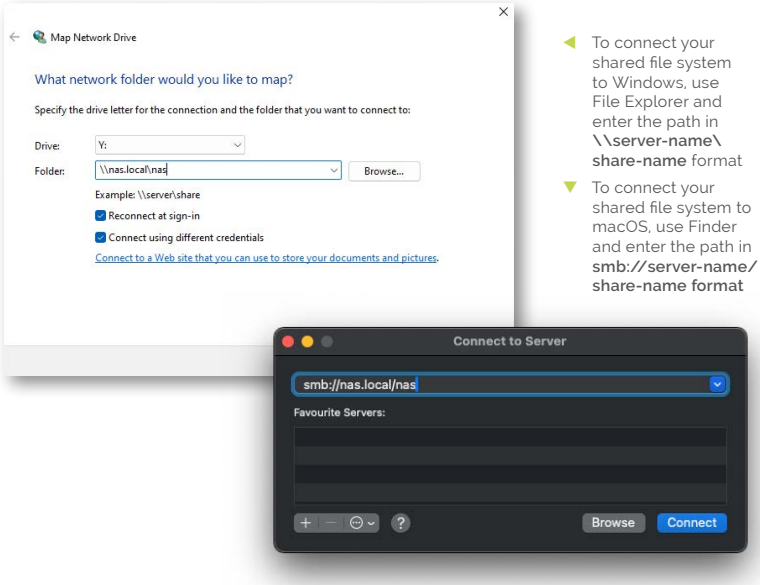
12 More with OpenMediaVault

We have barely scraped the surface of what OpenMediaVault can do. Make sure you explore the menus and look for other features such as email alerting, configuring disks to run quieter and, importantly, using S.M.A.R.T. to monitor the health of your disks. You now have file sharing available across your home network that you can share with your housemates or family. You can even create individual secured folders for personal use. Next time we'll look at accessing that data securely from anywhere on the planet, the first step in creating a true private cloud server.

Top Tip

What about RAID?

We've not used RAID (Redundant Array of Inexpensive Disks) in our setup as we're prioritising backup over availability. RAID is not a backup solution – if you delete a file on one disk, it's immediately gone from the other!



To connect your shared file system to Windows, use File Explorer and enter the path in **\\server-name\share-name** format

To connect your shared file system to macOS, use Finder and enter the path in **smb://server-name/share-name** format

Part 02

Build a private cloud server

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 from the previous chapter
- 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

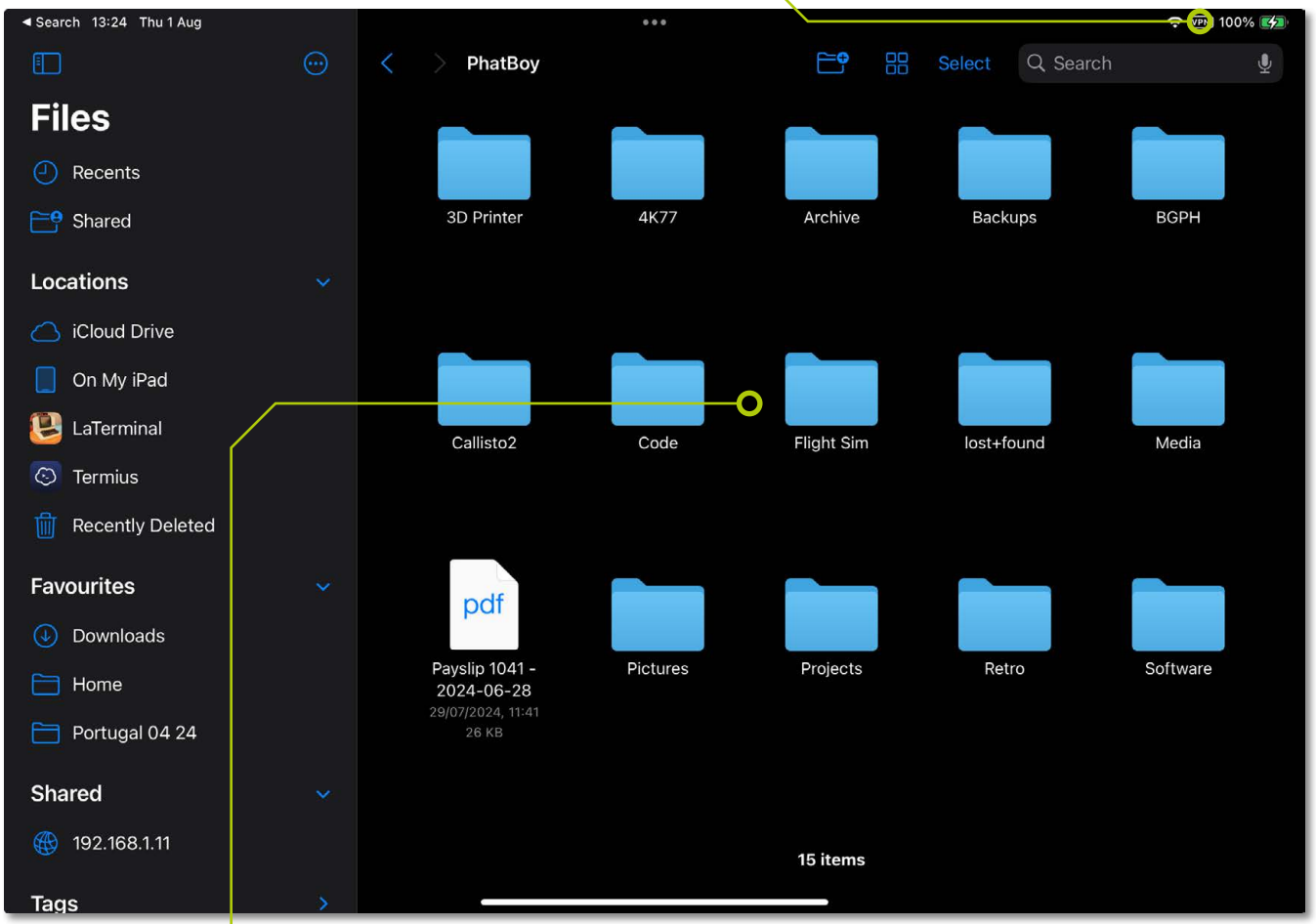
The domain supplied by a service such as DuckDNS will probably not be ideal and cannot be used for creating sub-domains or hosting things like email servers. This is why we recommend registering your own domain name. We can then map a domain to your dynamic DNS provider, which is known as aliasing. In 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.

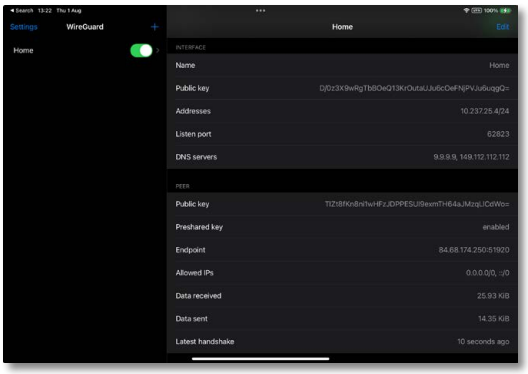
04 Install PiVPN

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

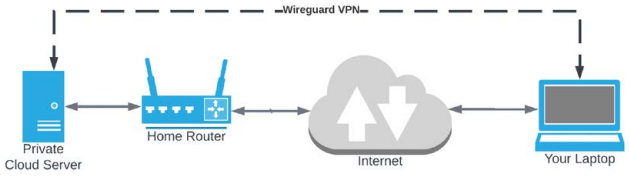
05 Configuring PiVPN

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.

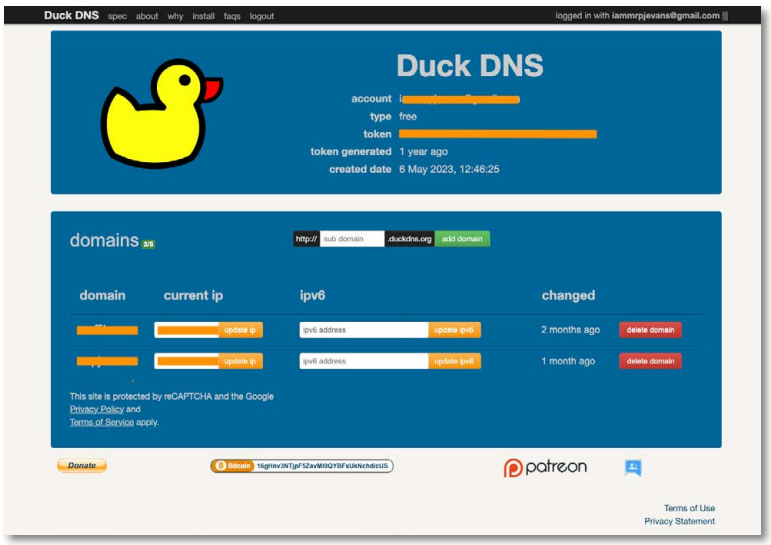
12 Next steps

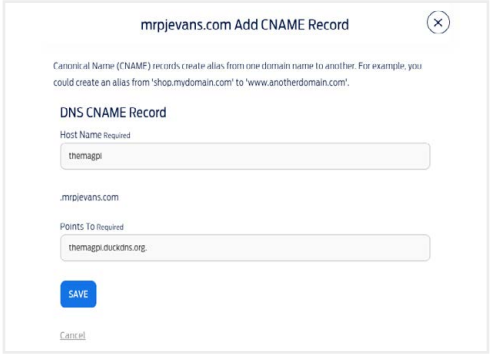
This was a complicated part of the process, but it enables all kinds of possibilities for secure access to your precious data. You can now get access to your home network from anywhere in the world and not just your cloud server, you can also reach other devices on your internal network too. However, you don't want to go through the process of creating VPN profiles every time you want to share a file with someone and in the next part 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 03

Build a private cloud server: share with friends

Share files with friends, and let them share with you, with no service provider required



MAKER

PJ Evans

PJ is a writer, software engineer and home server enthusiast. (At least, his server's AI tells him he is)

@mrpjevans

Previously, we have built our network-attached storage server and set up VPN access to your files from anywhere in the world. Now we're going to take it to the next logical step with a way to easily share your files with family and friends and let them upload files to you as well. We'll do this by installing a private server platform to your existing NAS and then adding new functionality. This will form the basis of the extra services we can add. So let's get started with the world of Docker and CasaOS.

01 Introducing CasaOS

Rather than all those fiddly command line instructions, we're going to install CasaOS (**casaos.zimaspace.com**) a dedicated solution for running home cloud servers. It uses Docker containers, a way of wrapping apps up in their own dedicated OS, to make installing server applications a breeze. Everything is done using their web-based interface, so it's a lot friendlier than a blinking cursor. We'll be using CasaOS from now on, so even if you don't want to implement file sharing, make sure you follow this section.

02 Reconfigure OpenMediaVault

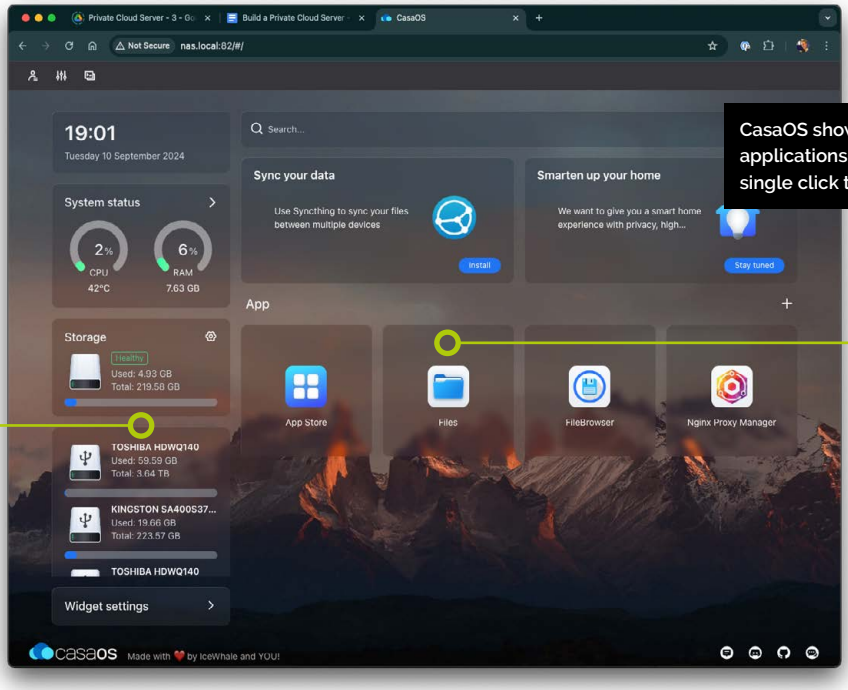
CasaOS installed its web server on port 80, which means it will clash with OpenMediaVault. We have to move OMV first. Open a web browser and go to your server (ours was called 'nas' so we went to **http://nas.local**). Login to OMV and select 'System' then 'Workbench'. Change the value of 'Port' from 80 to 83. Click 'Save' and apply the settings when prompted. You'll eventually get a red failure message. Don't worry this is just because you've moved the port. Browse to **http://nas.local:83/** and you'll be back.

03 Install CasaOS

CasaOS acts as a dashboard for all your self-hosted apps, making installation and maintenance as easy as possible. To install, start by getting a terminal window open (or using SSH) and updating using:

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

Once that has completed, run the following terminal command:



CasaOS shows all your installed applications as 'tiles' with a single click to get access

CasaOS also provides useful information on your Raspberry Pi's performance. Everything is highly customisable

```
$ curl -fsSL https://get.casaos.io | sudo bash
```

There's a lot to install, so it may take a few minutes based on your internet connection. If all is well, you'll be informed that CasaOS' web server is running. You can now visit the original URL of **http://nas.local** and you should see the CasaOS welcome screen.

04 Install FileBrowser

From the welcome screen you'll be invited to set up your account. Then you'll find yourself on the dashboard. You can immediately see that your CPU, disks and network are being monitored. In the main panel are Files and App Store. Files enables you to access your entire storage including lower-level configuration files. What we're interested in is the App Store. Click the App Store tile, then search for 'FileBrowser' and click Install. Within a few seconds, you'll be returned to the dashboard, and a shiny new tile will have appeared.

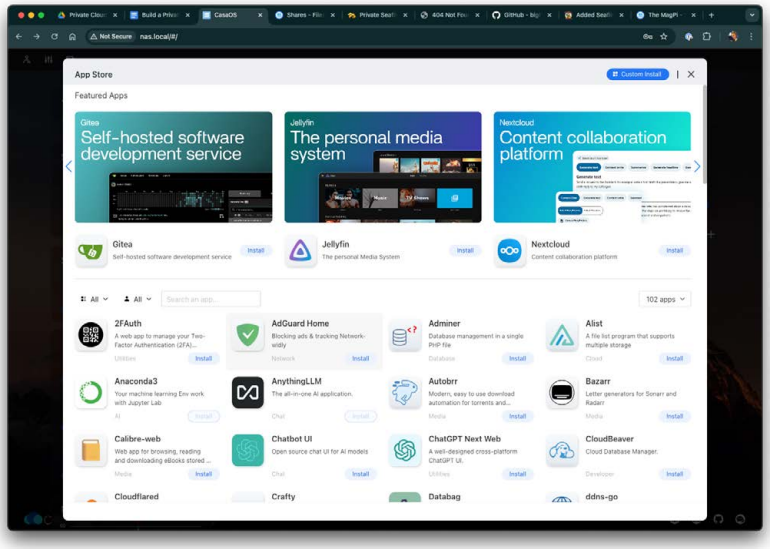
▶ CasaOS' App Store provides instant installation of many self-hosted services. You can add other repositories too

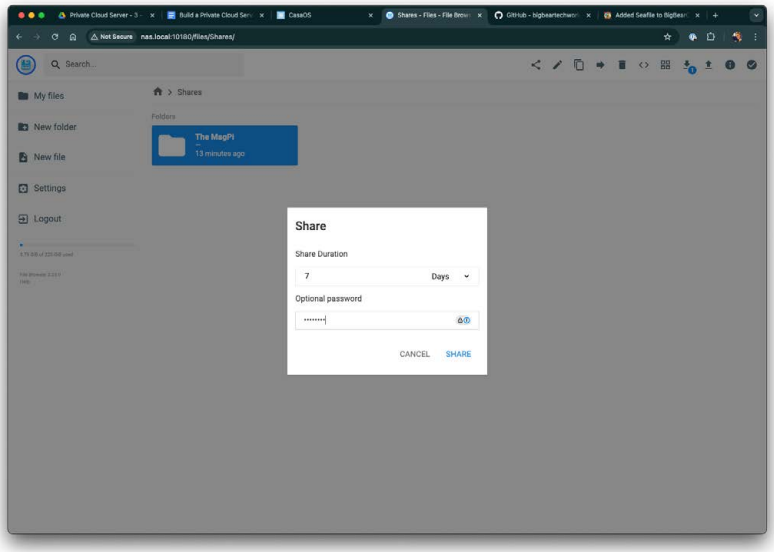
05 Set up a share space

To access FileBrowser, just click the tile. Both the username and password are 'admin' (you can change this in settings and we strongly recommend you do). You'll see a number of folders that correspond to CasaOS' **DATA** directory. Click 'New Folder' and call it 'Shares'. This can be the home for all your shared data. We created another folder in this called **The MagPi**. Go into the directory and you can upload files and folders using the top toolbar. You can create as many directories as you like and sub-directories too.

You'll Need

- Private cloud server from part 1
- Admin access to your internet router
- A domain name, see part 2





Top Tip

Adding your own tiles

You can use CasaOS' tiles to add your own bookmarks. For example, you can create a shortcut to OMV on port 23.

06 Share and share alike

You've now got something you want to share, but how to do so? There are two ways to share files. The quick way is to navigate to a folder and click the Share icon on the top toolbar. Here you can set an expiry time for the share and optionally set an access password. Click Share, and a unique link will be generated that you can share with whoever you like. For longer-term shares go to Settings then User Management. Here you can create multiple users and restrict them to their own spaces. They can then log in and be taken straight to their shared directory. However, there's a problem...

07 Getting access

Your server is behind your router, which acts like a firewall, so your friends and family have no access to your server. To give them access, and to do it securely, we're going to have to make some changes. This is only advisable if you need to share a lot of files. If it's infrequent and with people you trust, you might want to consider giving them VPN access to your network using WireGuard (see part 2). If you're happy exposing a service to the internet, we're going to have to install a SSL (aka TLS) certificate to ensure traffic is encrypted so passwords and data cannot be sniffed.

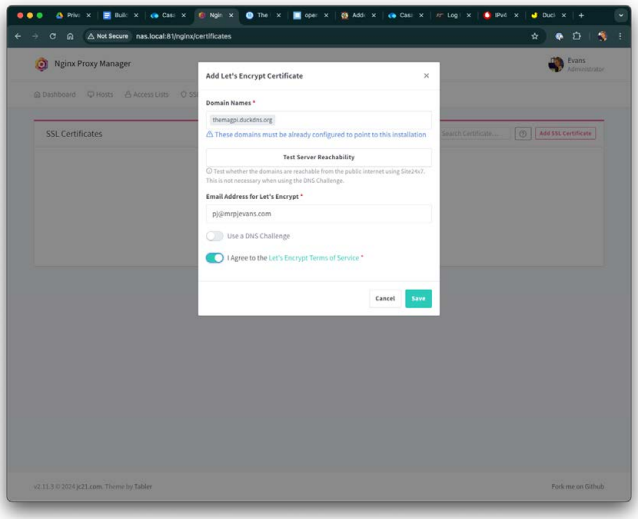
> We're going to have to install a SSL (aka TLS) certificate to ensure traffic is encrypted

File Browser is a simple server app that makes sharing files with others easy and secure

08 Moving time again

To be able to handle a TLS certificate, we need to use Nginx (engine-x), a web server that can proxy connections to our existing services. It must run on port 80 so again we need to move things around. We're going to move CasaOS to port 82 so 80 is freed up. On the CasaOS dashboard, click the settings icon in the top-left corner. On the panel that appears, change the WebUI port from 80 to 82. As before, your connection will now break. Go to your equivalent of **http://nas.local:82/** to get back in. Now go to the App Store, search for 'nginx' and install Nginx Proxy Manager.

The Nginx Proxy Server app takes the pain out of creating a proper SSL-encrypted web service



09 Router configuration

Nginx is now our gatekeeper and running on ports 80 (plaintext) and 443 (encrypted). We now need to route traffic from your Internet router to Nginx. This varies by router: it normally entails setting up port forwarding TCP traffic from ports 80 and 443 on the router to the same ports on your private cloud server. Once implemented, the outside world can reach your Nginx server using the domain name you configured in the previous part, but there's nothing to see yet bar a 'Congratulations' message. In CasaOS, click on the Nginx tile to get to its control panel. The username is 'admin@example.com' and the password 'changeme'. You'll be guided through changing these.

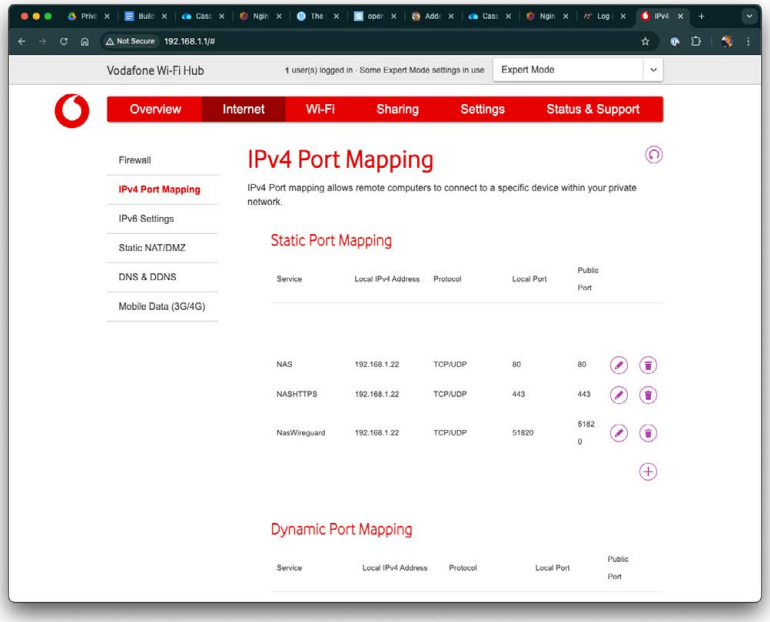
10 Get certified

Acquiring an SSL certificate used to be a complicated process costing hundreds of pounds. Thanks to the amazing work of Let's Encrypt, it's now free and takes seconds. In the control panel click SSL Certificates then Add SSL Certificate. In the panel, add your domain name and check your server is reachable. Add your email address and accept the terms and conditions. Click 'Save' and the process will begin. This may take a few minutes to complete. Once done, you have a certificate and can configure secure access.

11 Proxy work

The final step is to proxy your new secure connection to FileBrowser. Staying on the Nginx Proxy Manager configuration page, click on Hosts then Proxy Hosts. Click Add Proxy Host then complete the form. Add your public domain name at the top, leave the scheme as 'http', add the IP address of your server next followed by port 10180 (the default port for File Browser). Check Block Common Exploits then go to the SSL tab and select the certificate you just created. Now save. If you now go to your domain name prefixed with 'https://', you should be taken straight to File Browser. You now have an encrypted service to share with your friends, family and colleagues.

▼ You will need to forward ports from your router to your server. Here's an example for a Vodafone router



> We've added CasaOS, installed File Browser, and provided secure access

12 Summary and next steps

Let's look at what's been done. We've added CasaOS which will be endlessly helpful for adding new services. We installed File Browser so we could share files with others, we then used router port forwarding and Nginx to provide secured access to File Browser using an SSL certificate. Please note that File Browser can now be 'seen' by anyone who comes across it, and if you don't plan on using it for a while, consider disabling the port forwarding. Next time, we start building on our new infrastructure with some business apps and advanced collaboration tools.

Top Tip

Other sharing apps

File Browser is admittedly simple and great for uncomplicated uses. Check out Seafile and Project Send if you want something with more features.

Part 04

Build a private cloud server: collaborate!

Take control of the cloud with your own collaboration and office suite hosted on Raspberry Pi

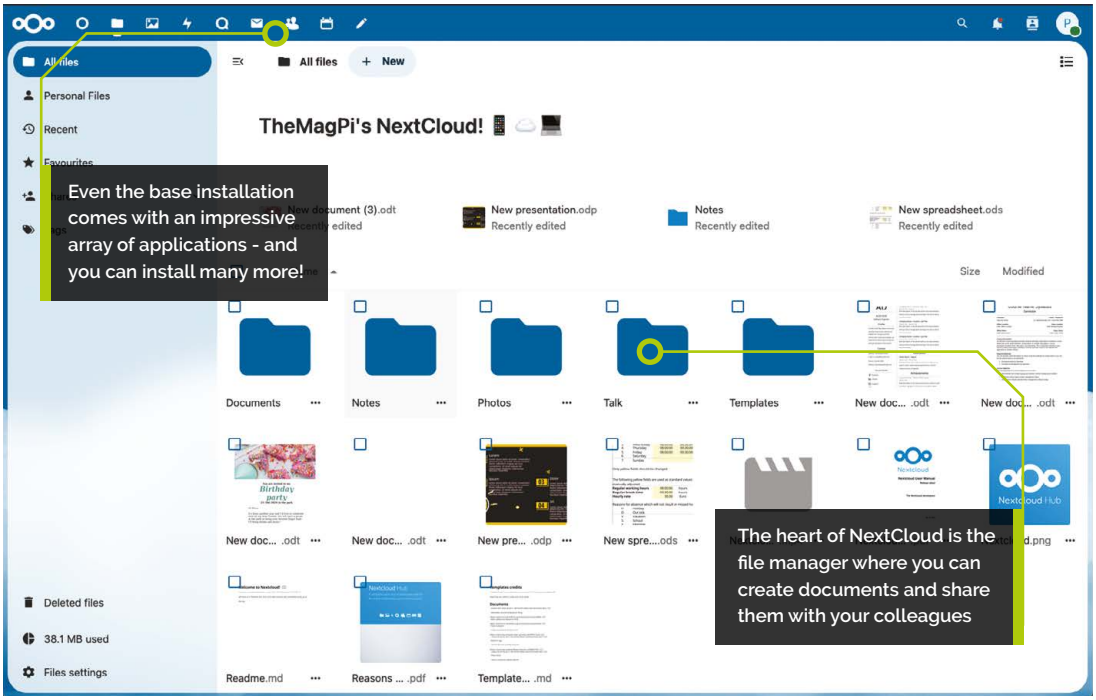


MAKER

PJ Evans

PJ is a writer, software engineer and homelab enthusiast. He likes to stop, collaborate, and listen (you might have to ask your parents).

@mrpjevans



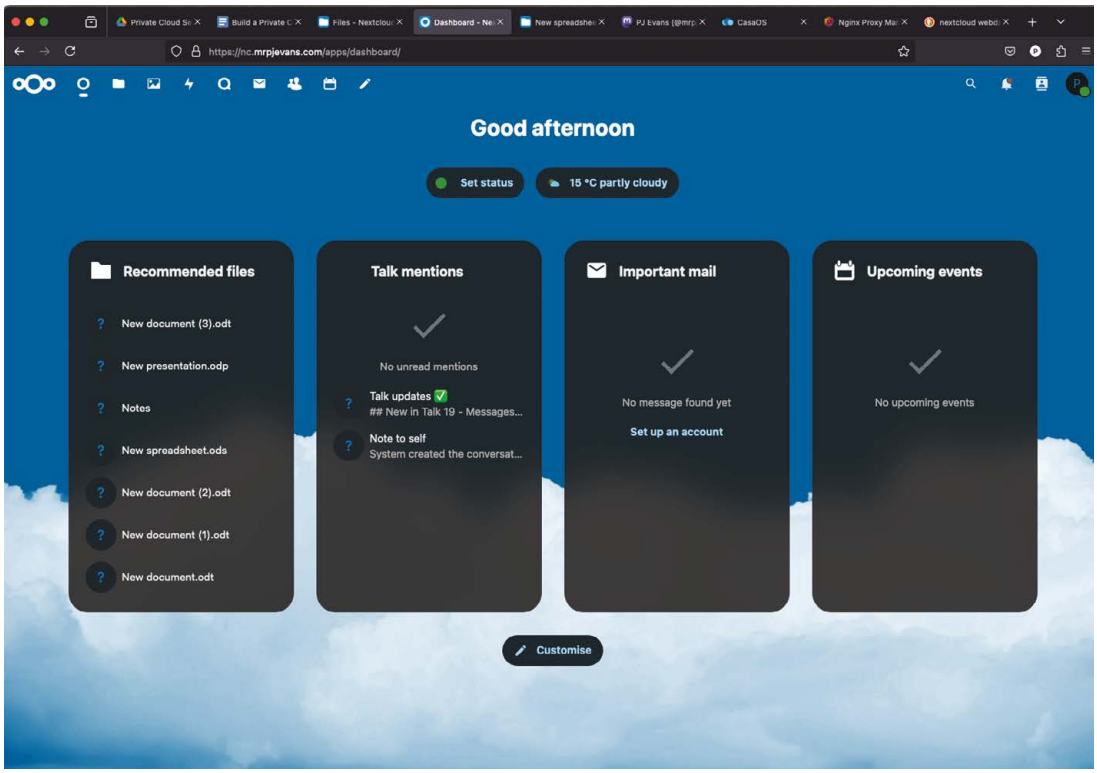
You'll Need

- Private cloud server (see last three parts)
- Domain name
- Static IP (or DuckDNS setup)

One of the great things about cloud services is the ability to collaborate with people all over the world. You can share documents and work on them together. You can have shared calendars, contact lists, and more. It was once true that this kind of power meant sharing your data with large companies. Now, open source tools mean you can have your very own groupware running on your device that can be accessed from anywhere. Now we have our cloud server up and running, it's time to unleash its true potential.

01 Introducing NextCloud

If we need all the common tools for group collaboration then we're talking calendars, contacts, notes, email and maybe chat. And that's for starters. What about being able to



This friendly dashboard is the first thing you see upon logging in and provides a useful summary of activity

> We're talking calendars, contacts, notes, email and maybe chat

view and edit documents or spreadsheets? You would think doing this would require installing many, many packages and trying to get them all talking together. Thankfully, the good people of NextCloud have created a fully integrated suite of products that make running a collaboration system easier than ever before. We're going to install a simple version of the NextCloud suite and make sure it can be accessed from anywhere.

02 Installation

In the previous part of this series we installed CasaOS, a control system and dashboard for installing server-side apps. Again, CasaOS will take the pain out of installing NextCloud. Log into CasaOS on your server (if you followed the instructions it's on port 82) and select the App Store. Search for NextCloud and click to install. It's that simple. Give it a couple of minutes, maybe a bit more if you're on a slower connection, and you should be returned to the CasaOS dashboard with a shiny new NextCloud icon. Best thing to do now is click it!

03 Set up the admin account

Upon clicking on NextCloud you will be taken to a new browser tab on port 10081. This is NextCloud's entry point locally, although we'll make that easier later. For now, the most important thing to do is set up the first account, which will double as the administration account for the whole system. If this is for an organisation, you may want to consider a dedicated admin account, although you can promote and demote accounts later on. Also, remember to choose a decent password, the longer the better. Now you'll be taken through a brief introduction and then to your dashboard.

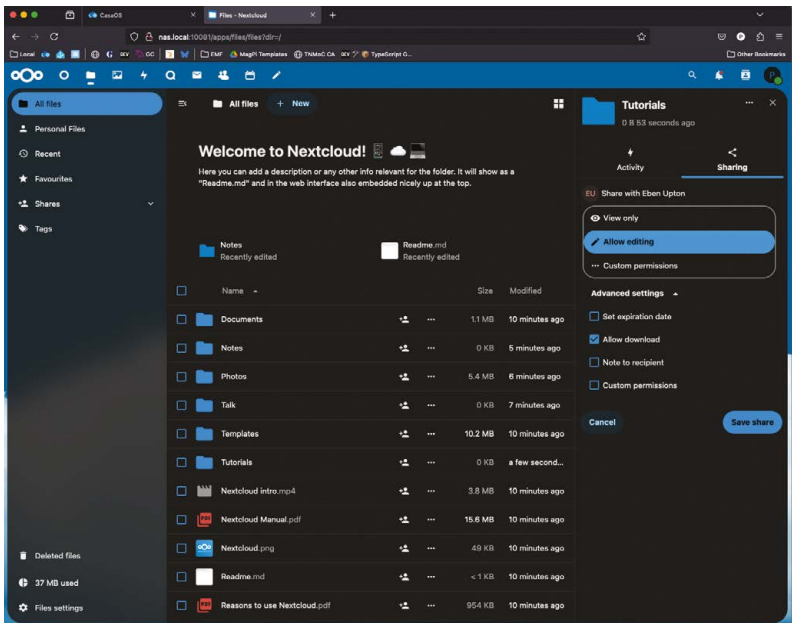
04 Create the domain

NextCloud is very particular about the domain name and security. Therefore we

Top Tip

Mail matters

Running your own email server is not for the faint-hearted. If you really want to, we recommend reading 'Run Your Own Email Server' by Michael W Lucas: **magpi.cc/emailserver**



▲ Sharing a file or folder with another user takes just a couple of clicks. You can also set various permissions and expiry dates

recommend using a real external domain name. If you followed the previous tutorial (**magpi.cc/146**) you will already have one for file sharing. In this case, you need an additional one that is either pointing to your static IP address or dynamic DNS service provider. We'll use 'nc.themagpi.com' as an example. If you haven't already, configure your router to forward ports 80 and 443 to your server. See part 3 of this series for the full guide. Any requests coming to your new domain name will now be sent to your private cloud server.

05 Configure Nginx

Last time we installed Nginx to act as a proxy between the outside world and your server. This also allows the traffic to be encrypted using SSL. We're now going to use another trick up Nginx's sleeve which is domain proxying. From CasaOS, click on Nginx Proxy Manager, log in and click on 'Proxy Hosts'. Now enter your new domain name, leave 'http' unchanged and add the IP of your private cloud server under 'Forward Hostname'. Enter 10081 for the port. Now click on the 'SSL' tab and select 'Get a new certificate from Let's Encrypt'. Click ok to configure everything. You should now be able to access NextCloud from your new domain name using HTTPS.

06 Add trusted host

Well, you can access NextCloud but you'll probably see an error about now being a trusted host. Again, NextCloud is trying to keep things as secure as possible and you've arrived on a domain name it doesn't know about. To fix this we need to add your new domain as a trusted domain. Unfortunately, this requires a bit of command-line work. SSH into your server and run these commands:

```
 cd /DATA/AppData/nextcloud/var/www/html/
config
 sudo nano config.php

 Carefully amend the trusted_domains array
so you add the line starting '1':

   'trusted_domains' =>
   array (
      0 => 'nas.local:10081',
      1 => 'nc.themagpi.com'
   ),
```

CTRL+X, followed by Y, to save and leave Nano. The changes take effect immediately.

07 Take the tour

That's all the hard work over with. If all is well, the error message will have disappeared and you can log in to NextCloud. If you find the server is no longer working, return the file you edited in the previous step and check everything is exactly right. One character out of place may break everything. Hopefully, you're now in and can have a look around. You'll see a useful dashboard that will summarise what's been going on (probably not a lot to begin with) and a range of apps across the top that perform all manner of useful functions. To the top-right you are able to access both your account and the server settings.

08 Meet the apps

Out of the box, NextCloud has a range of useful features so do spend some time exploring them. It has its own dedicated file storage and sharing app which kind of acts as a central hub. You have a personal folder and can share

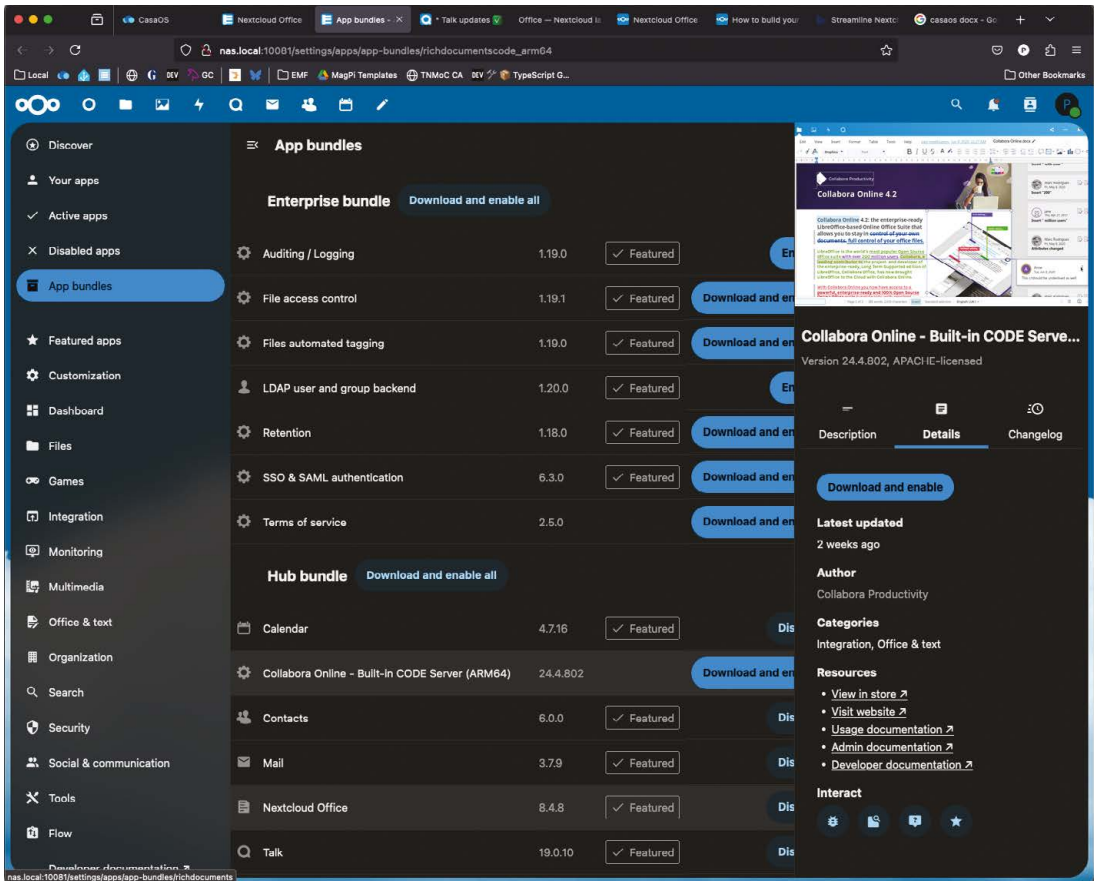
folders with others by creating new users in Administration and granting them permissions. You also have access to calendars, contacts, chat, notes and email. You can create multiple instances of these and share them. Try creating a second user and setting up shared file space, calendars and contact lists. NextCloud doesn't come with an email server but can act as a client and use it to integrate with the other features.

09 Add new apps

Did we mention the app store? By no means have you reached the limits of NextCloud's potential. NextCloud provides a community app store with literally hundreds of enhancements for your cloud server. Some are simple integrations to make it easier to work with other products and others are business-class apps in themselves such as charting, mind mapping and technical drawing. Best of all, these are all just a click away with no fuss installation. Have a browse around and see how you could enhance your server! To access, just click Apps under your account menu on the top-right.

10 Enabling office features

We've got all the collaboration and communication good stuff ready to go, but what about creating documents? Out-of-the-box NextCloud can edit simple text files but what if you need more? NextCloud uses Collabora CODE as a back-end for office apps. A simple version is available built-in but needs a couple of steps to enable. Under Apps, click on 'Office & text' then look for Collabora Online (ARM64) and install it. Then go to 'Administration' then 'Built-in CODE Server'. You can now enable it. Go back to the files app and click 'New'. You'll be able to create documents, spreadsheets, presentations and more.



Without even having to leave NextCloud, you can install hundreds of apps in just a single click

Top Tip

Memory matters

NextCloud needs a lot of memory to run, even more with Collabora. A Raspberry Pi with 8 GB of RAM is a must.

11 Connecting

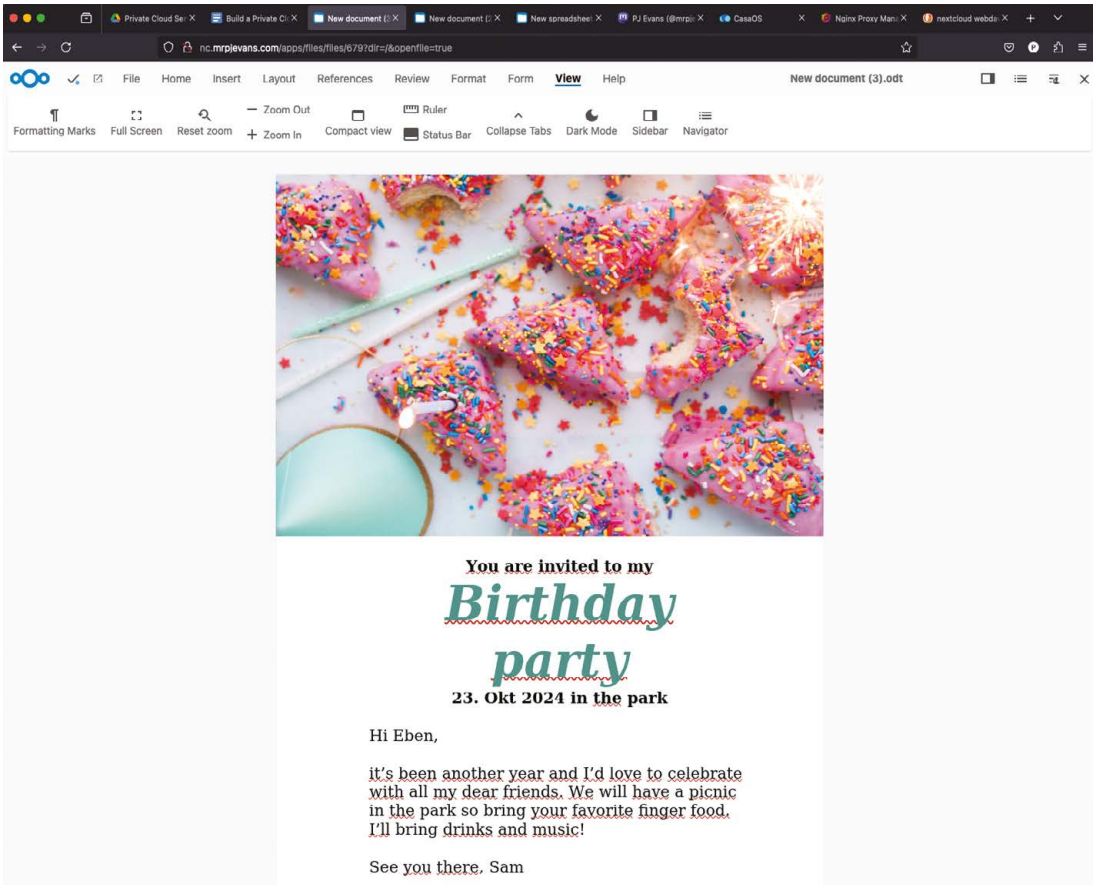
NextCloud doesn't just restrict you to the web interface. It also has a range of services available so you can use your favourite client apps if you wish. Files can be accessed directly using the common WebDAV protocol (which is built-in to many operating systems). A free background sync app is also available for download. Calendars and contact lists can be accessed over the CalDAV and CardDAV protocols which many apps support. For mobile access, you can use the dedicated NextCloud app for the full experience. With your setup you'll be able to access everything from anywhere in the world from a phone, laptop, or computer.

12 Going to the next level

Congratulations, you have an amazing system for collaboration that you own, and therefore your data is private. However, there are a few things we should warn you about before carrying on. NextCloud is a well-developed product, but all software of this size has bugs and there are occasionally security

> For mobile access, you can use the dedicated NextCloud app for the full experience

risks. Make sure NextCloud is kept up-to-date (via CasaOS) and consider using VPN (**magpi.cc/vpn**) for access if you're unsure. Also, if you're considering a lot of usage, read up on implementing a more capable database and a dedicated Collabora instance. More than anything, make sure you back everything up! Now the serious business is done, next time we'll be getting a bit more social.

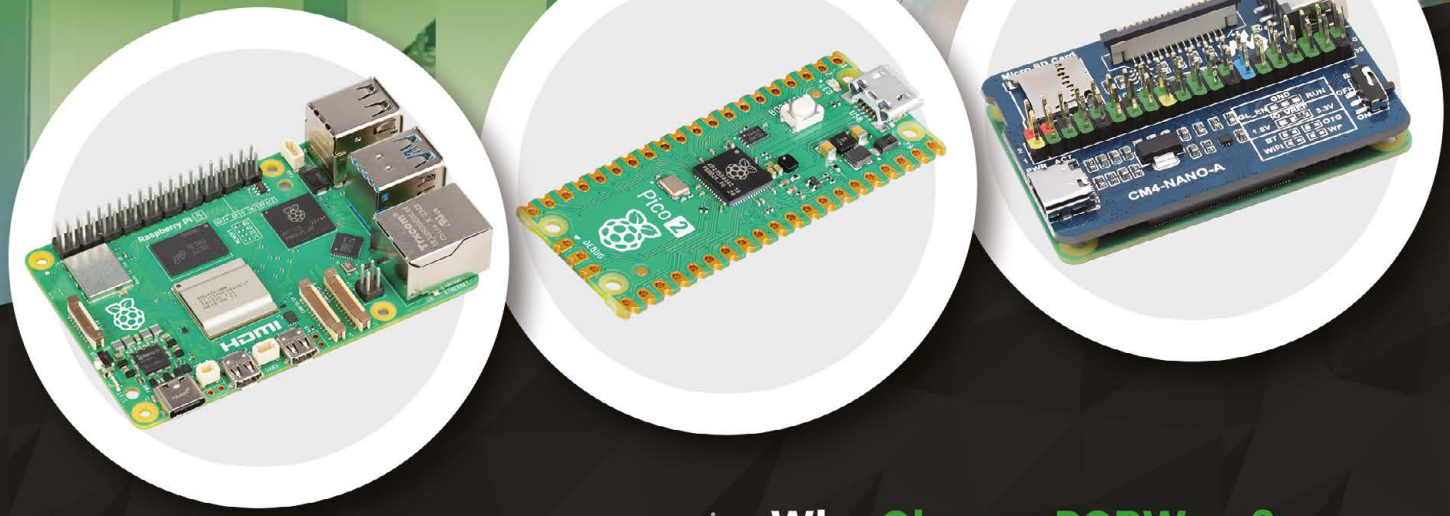


After a little configuration NextCloud becomes a suite of office apps including word processing, spreadsheets and presentations

PCBWay

PRECISION PCBS FOR RASPBERRY PI PROJECTS

High-quality, affordable, and fast PCB manufacturing trusted by makers worldwide.



Calling all makers, tinkerers, and Pi enthusiasts!

Turn your Raspberry Pi ideas into reality with fast, reliable, and fun PCBs. Whether it's a home automation system, a retro gaming console, or a robot sidekick, PCBWay helps bring your Pi projects to life and take your creativity further.

Start your project today at:

www.pcbway.com
service@pcbway.com

Why Choose PCBWay ?

SPEEDY PROTOTYPING
Don't let your ideas gather dust. Build fast, iterate faster.

QUALITY YOU CAN TRUST
Your circuits deserve perfection, and we deliver it.

AFFORDABLE FOR MAKERS
Spend less, create more!

GLOBAL SHIPPING
From your desk to your doorstep, anywhere in the world.

ESSENTIAL ELECTRONICS

Build your first simple circuits with a handful of cheap components

Sean McManus

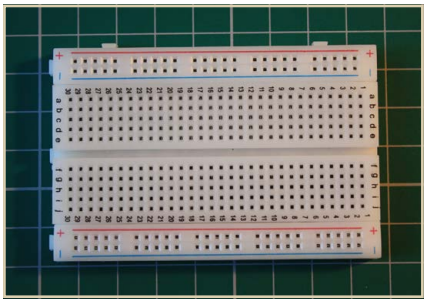
The magic of Raspberry Pi is that it can interact with the world. You can gather input from buttons and sensors that detect light, movement or distance. Send output through lights, buzzers or motors that drive robots around the room.

It's easy to get started. Using a breadboard, you press components and wires into holes to build a circuit, with no need for soldering. Jumper wires make it easy to connect your circuit to Raspberry Pi's general-purpose input/output (GPIO) pins.

The GPIO Zero library makes it easy to accept input and control your circuits from Python.

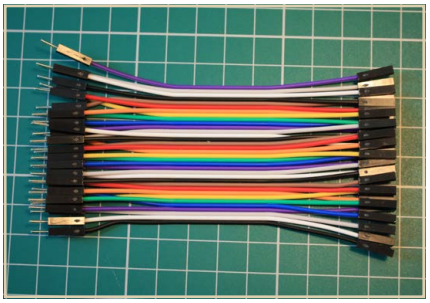
SHOPPING LIST

Discover basic components you can combine to make a variety of projects



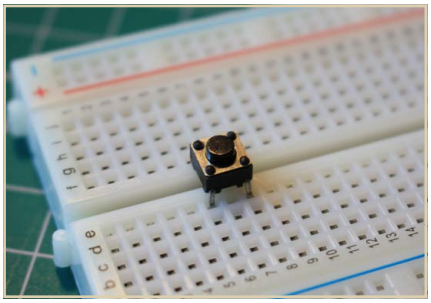
Breadboard

Ideal for prototypes and experiments, breadboards enable you to connect components without soldering. Simply press them into the holes on the board.



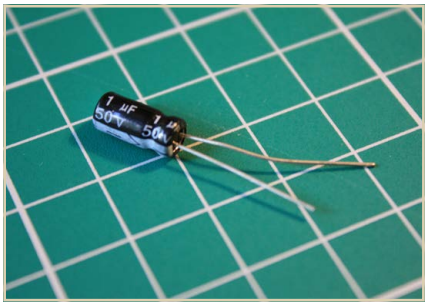
Jumper wires

Use socket-to-pin jumper wires to connect a Raspberry Pi GPIO pin to the breadboard. Pin-to-pin wires connect between points on the breadboard.



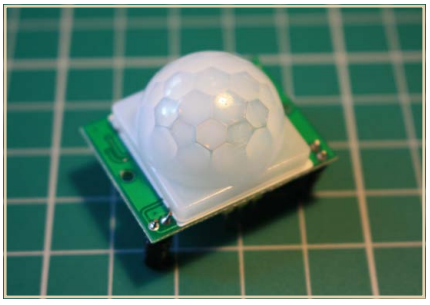
Button

Pressing a button can complete a circuit to, for example, turn a light on. Buttons are great input devices for Raspberry Pi and a vital part of your collection.



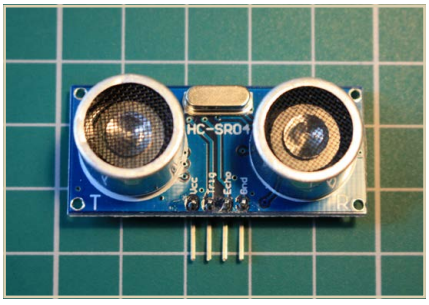
Capacitor

Capacitors can be charged up to store small amounts of electricity, which they can later discharge into the circuit. They're often used to make timers.



Passive infrared (PIR) sensor

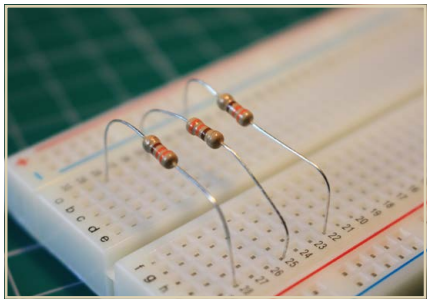
Motion sensors like this are often used in burglar alarms or automatic lights. These are great for triggering spooky Halloween projects when someone approaches.



Ultrasonic distance sensor

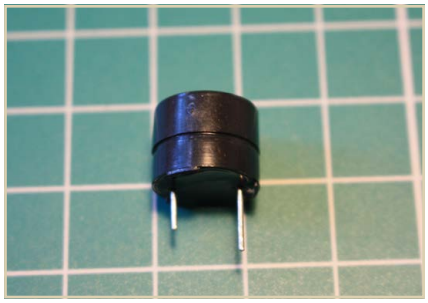
Essential for robots detecting walls or obstacles, this distance sensor by Kitronik measures distances of between 2cm and 400cm, with accuracy as good as 3mm.

> Passive buzzers give you more flexible pitch control, so you can program tunes



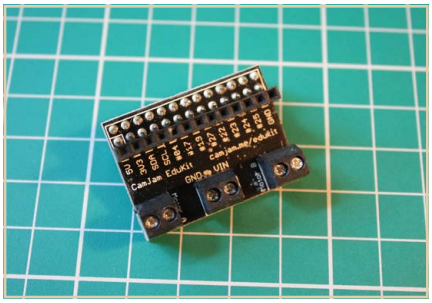
Resistors

Resistors reduce current flow in a circuit. Coloured stripes indicate the resistor's value. Find decoders online (see **magpi.cc/resistorcalc**) or see the table in the *Raspberry Pi Beginner's Guide*.



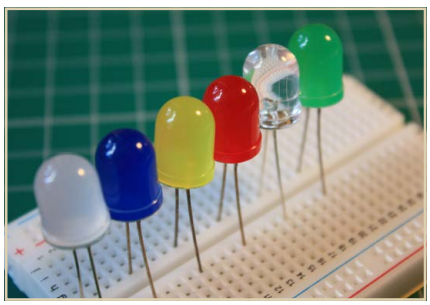
Buzzer

Active buzzers are easiest to wire up but usually just produce one tone. Passive buzzers (also known as tonal buzzers) give you more flexible pitch control, so you can program tunes.



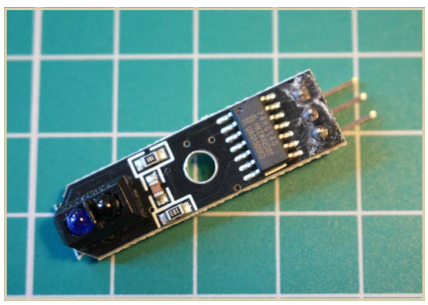
Motor board

A motor controller board, such as this one from the CamJam Robotics EduKit, sits between your Raspberry Pi's GPIO pins and your project's motors. It allows you to control things like robot wheels.



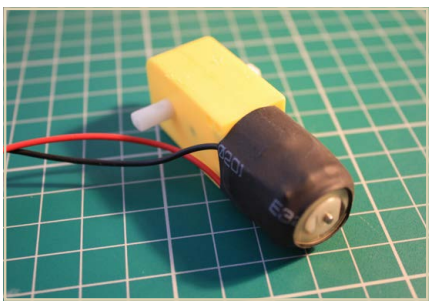
Light emitting diodes (LEDs)

Lights! They come in a range of colours and sizes, and they add sparkle and joy to any project. Place them carefully: they only work one way around.



Line-following sensor

This sensor has both a light emitter and a light detector. Using it, you can create a robot that can follow a black line drawn on a white surface.



Motor

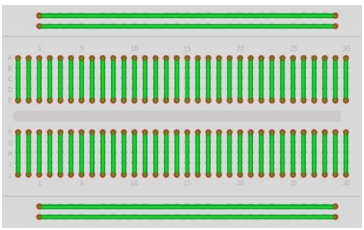
Essential for mobile robots, DC motors like this connect to your Raspberry Pi through a motor controller board. To save time, get one with pre-soldered wires.

CREATE A MORSE CODE TRANSMITTER

Wire up an LED to Raspberry Pi, and flash the bulb to send messages

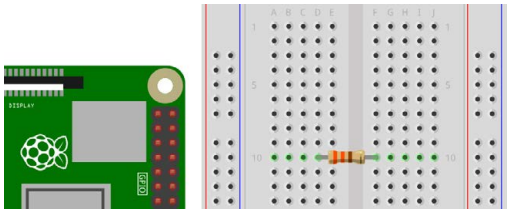
01 Understanding the breadboard

Inside the breadboard are electrical connections between the holes, as shown in this picture. In the middle of the breadboard, there are numbered rows. The holes in a row that form a group are connected to each other. Groups are usually separated by a trench.



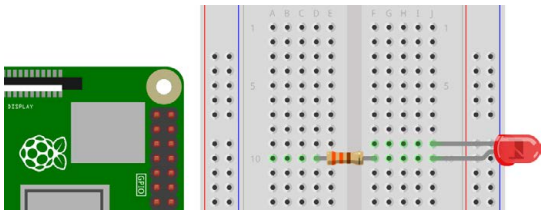
02 Connecting the resistor

In our circuit, current flows from Raspberry Pi's GPIO pin, through a resistor and LED, and back to Raspberry Pi's ground pin. We use a 330 ohm resistor to stop the LED drawing too much current, which might damage the LED or Raspberry Pi. To force the current to go through the resistor, we have to connect each end of it to a different group of breadboard holes. A resistor can go either way around.



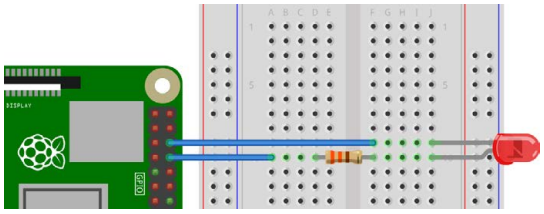
03 Connecting the LED

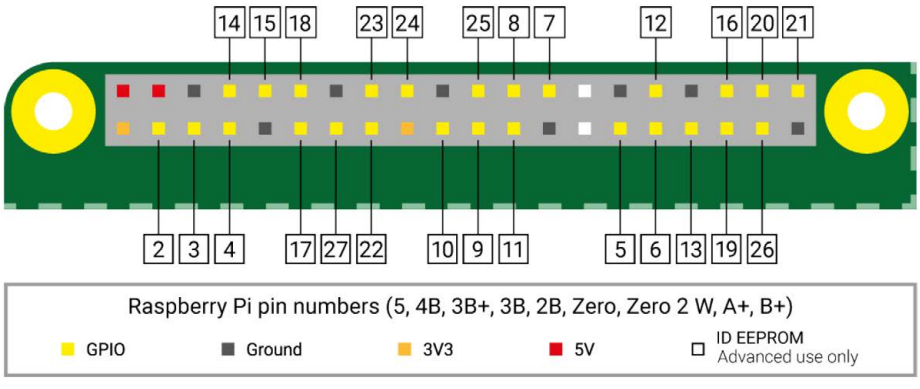
The LED's long leg is the anode (positive end), and its short leg is the cathode (negative end). Connect the anode to the same group of breadboard holes as one end of the resistor. Connect the cathode to a new group of holes.



04 Connecting Raspberry Pi

Power off your Raspberry Pi before connecting wires or components. The GPIO header has pins that provide 3.3V or 5V of power constantly, general-purpose input/output (GPIO) pins, and ground pins for completing a circuit. To control our circuit, we'll use GPIO pin 14, which is the fourth pin on the top row. Connect a jumper wire between that pin and the resistor, at the opposite end to the LED. Connect a ground pin to the LED's negative leg.





◀ We use BCM pin numbers, which aren't the same as the physical pin locations

MORSE CODE TRANSMITTER PROGRAM

For if you always wanted to learn Morse code, but never did it. Da-dit, da-dit, etc...

240625 magpi morse code.py

DOWNLOAD THE FULL CODE:

magpi.cc/seancode

Language: **Python**

```
001.  from gpiozero import LED
002.  from time import sleep
003.
004.  led1 = LED(14)
005.
006.  def blink(flash_duration):
007.      led1.on()
008.      sleep(flash_duration)
009.      led1.off()
010.      sleep(0.5)
011.
012.  def flash_message(message):
013.      for symbol in message:
014.          if symbol == ".":
015.              blink(0.5)
016.          if symbol == "-":
017.              blink(1.5)
018.          if symbol == " ":
019.              sleep(1.5)
020.
021.  flash_message(".... . .-.. .-.. ---")
```

> Send our Morse message to the flash_message function

Line 1: Set up GPIO Zero so we can use the LED code

Line 2: Import the time library to control the length of light flashes

Line 4: Set up led1 as an LED on GPIO pin 14

Line 6: The blink function receives the flash duration in seconds

Line 7: Turn the LED on!

Line 8: Pause for as long as we want the light lit

Line 9: Turn the LED off

Line 10: A short pause stops the flashes merging

Line 12: This function receives a Morse code message

Line 13: The loop looks at each character in the message

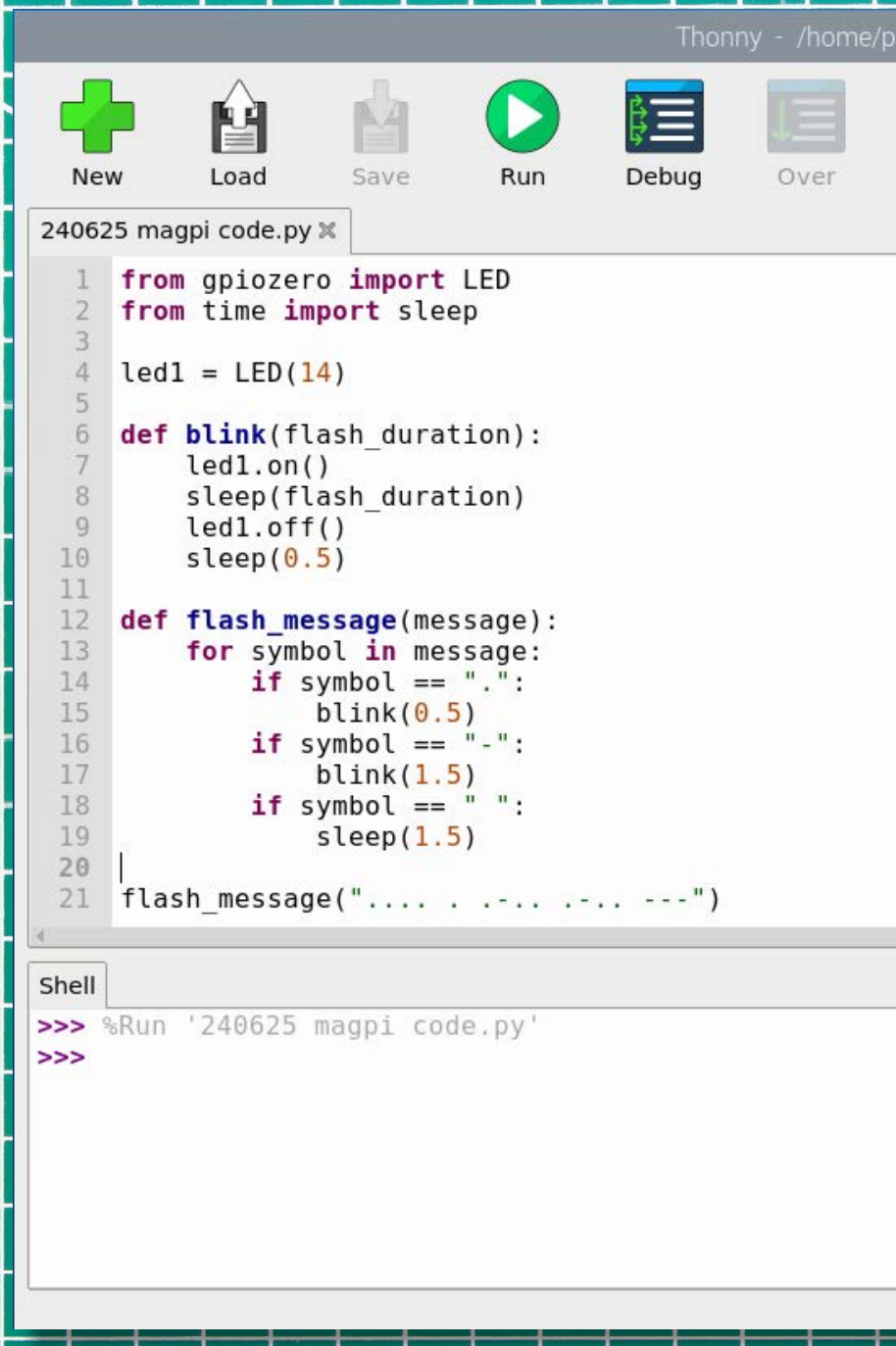
Line 14 and 15: If the character is a dot, we blink for half a second

Line 16 and 17: If it's a dash, we blink for 1.5 seconds

Line 18 and 19: If it's a space, we add a 1.5 second pause

Line 21: Send our Morse message to the flash_ message function

Run this program in Thonny by clicking the Run button. Get the code at **magpi.cc/seancode**.



▲ Find Thonny in the Programming folder of the Raspberry Pi OS menu

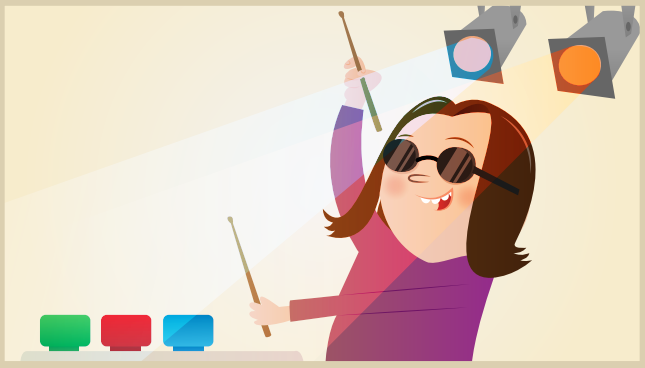
ELECTRONICS PROJECTS TO TRY

Discover how to use buttons, sensors and motors with these starter projects

GPIO Music Box

Components: breadboard, buttons, pin-to-socket and pin-to-pin jumper wires, speakers
magpi.cc/gpiomusicbox

Buttons are the simplest way to control circuits and collect input. In this project, you see how to connect four of them to Raspberry Pi. They're used to trigger sound effects played with Python's Pygame library, which you could customise with your own recordings. You see how to connect all your buttons to the same GPIO ground pin, by using the ground rail along the long side of the breadboard. With this approach, you don't need as many jumper wires to Raspberry Pi, so your circuit is easier to build and understand.



Quick Reaction Game

Components: breadboard, buttons, LED, resistor, jumper wires
magpi.cc/pythonqrgame

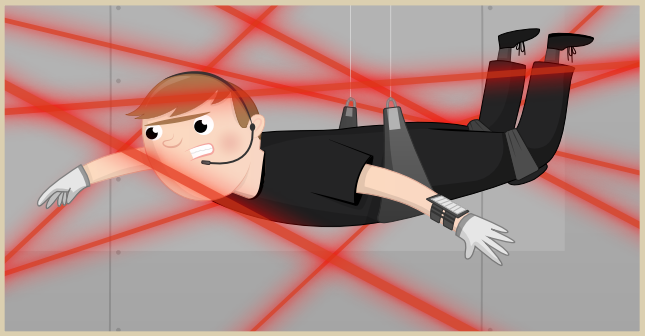
Who can push their button quickest when the light goes off? This two-player game uses a breadboard to connect two buttons and an LED to Raspberry Pi. With the music box, it doesn't matter in what order the buttons are pressed, but in this game you see how to detect which button was pressed first, and announce the winner on-screen. The program also shows how a single Python function can be used with GPIO Zero to provide different outputs for different buttons. You can extend the project by adding a timer or keeping track of scores.



Laser Tripwire

Components: breadboard, capacitor, light-dependent resistor (LDR), jumper wires
magpi.cc/lasertripwire

When intruders break the invisible beam, the alarm sounds. This project works by shining a laser pointer at a photoresistor, and sensing when the light changes because somebody has walked between them. GPIO Zero enables you to wait until light or dark is detected, and to run a particular function when it is. You can raise the alarm by playing a sound file through speakers, or by connecting a buzzer to Raspberry Pi.



Parent Detector

Components: PIR motion sensor, Raspberry Pi Camera Module, jumper wires
magpi.cc/parentdetector

The parent detector project is a great way to experiment with a PIR motion sensor. The sensor has pins that you can connect directly to your GPIO pins using socket-to-socket jumper wires, with no need for a breadboard. This project uses the sensor to trigger video recording, and only stops when no motion is detected. The PIR sensor has dials you can use to adjust the sensitivity and detection time of the sensor. Perhaps you could turn down the sensitivity and make a game where players must sneak up on the Raspberry Pi undetected?



Ultrasonic Theremin

Components: breadboard, ultrasonic distance sensor, tonal buzzer, jumper wires
magpi.cc/theremin

The theremin, patented by Leon Theremin in 1928, is an instrument that you play by moving your hands near it. It's famous for creating the woo-ooo sound effects in sci-fi films. You can make something similar by connecting an ultrasonic distance sensor and a buzzer to Raspberry Pi. The sensor sends out sound pulses, and measures how long they take to bounce back, so it can measure the distance to the nearest object. GPIO Zero includes simple code to measure the distance in metres, and to make a tonal buzzer play musical notes using the MIDI standard.



Robot Buggy

Components: Motor controller board, motors, wheels, jumper wires, AA battery holder and batteries for the motors, USB battery pack for Raspberry Pi, ball caster
magpi.cc/robobuggy

This *is* the droid you are looking for! Build your first robot by connecting a motor controller board, two motors and wheels to Raspberry Pi. A ball caster keeps everything balanced, acting as a central third wheel. The motors are powered by AA batteries. Log in to Raspberry Pi remotely using VNC or SSH and use a USB battery pack for power, so there's no need for monitor or power cables and your robot can roam freely. Thanks to GPIO Zero, you can use simple functions to move your robot forwards, backwards, left and right. You can extend this project by adding a line-following sensor (**magpi.cc/linefollower**). For motor boards and other components, see CamJam EduKit 3 and Monk Makes Servo Kit.



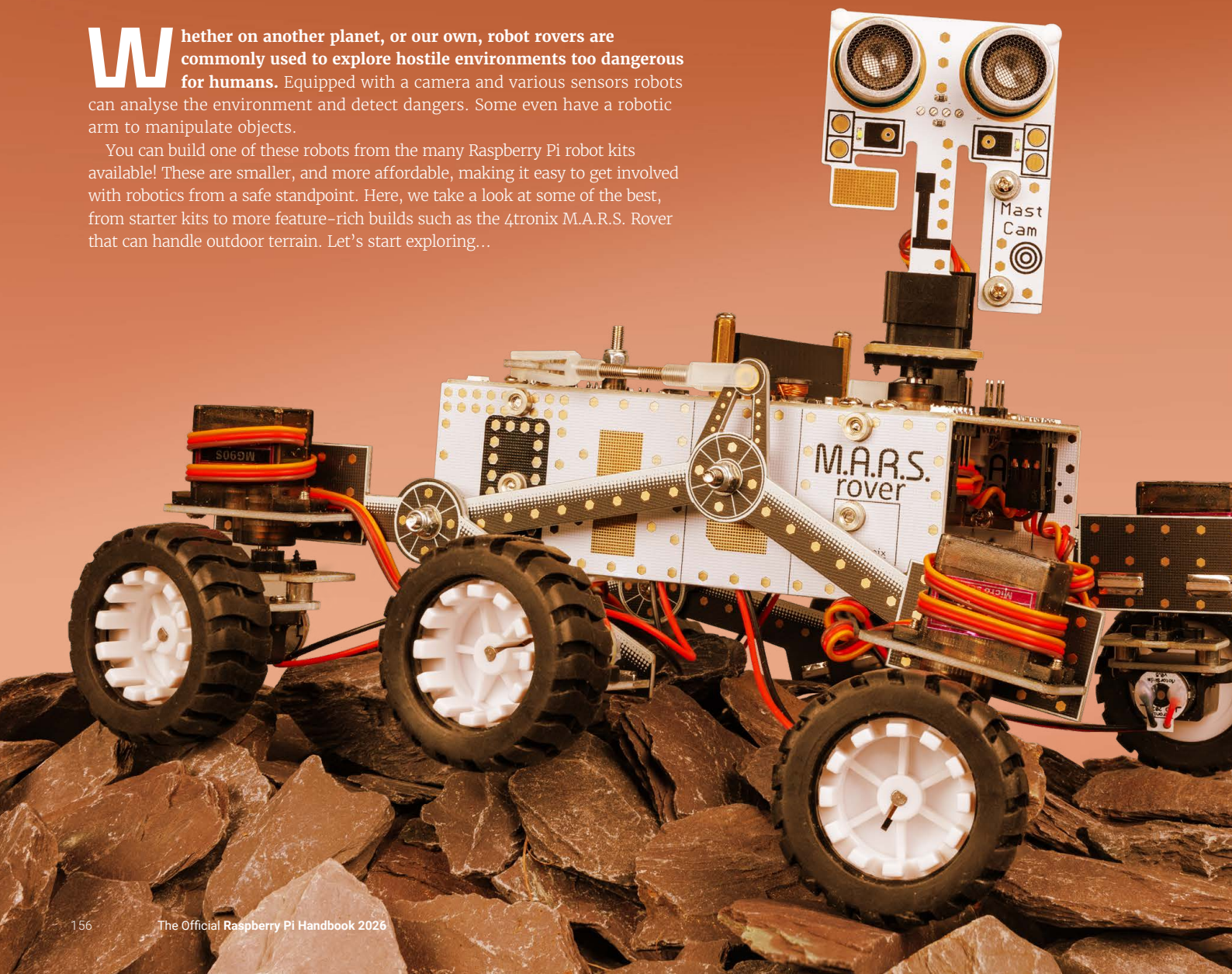
ROBOT EXPLORERS!

WITH A RUGGED ROBOT, EQUIPPED WITH WHEELS OR LEGS, YOU CAN EXPLORE THE SURFACE OF A PLANET AND USE SENSORS TO ANALYSE ITS ENVIRONMENT

BY **PHIL KING**

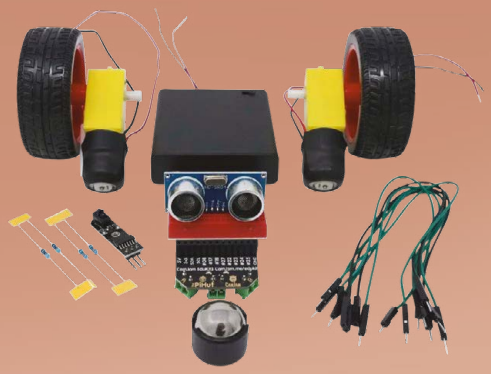
Whether on another planet, or our own, robot rovers are commonly used to explore hostile environments too dangerous for humans. Equipped with a camera and various sensors robots can analyse the environment and detect dangers. Some even have a robotic arm to manipulate objects.

You can build one of these robots from the many Raspberry Pi robot kits available! These are smaller, and more affordable, making it easy to get involved with robotics from a safe standpoint. Here, we take a look at some of the best, from starter kits to more feature-rich builds such as the 4tronix M.A.R.S. Rover that can handle outdoor terrain. Let's start exploring...



STARTER ROBOTS

IF YOU'RE NEW TO ROBOTICS AND WANT A SIMPLER PROJECT TO GET STARTED WITH, WHY NOT BUILD ONE OF THESE KITS?



CAMJAM EDUKIT #3

magpi.cc/camjamedu3

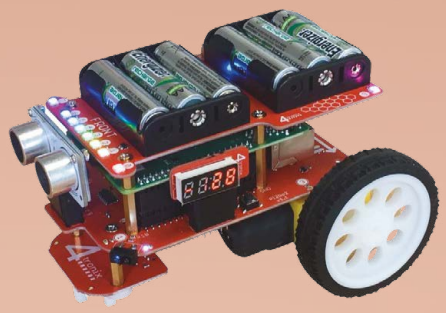
£20

One of the most affordable starter kits around, it includes the components needed to build your first wheeled robot, including a motor controller board, two DC motors and wheels, ball castor, mini breadboard, jumper cables and resistors. You even get a couple of sensors: ultrasonic for obstacle detection, and a line follower to track black lines marked on the floor.

The only thing missing – apart from a Raspberry Pi and four AA batteries to power it – is a chassis. You can either buy one or use the kit's cardboard box.

Detailed online worksheets, based around Python 3 and GPIO Zero, take you through building and programming the robot, including getting it to move autonomously.

◀ This entry-level kit is ideal for beginners and even includes a couple of sensors



PI2GO MK2

magpi.cc/pi2go2

FROM £43

In the standard Pi2Go kit, you get everything apart from a Raspberry Pi and six AA batteries – if using a Raspberry Pi 4 or 5, you'll need to switch in a 2 × 18650 battery board. There's also a 4WD pack option to convert it into a four-wheeled robot.

The main motor driver board is packed with sensors: four analogue light sensors, two infrared, and two line-followers. Two breakout slots let you connect the supplied ultrasonic distance sensor and it includes a four-digit display, although you could switch these out for other Breakout Garden-standard sensors. An extra 12-pin connector enables you to add up to four servos too.

◀ This two (or four) wheeled robot is packed with features and sensors, plus expansion options



TRILOBOT

magpi.cc/trilobot

FROM £53

Described by Pimoroni as a 'mid-level' robot, the Trilobot is designed to be simple for newcomers to get started with while offering plenty of possibilities for adding extra functionality via numerous ports and headers.

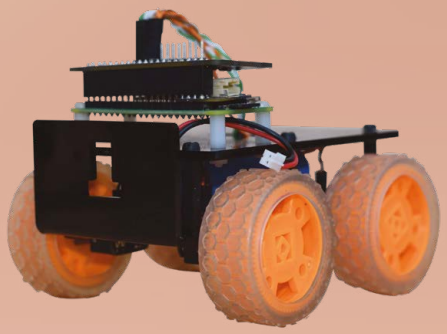
The standard Base Kit includes everything you need apart from a Raspberry Pi 4, USB-C power bank, and optional Camera Module. The main PCB seamlessly integrates a DRV8833PWP dual H-bridge motor controller, connected via short cables to the pre-soldered shims of the metal-gear motors. Two moon buggy wheels are supplied alongside a metal ball castor for the rear.

While not yet compatible with Raspberry Pi 5 (or Raspberry Pi OS based on Bookworm), the Trilobot is a terrific two-wheeled robot that even features six RGB LEDs for cool underlighting effects.

◀ The supplied ultrasonic distance sensor and optional Camera Module are mounted at the front of the robot

EXPLORER ROBOTS

START EXPLORING THE OUTDOOR TERRAIN OF THE PLANET WITH ONE OF THESE ROBOT KITS, MANY EQUIPPED WITH MULTIPLE SENSORS



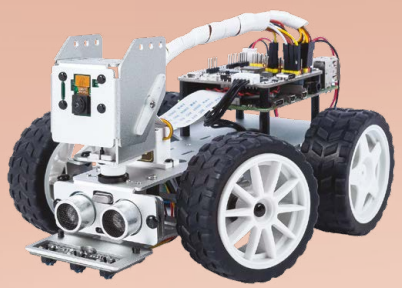
TINY 4WD

magpi.cc/tiny4wd | **£55**

The Tiny 4WD's design originated in a tutorial written for *The MagPi* many moons ago, but this is a much-improved version. Controlled by a Raspberry Pi Zero W (not supplied), this mini robot is sturdy and powerful enough to be used outside, even on gravel paths.

The kit contains all you need to build the chassis, including a mount for a Camera Module, while a Pimoroni Explorer pHat drives four motors that spin the large grippy wheels. A mini breadboard is also included, enabling you to add optional sensors.

◀ One of the smallest robots around, the Tiny 4WD is a mini marvel that can handle the outdoors

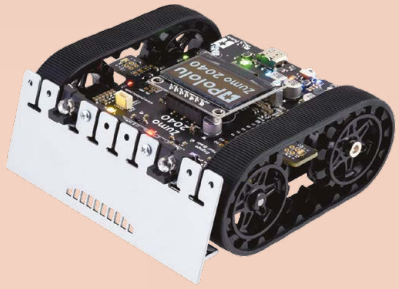


PICAR-X

magpi.cc/picarx | **$82 (£64)**

One of SunFounder's range of PiCar kits, it has four chunky wheels and is crammed with features including ultrasonic distance and line-follower sensors, a built-in speaker, rechargeable custom battery pack, plus a camera with a servo to rotate it. By streaming live video, you can get a first-person view from the robot. The PiCar-X is programmable in Python or Blockly – online guides and videos help you get started. AI computer vision enables the robot to drive itself and recognise objects, faces, and hand gestures.

◀ Packed with features, this is one smart car – with text-to-speech, it can even talk



ZUMO 2040

magpi.cc/zumo2040 | **£150**

A classic method for navigating tough terrain is to equip a vehicle with caterpillar tracks. That's the case with the Zumo 2040 from popular robotics brand Polulu. As the name suggests, it's powered by an RP2040 chip, as featured in Raspberry Pi Pico. So it's easy to program using MicroPython, C/C++, or the Arduino language. At just 10cm long it's small, but is jam-packed with features including four proximity sensors (on the front and sides), five downward-facing reflectance sensors for line following or edge detection, and even a built-in IMU (inertial measurement unit).

◀ This mini tracked robot can navigate difficult terrain while using an impressive array of sensors



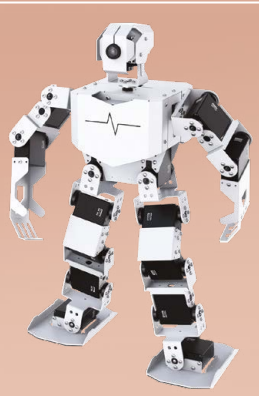
TURBOPI

magpi.cc/turbopi

$190 (£149)

When it comes to manoeuvrability, Mecanum wheels are the ultimate upgrade, enabling a vehicle to move sidewards and spin around on the spot. That's why they're used on some forklift trucks. As well as offering 360° omnidirectional movement, HiWonder's TurboPi car carries an HD camera on a pan-tilt mount. This can be used with the OpenCV Python computer vision library to recognise objects and react to hand gestures. There's also a four-channel line follower sensor and a smartphone app for remote control.

◀ Mecanum wheels make this one of the most manoeuvrable Raspberry Pi robotic rovers



TONYPI

magpi.cc/hwtonypi

$570 (£447)

Not every robot moves about on wheels – some have legs, like this amazing mechanical humanoid from HiWonder. Powered by Raspberry Pi 4, the TonyPi has a built-in IMU (inertial measurement unit) to help maintain its balance as it walks around – it can even get up from lying on its back. It also boasts a pair of robotic arms with gripping hands to pick up objects. Equipped with an HD camera, its head can tilt and pan to see around. With computer vision, you can get it to recognise and track objects, enabling it to kick a football.

◀ This impressive humanoid robot has AI vision, gripping hands, and the ability to walk



RASPCLAWS HEXAPOD

magpi.cc/raspclaws

£98

There are quite a few kits available for building an insect-like Raspberry Pi robot. While some have four legs, this one from Adeept has six limbs as well as a self-stabilisation mode, making it capable of creepy-crawling over rough ground. With a camera mounted on a servo on top and four NeoPixel strips for lighting, it can also look around and use computer vision to recognise objects and detect motion. Note that for lower power drain and legacy software compatibility, it's advisable to use it with a Raspberry Pi 3B/3B+.

◀ This bug-like robot can crawl over surfaces and use a camera to look around

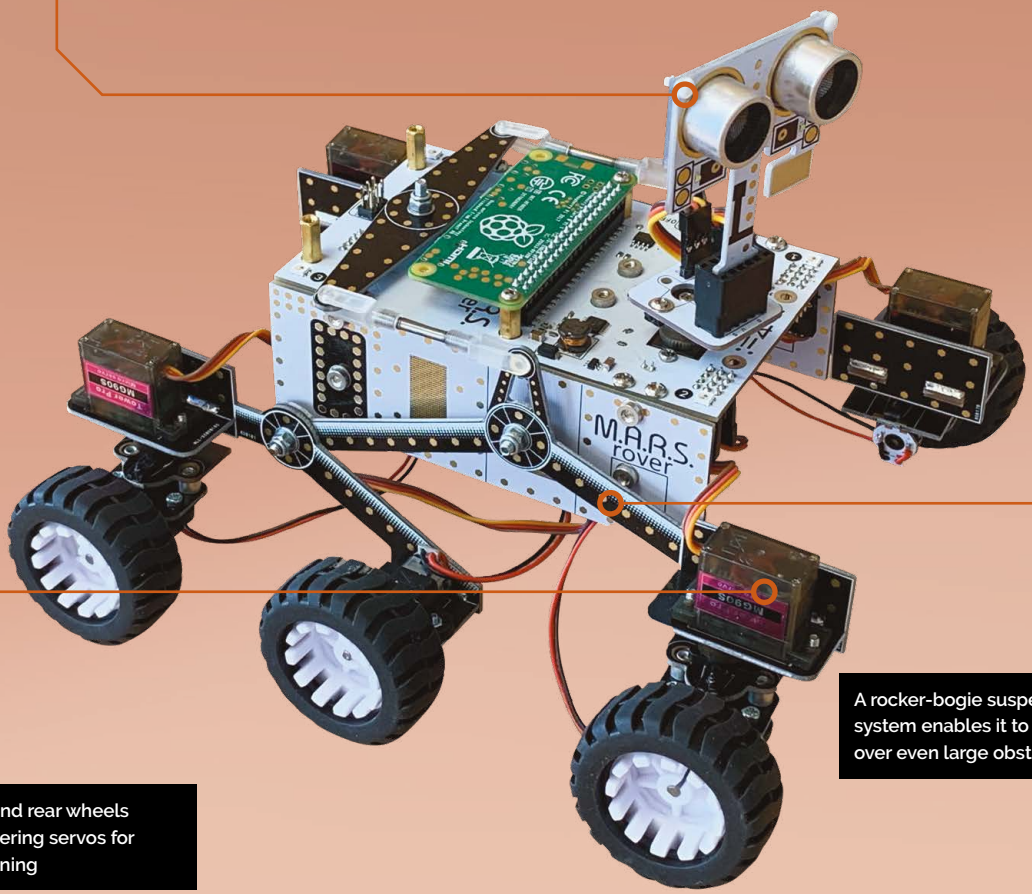
UNDERWATER ROV

Exploring the land with a robotic rover is cool, but getting a submersible ROV (remotely operated vehicle) to dive under the water is even cooler. We've seen a few such Raspberry Pi-based projects over the years, one of the most impressive being the underwater drone built by Ievgenii Tkachenko (see **magpi.cc/80**). Its four motors, lights, and gyroscope are handled by Raspberry Pi, which also sends a live video stream. An onshore Wi-Fi router is connected to the submersible via an Ethernet cable, enabling remote control from a smartphone. Similar commercial ROVs are used for boat inspections and to aid rescue operations.

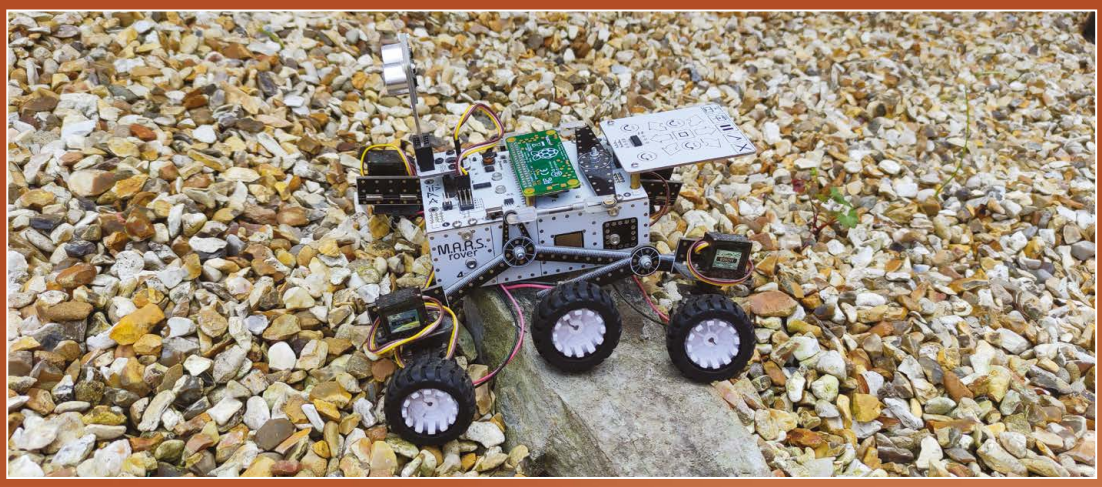


M.A.R.S. ROVER ROBOT

ONE OF THE BEST ROBOT KITS AROUND, IT LETS YOU EXPLORE TERRAIN JUST LIKE A NASA MARS ROVER, AND EVEN USES A SIMILAR SUSPENSION SYSTEM



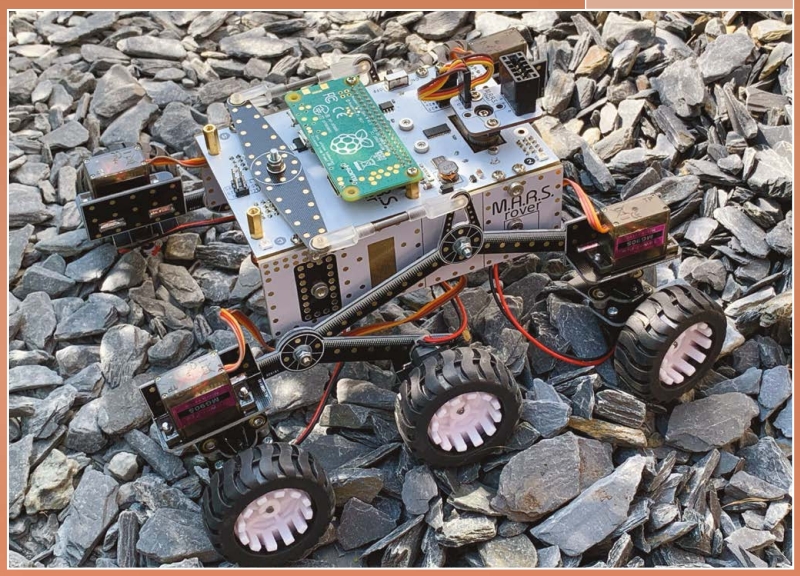
M.A.R.S. ROVER ROBOT FOR PI ZERO	magpi.cc/marsrover	£126



The 4tronix M.A.R.S. Rover looks very much like the real thing and can handle tough terrain

> IT'S AMAZING TO WATCH IN ACTION AND FAR SUPERIOR TO FIXED-WHEEL BUGGIES

A clever rocker-bogie suspension system enables M.A.R.S. Rover to clamber over large obstacles



Not only does this robot look remarkably similar to the real Mars Curiosity rover, it uses the same type of rocker-bogie suspension system developed by NASA. This allows the six wheels to move up and down semi-independently so they all maintain contact with the ground while the rover's body stays level. It's amazing to watch in action and far superior to fixed-wheel buggies in handling difficult terrain. It can even clamber over fairly large rocks.

The kit does take a little while to assemble, but the result is a quality build with metal PCB panels, six N20 micro gear motors, and chunky wheels. The finishing touch is a mast with an ultrasonic distance sensor to the top – it's mounted on a servo so you can rotate it. The four corner wheels have steering servos too, enabling quicker turning. An optional keypad can be added on the rear for hands-on route programming.

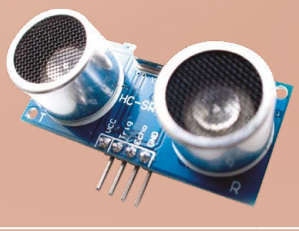
REAL MARS ROVER: CURIOSITY

The 4tronix M.A.R.S. Rover was inspired by NASA's Curiosity rover, which – after a journey of 350 million miles – landed on the Red Planet in 2012 and is still operational today (along with close relative Perseverance, which arrived in 2021). An ingenious suspension system for its six wheels helps it to navigate the rocky landscape. Equipped with an array of scientific instruments, along with a robotic arm and two cameras, its main mission is to examine the Martian geology (it can drill into rocks to obtain samples to analyse) and look for any signs that life could once have existed there.



ROBOT SENSORS

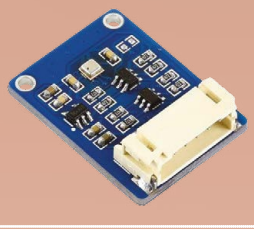
GIVE YOUR ROBOT AN AWARENESS OF ITS SURROUNDINGS BY ADDING ONE OR MORE SENSORS



ULTRASONIC

magpi.cc/hrs04	£5

Unless it has the more complicated computer vision, the most common way a robot can detect large obstacles is to use an ultrasonic sensor such as the HC-SR04. This works like a form of sonar, and involves emitting a signal and then listening for the echo to return. The time delay indicates the distance to the object.



TEMPERATURE & MORE

magpi.cc/wsbme280	£9

A key metric for analysing your robot's environment is the ambient temperature. Many popular temperature sensors can also measure relative humidity and barometric pressure. The BME280 measures all three and delivers the data via a digital output to Raspberry Pi, so there's no need to use an ADC to decode analogue readings.



GAS

magpi.cc/gassensor	£6

When exploring an unknown environment with your rover, you'll want to sniff out any dangerous gases. The MQ-5 gas sensor can detect LPG, natural gas, and coal gas. It has both digital and analogue output pins. You could combine it with a flame sensor (e.g. **magpi.cc/flamesensor**) to detect both gas leaks and fires.



SOUND

magpi.cc/soundsensor	£4

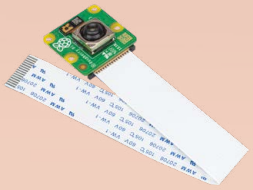
Your robot may have eyes (or at least ultrasonic object detection) to help it find its way around, but adding 'ears' can aid it in understanding its surroundings. This sound sensor has an adjustable loudness threshold – when reached, it switches the digital output to high. Alternatively, you could use a USB mic to record and analyse sounds.



MOTION

magpi.cc/imu9dof	£15

An IMU can determine a robot's motion and orientation. Sensors come with varying DOF (degrees of freedom); a 9DOF one (as here) can detect three-axis acceleration, three-axis gyroscopic motion, and three-axis compass heading. While not essential for a wheeled rover, an IMU is vital for a walking robot's sense of balance.



CAMERA

magpi.cc/camera	£24

When controlling your rover remotely, a camera is a vital aid for navigation and getting a detailed view of its environment. Whether you use a Raspberry Pi Camera Module or a USB webcam, there's the option of using computer vision such as OpenCV (**magpi.cc/opencv**) to recognise objects automatically.

WIZnet

W6300

The Ethernet Solution for Faster, Smarter Networking!

Need ultra-fast, stable Ethernet?
W6300 delivers up to 90 Mbps with powerful IPv4/IPv6 dual stack support!



Key Benefits

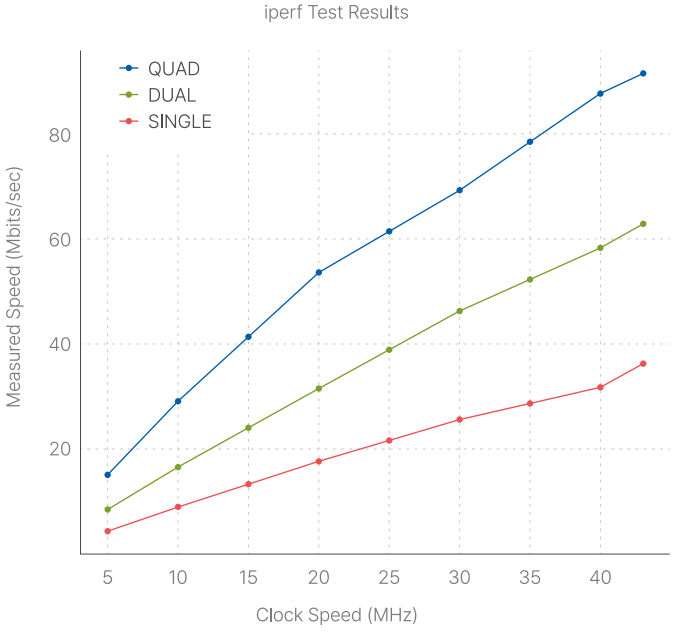
- **High-speed QSPI Interface**
  SINGLE, DUAL, QUAD modes supported
- **8 Independent Sockets**
  Multi-device connectivity made easy
- **Low Power & Wake on LAN**
  Efficient and remote-friendly
- **Seamless IoT & Industrial Integration**
  POS, cameras, automation & more

Where to Use W6300?

- **Smart Home & IoT**
  Network sensors, smart APs, home automation
- **Industrial & Factory Automation**
  POS, network printers, LED displays
- **Security Systems**
  DVRs, CCTV, access control systems
- **Embedded Servers & Cloud Devices**

Performance Test Results

- iPerf3 Performance
  Up to 90 Mbps on RP2040/RP2350 in 43MHz QUAD mode
- Optimized speed across different QSPI modes



WIZ630io 

W6300-EVB-Pico (W6300 + RP2040) 

W6300-EVB-Pico2 (W6300 + RP2350) 



PLAY RETRO HORROR CLASSICS ON RASPBERRY PI 5

Spattered with blood, gore, and overcome by a desperate urge to prove that computer games weren't just for families, let's revisit the classics from gaming horror's great 1990s golden age.

By **KG Orphanides**

Retro styled horror games for modern platforms are numerous and many of them are genuinely outstanding. It's a genre that lends itself to small-scale indie development effectively as it does to massive triple-A studios, and where art house or B-movie sensibilities can often hit harder than glossy big-budget production values. But to get a real handle on where modern gaming's obsession with retro horror comes from, it's worth taking time to visit the genre's roots.

Although many older horror games can now feel stilted or clichéd, there's plenty to appreciate in terms of both their design, their clever use of the technologies available to their developers, and their writers' willingness to engage with some genuinely dark subject matter. For this latter reason, many of the games we've included received Mature or 18 ratings at the time of their release. While the gaming gore of the last century may no longer convince us, the subject matter of the games can still be disturbing, so we've added content warnings where appropriate. This project is not all-ages.

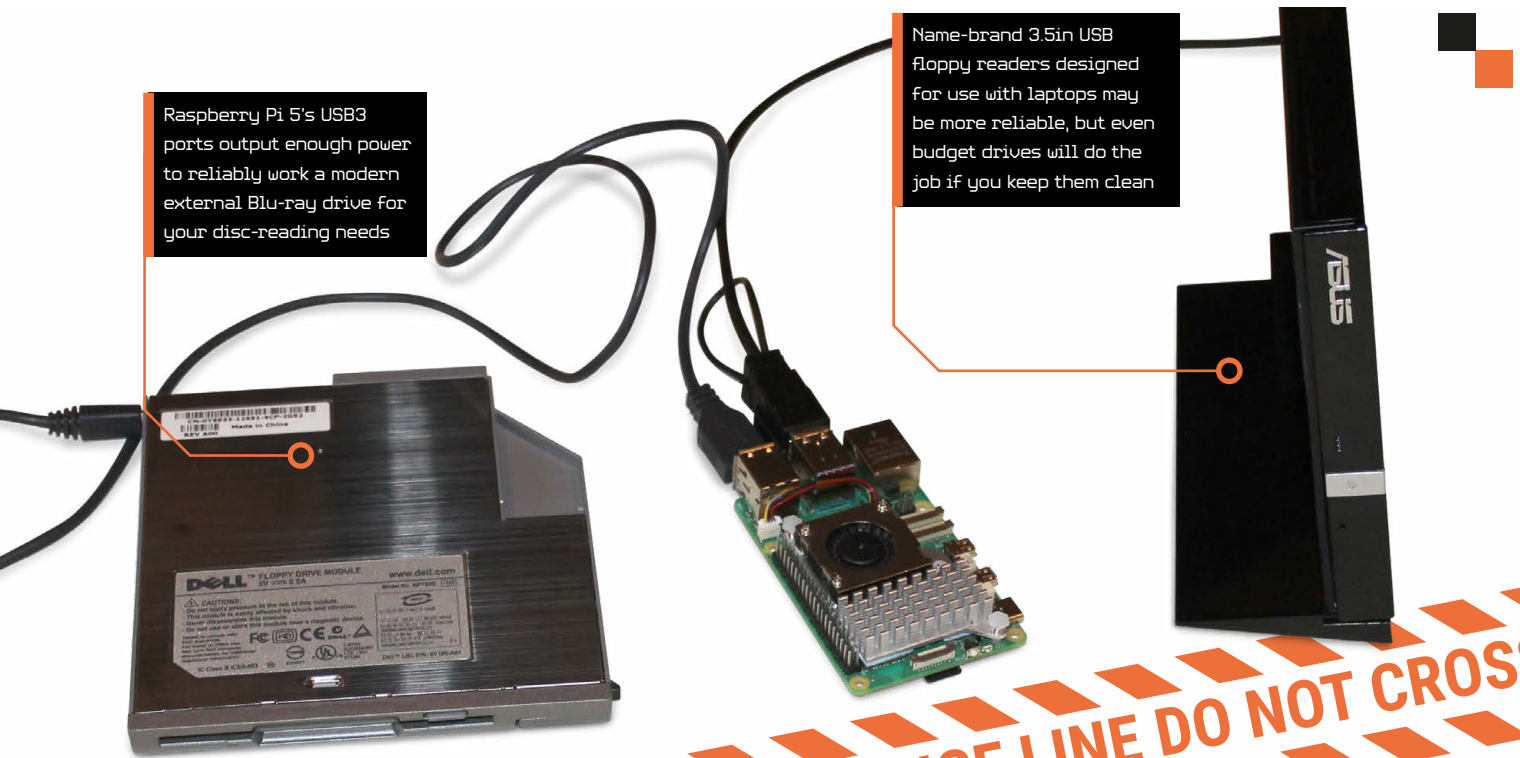
We'll start by assembling our retro toolkit – the hardware and software we'll need to play these old-school classics, from emulators to disk drives. Although we'll look at installing or running games from original hardware – the only viable approach for original PlayStation games, for example – where possible, we'll favour games that are currently legally available to buy, making this tour of retro gaming's dark side as accessible as possible for those who don't happen to have a stash of ancient floppy disks or CD-ROM installation material mouldering in a crypt somewhere.



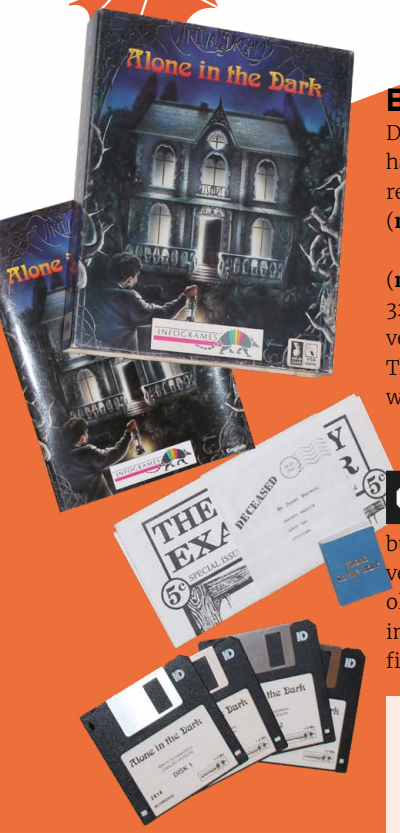
Warning! Mature content

The games mentioned in this feature include themes and imagery that may not be appropriate for sensitive players. Several are rated by PEGI as only suitable for those aged 18 and over.

pegi.info



Your Retro Toolkit



Build DOSBox Staging

DOSBox Staging is easy to use and tries accurately handle retro quirks such as the reproduction of the rectangular pixels of the pre-640×480 graphics era (**magpi.cc/dbsgraphics**).

You'll find an aarch64 version on Flathub (**magpi.cc/dbsflathub**), but if you're on a 32-bit operating system or want to try pre-release versions, building from source is your best option. The source build also integrates more smoothly with your OS.

01 Dependency

First, open a terminal and install the build dependencies. These are for the latest version of Raspberry Pi OS Bookworm. Users on older releases or alternative distros may need to install meson via pip. See the included **BUILD.MD** file for details.

```
$ sudo apt install meson ccache build-
essential libasound2-dev libatomic1 libpng-
dev \
          libsdl2-dev libsdl2-net-dev
libopusfile-dev \
          libfluidsynth-dev libslirp-dev
libspeexdsp-dev libxi-dev
```

02 Bleeding edge

If you want to try the version of the code that's currently being worked on:

```
$ git clone https://github.com/dosbox-
staging/dosbox-staging.git
$ cd dosbox-staging
```

Otherwise, download the latest source code package from **magpi.cc/dbssource** – that was 0.80.1 at the time of writing, and extract it, thus:

```
$ wget https://github.com/dosbox-staging/
dosbox-staging/archive/refs/tags/v0.80.1.tar.gz
$ tar -xzf v0.80.1.tar.gz
$ cd dosbox-staging-0.80.1/
```

03 Meson scene

Regardless of how you obtain the source code, the following build process is the same:

```
$ meson setup build/release
$ meson compile -C build/release
$ cd build/release
$ ./dosbox
```

Once we've confirmed that it runs, and allowed it to create its config file, exit and type:

```
$ sudo meson install
```

04 dosbox.conf

A config file is automatically created at **~/.config/dosbox/dosbox-staging.conf**. This serves as your primary configuration. DOSBox Staging will also check the directory you run it in for an additional **dosbox.conf** file, so you can easily create optimised per-game configurations. Any instructions you put in a per-game **dosbox.conf** file will supersede those in the main **dosbox-staging.conf** file.

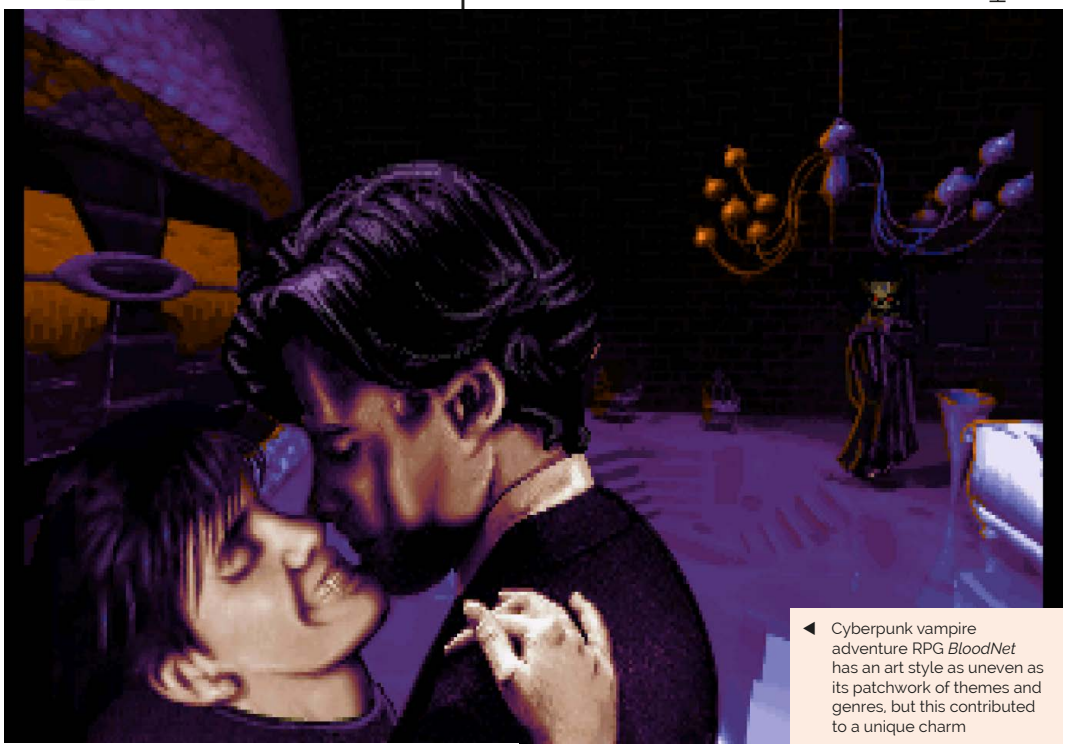
05 Ease of assembly

You can alternatively install DOSBox Staging as a Flatpak and then, because Flatpaks are deliberately air-gapped from the rest of your system, create an alias that will allow you to conveniently run it from the command line



▲ *Alone in the Dark*'s graphics are extremely low-poly, but its original release came with a rich stash of feelies and background lore

▶ *Veil of Darkness* might be an isometric game published by SSI, but it's firmly in the realm of adventure gaming



◀ Cyberpunk vampire adventure RPG *BloodNet* has an art style as uneven as its patchwork of themes and genres, but this contributed to a unique charm

```
$ sudo apt install flatpak
$ flatpak remote-add --if-not-exists flathub
https://dl.flathub.org/repo/flathub.flatpakrepo
$ flatpak install dosbox-staging
$ nano ~/.bashrc
```

Add the following line:

```
$ alias dosbox-staging="flatpak run io.github.
dosbox-staging"
```

Save, and then refresh your bash profile by typing this:

```
$ source ~/.bashrc
```

Build ScummVM

ScummVM was originally a tool for playing point and click adventure games created with LucasArts' SCUMM (Script Creation Utility for Maniac Mansion) engine, but now runs scores of games, from 1978's *Adventureland* to new releases like *Gobliiins 5*.

It supports aarch64 systems like Raspberry Pi 5 via its Flatpak release, or you want to build a release version of ScummVM yourself following the instructions below, official source code releases can be found at **magpi.cc/scummvmgit**.

To build these, you can follow the instructions below, but ignore the git clone stage and instead unzip the code you've downloaded.

If you need DEV version game support (**magpi.cc/scummvmcomp**), or wish to contribute to ScummVM, you should clone the git repository.

To build the current development version from the ScummVM Git repo:

```
$ sudo apt install g++ make git nasm libsdl2-
dev libsdl2-net-dev liba52-dev libjpeg62-
turbo-dev libmpeg2-4-dev libogg-dev libvorbis-
dev libflac-dev libmad0-dev libpng-dev
libtheora-dev libfaad-dev libfluidsynth-dev
libfreetype6-dev zlib1g-dev libfribidi-dev
libgif-dev libcurl4-openssl-dev libgtk-3-
dev libspeechd-dev libsndio-dev libvpx-dev
libmikmod-dev
$ git clone https://github.com/scummvm/
scummvm.git
$ ./configure
$ make clean
$ make -j4
$ ./scummvm
```

If it works and you wish to install it system-wide:

```
make install
```

Top Tip

The X Factor

DOSBox Staging is easy to use, but if you want a GUI and even more configurable hardware emulation, DOSBox-X (**dosbox-x.com**) is also outstanding.



Phantasmagoria used state-of-the-art video alongside traditional 2D environments to bring a gory adventure to home computer screens

> Plenty of online stores will sell you digital retro games

Hardware: External disc reader

We looked in detail at using external CD/DVD readers with Raspberry Pi in *MagPi* #140 (**magpi.cc/140**). Note that Raspberry Pi 4 and below will not reliably work with most modern external disc drives.

If your software comes on a single disc, you can mount the CD or DVD and point your software at the folder your OS gives it under **~/media/YourUserName/**

If you need to swap discs, pmount, a user-space wrapper for the mount command, can arbitrarily create mount points.

```
$ sudo apt install pmount
$ sudo nano /etc/pmount.allow
```

Add the following to the bottom of the file:

```
/dev/sr0
```

Now open File Manager. Go to Edit > Preferences > Volume Management and untick all the Auto-mount options. Reboot your Raspberry Pi.

To mount a disc, insert it, let it spin up and, in a terminal, type:

```
$ pmount /dev/sr0 /media/cdrom
```

To unmount it:

```
$ pumount /dev/sr0
```

Top Tip

Come get SCUMM

If you're looking for games to play on ScummVM, the team maintains a handy list of currently available free and commercial titles at **magpi.cc/scummgames**

Hardware: Floppy disk drive

To read floppy disks, you'll need an external reader. We use a DELL MPF82E. Multi-floppy games will have the same problem with disk swapping in DOSBox as multi-CD ones. To work around this, add the following to **~/etc/pmount.allow**:

```
/dev/sda
```

You can now mount and unmount floppy disks thus:

```
$ pmount /dev/sda /media/floppy
```

You can unmount them with:

```
$ pumount /dev/sda
```

However, physical floppy swapping does not require unmounting and remounting.

Buying digital games

If you don't have original releases, plenty of online stores will sell you digital retro games. We prefer GOG, as the Windows downloads of its retro games use a package format that we can extract directly on Raspberry Pi. Open a terminal and:

```
$ sudo apt install innoextract
```

Innoextract includes a special --gog (or -g) flag to handle GOG-specific packaging standards, but it's sometimes found it necessary to rename files in multi-file exe and bin sets before extraction.

If you've bought old games elsewhere that come packaged with DOSBox or ScummVM, you can usually transfer installed files from your x86-64 PC to play on Raspberry Pi.

You can also buy retro games on Steam (**store.steampowered.com**), Zoom Platform (**zoom-platform.com**) and – especially for new 'retro' games – Itch (**itch.io**).

Games

Alone in the Dark (1992)

Released in 1992, the original *Alone in the Dark* is one of the games that birthed the survival horror genre. Part of the '90s wave of French adventure games inspired by the work of author H.P. Lovecraft, its third-person view and tank controls would inspire later classics such as *Resident Evil*. Although the series would pass through the hands of many publishers and developers, with some less-than-inspiring instalments, this tensely ponderous classic is worth a visit in all its low-poly glory.

The original 1992 version of *Alone in the Dark* is available to buy from various digital storefronts. Although it's emblazoned with an 18 certificate on some of them, this is a lookup error confusing it with Atari's 2024 reboot. The original game has never been rated, and although foes like the Night Gaunt and bathtub monster can be scary, especially when you're trying to escape them using the awkward controls, there's no significant gore and the monsters' design is unlikely to inspire visceral terror.

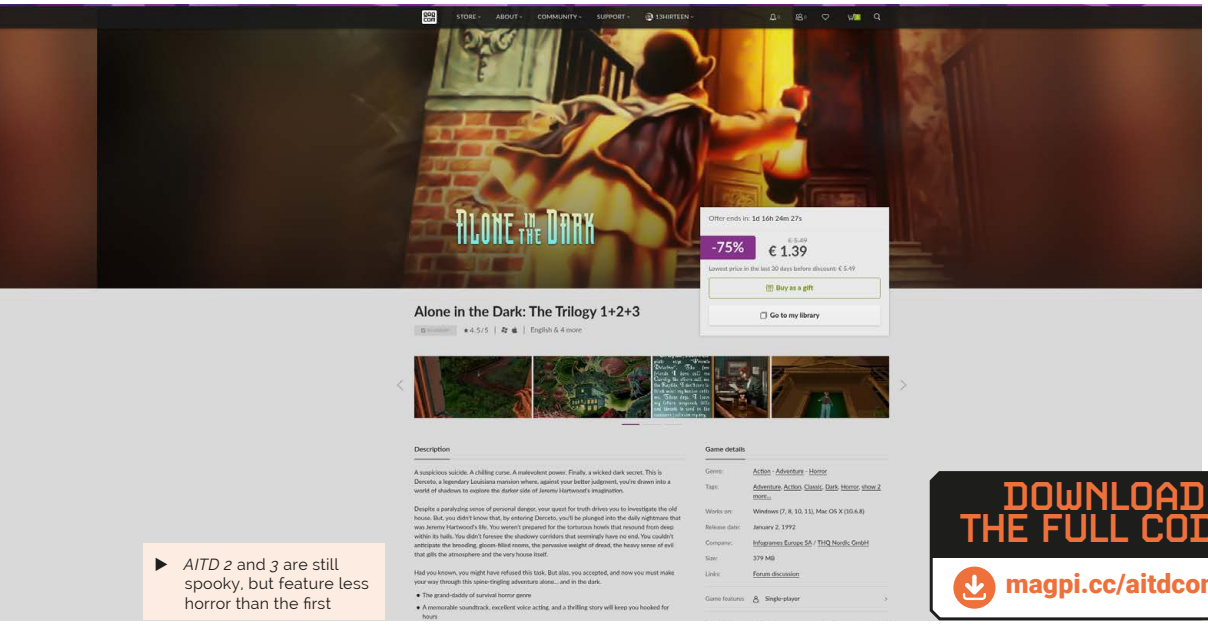
We'll use the GOG version. Buy and download the *Alone in the Dark* trilogy for Windows from GOG. This package gets you stand-alone downloads for each game, and the first includes both *Alone in the Dark 1* and the stand-alone mini adventure, *Jack in the Dark*, which was given away on magazine cover disks.

Copy the game's setup file into a directory called **~/dos/AITD** then open a terminal:

```
$ cd dos/AITD
$ innoextract -g setup_alone_in_the_dark_1.0_
cs_\(28043\).exe
```

GOG's own config files don't work well with DOSBox Staging, so we've created our own, incorporating the game selector from GOG's config. This **dosbox.conf** file should be placed in the **~/dos/AITD** directory. Then, to run the games, open a terminal and type:

```
$ cd  ~/dos/AITD
$ dosbox
```



▶ *AITD 2* and *3* are still spooky, but feature less horror than the first

DOWNLOAD THE FULL CODE:

magpi.cc/aitdconfig



DOWNLOAD THE FULL CODE:
magpi.cc/vodconfig

Veil of Darkness (1993)

Strategic Simulations Interactive (SSI) is best known for its wargames and licensed Dungeons & Dragons RPGs, but also published some more unusual titles. *Veil of Darkness* is an isometric adventure game with RPG combat, developed by Event Horizon (later DreamForge Intertainment), which is also known for grimdark RPG *The Summoning*, horror-themed AD&D games in the Ravenloft campaign setting, and horror masterpiece *Sanitarium*.

We're going to install this one from floppy disks as an example of how to do so, but if you don't have a scruffy box of original '90s media lying around the place, you buy it on GOG (**magpi.cc/vodgog**) and use innoextract to unpack its files, as we did with *Alone in the Dark*, or install it from Steam and copy its files to Raspberry Pi.

> "Veil of Darkness is an isometric adventure game with RPG combat"

▶ We installed Veil of Darkness from floppy, but disks of this age are hard to find risk being deteriorated, so it might be best to buy a digital version

Open a terminal window and type:

```
$ pmount /dev/sda /media/floppy
```

Wait for this process to finish and for the disk to mount.

In a separate terminal window:

```
$ cd dos
$ dosbox
```

Once DOSBox Staging has loaded, type:

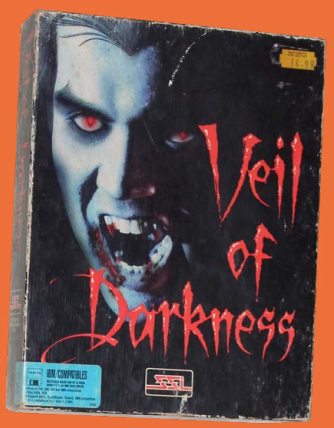
```
$ mount  c .
$ mount a /media/floppy
$ a:
$ install
```

Wait a shockingly long time for the disk to unpack its contents. Read the manual. Make some tea. Installing from floppy was never quick, and installing from 30-year-old floppies is even slower. When you're finally told to insert disk 2 into A:, just eject the floppy, put in disk 2, press **Enter** to continue installation and wait.

When the installer produces its next distressing emulated PC speaker beep to tell you it's time to change the disk, repeat this process one last time. Once installation is complete, you'll be presented with a setup screen. It'll auto-select an Adlib card, but if you select No, go through all the setup options, and choose CMS Sound Blaster as your sound device, you should get full music and even a little intro voiceover.

Quit, and create the following **dosbox.conf** file in the **~/dos/VEIL** directory then, in a terminal:

```
$ cd ~/dos/VEIL
$ dosbox
```





BloodNet (1993)

MicroProse's *BloodNet* isn't an immortal work of art, but this gleeful, high '90s hybrid of vampire fiction, cyberpunk and noir detective tropes is a less-played entry in an unusual genre and a snapshot of a very particular time in game development. Even its art style is wildly, charmingly dissonant from one scene or UI element to the next. *BloodNet* never received an age rating and there's no real gore to speak of.

The CD version is, for better or worse, fully voiced. Wooden though protagonist Ransom Stark's actor is, the voice acting certainly gives us a feel for our cybernetically enhanced detective's inner sleazebag before he gets (partially) vampirised during the intro.

Manually create a character, and a series of ethical questions will determine your strengths and weaknesses. Being a mercenary, by picking violence-oriented responses, maximises your chances of surviving the game.

We're going to install it from a copy of the 1994 DOS CD-ROM release, but you can buy the game on GOG (**magpi.cc/bloodnet**).

First, let's pmount our CD-ROM somewhere sensible. Open a terminal and type:

```
$ pmount /dev/sr0 /media/cdrom
```

We already have a directory called **dos** in our home. Open another terminal and type:

```
$ cd dos
$ dosbox
```

We'll create a dedicated **conf** file later, but for now, in DOSBox, type:

```
$ mount C .
$ mount D /media/YourUserName/UNTITLED/ -t
cdrom -usecd 0 -ioctl
$ D:
$ install
```

Confirm that you want it to install to drive C, use the arrow keys to go to Sound, press **Space** and select Sound Blaster Pro, and the Roland SCC-1 for music. Use the mouse to select Save and Exit the test the game by typing:

```
$ bloodnet
```

Quit the game and DOSBox. To add MIDI sound in the style of Roland's SCC-1, we'll use S. Christian Collins' GeneralUser GS 1.471 soundfont (**magpi.cc/gusoundfont**).



DOWNLOAD THE FULL CODE:
magpi.cc/bnetconfig

▲ We installed *BloodNet* from an original CD-ROM, but you can grab it from GOG for easy extraction

Open a fresh terminal window and type:

```
$ wget https://www.dropbox.com/
s/4x27l49kxcwamp5/GeneralUser_GS_1.471.zip
$ unzip GeneralUser_GS_1.471.zip
$ cp 'GeneralUser_GS_1.471/GeneralUser GS
1.471/GeneralUser GS v1.471.sf2'  ~/.config/
dosbox/soundfonts.
```

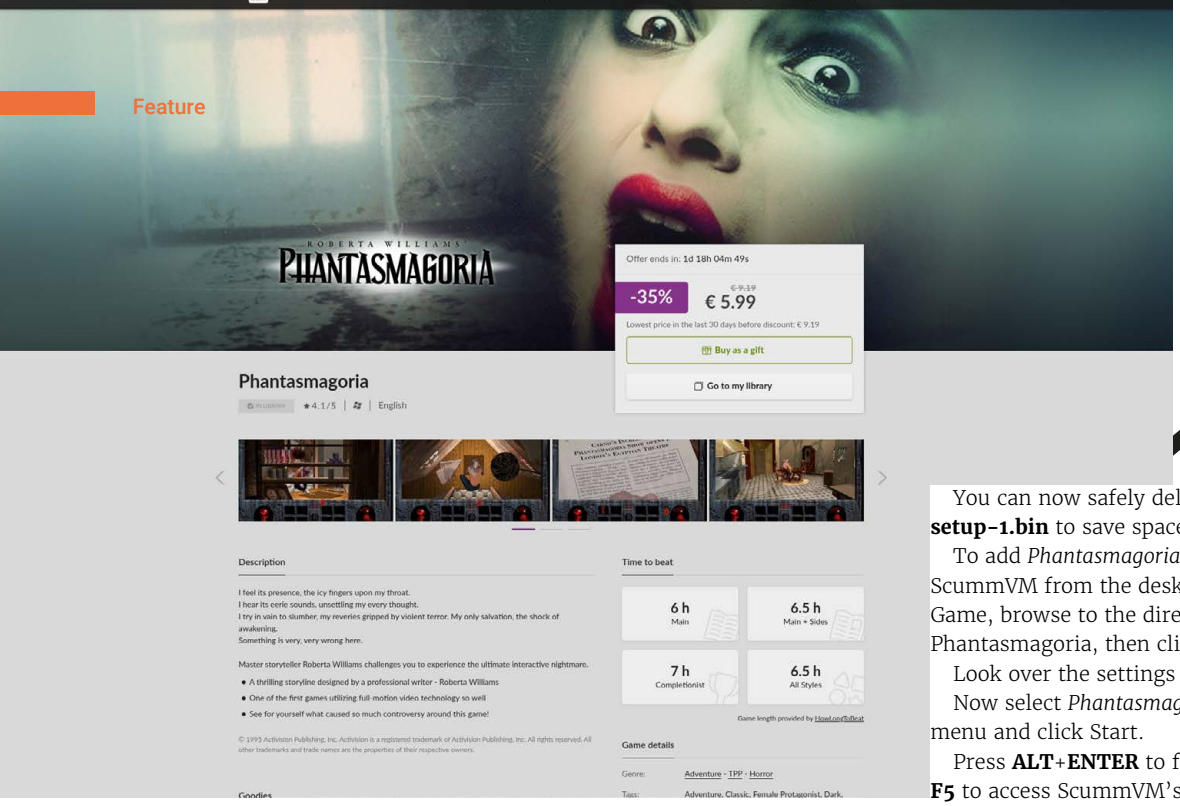
Now, create a custom configuration file:

```
$ cd /dos/MPS/BNCD/
$ nano dosbox.conf
```

Give it our supplied **conf** file and save, so that when you run DOSBox from *BloodNet*'s directory, it'll use our custom settings and auto-run it. Don't forget to leave the CD mounted while you're playing.



▼ Custom audio configuration will get you wavetable speech and effects and general MIDI music in *BloodNet*



▲ We bought and downloaded *Phantasmagoria* from GOG's extensive retro games collection.



Phantasmagoria (1996)

Phantasmagoria was written with the explicit intention of shocking. It includes scenes of violence, sexual violence and gore, and received a Mature rating at release. While the game's style is dated, writer/director Roberta Williams pulled the stops out on the unpleasantness for her venture into horror.

This includes scenes of torture, body horror, a pet cat whose name is a strong ableist slur in the UK and which dies unpleasantly, and a (clothed) FMV sexual assault scene against your protagonist that you're shown after completing Chapter 3, which you can't opt out of. You can enable and disable a censored mode in the settings to blur out violent and sexual cut-scenes, although the soundtrack plays on.

You can buy *Phantasmagoria* from GOG at **magpi.cc/phantasmagoria**. In your GOG library, search for the game, click it, then expand the Download Offline Backup Game Installers section. Download both parts of the Windows installer and put them in their own directory - we used **~/dos/phantasmagoria**. We'll use Innoextract to unpack them, and ScummVM to play them.

Innoextract isn't always happy with GOG's naming conventions, so we're going to rename the executable and its data files into something a bit easier to parse. Note that the version number in brackets may change if the version on GOG is updated at any point.

```
$ sudo apt install innoextract
$ mv setup_phantasmagoria_1.0_\(20239\).exe setup.exe
$ mv setup_phantasmagoria_1.0_\(20239\)-1.bin setup-1.bin
$ innoextract setup.exe --gog
```



You can now safely delete **setup.exe** and **setup-1.bin** to save space.

To add *Phantasmagoria* to ScummVM, open ScummVM from the desktop menu. Click Add Game, browse to the directory where you unpacked Phantasmagoria, then click Choose.

Look over the settings and click OK.

Now select *Phantasmagoria* from ScummVM's menu and click Start.

Press **ALT+ENTER** to fullscreen the game, and **F5** to access ScummVM's dedicated save menu.

Click Watch Intro to enjoy '90s FMV and *Hellraiser*-influenced 3D renders of protagonist Adrienne's nightmares, plus an extremely '90s softcore sex scene. Click Start New Game, name your save, select the first chapter, and start.

Phantasmagoria's blend of rendered environments and video-captured characters is unusual to the modern eye, and the low quality lends to its old-school B-movie charm. However, its single-mouse-button interface feels bare-bones compared to Sierra's earlier point and click adventures, so you'll want to read the manual.

Five more '90s horror classics to emulate

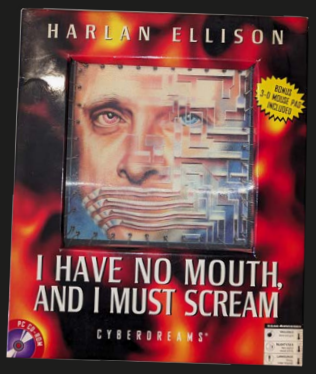
There are plenty more horror masterpieces and eccentricities to explore, available to buy now and play through DOSBox or ScummVM. Here are five of the best.

Gabriel Knight: The Sins of the Fathers
(ScummVM, DOSBox)
magpi.cc/gabknight

Sanitarium
(ScummVM)
magpi.cc/sanitarium

Realms of the Haunting
(DOSBox)
magpi.cc/rohgog

Killing Time
(DOSBox)
magpi.cc/killtime



I Have No Mouth And I Must Scream
(ScummVM, DOSBox)
magpi.cc/nomouthgog



Unlock the full potential of your Raspberry Pi

Universal housings from the UCS series

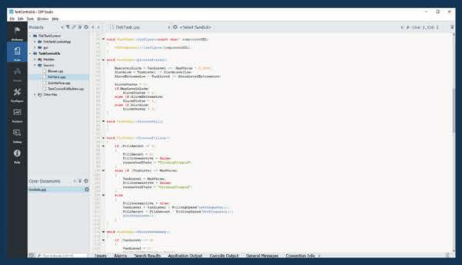


The UCS-RPI series is specifically designed for seamless integration with Raspberry Pi minicomputers. Whether you're a hobbyist, educator, or professional, our comprehensive range of accessories and range of sizes ensures that the UCS can be used not only for your Raspberry Pi but universally for all your projects

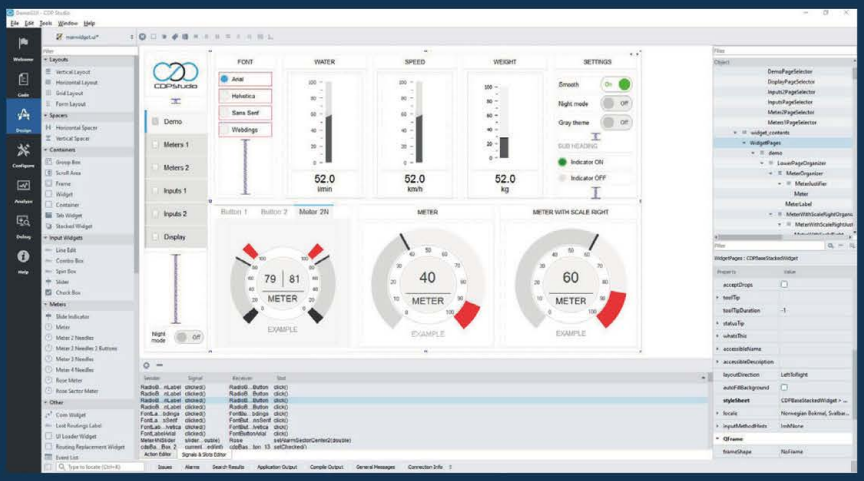
Upgrade your Raspberry Pi experience with the UCS series today!

For additional information, scan the QR code

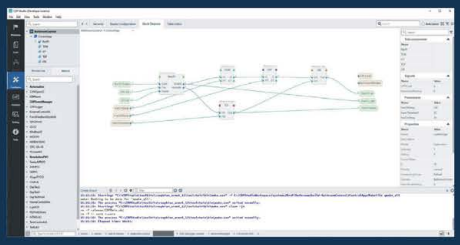
PHOENIX CONTACT



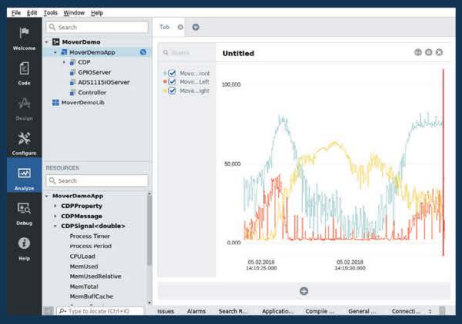
Full-Code



Design



No-Code



Analyze

No-Code UI Designer
for WEB and Native GUI

PROFESSIONAL CONTROL SYSTEM DEVELOPMENT TOOL

Home projects made easy.

CDP Studio, a great software development tool for your home projects. Build systems for Raspberry Pi, use C++ or NoCode programming, open source libraries, out of the box support for GPIO, I2C, MQTT, OPC UA and more. Create beautiful user interfaces. Built for industrial control system development, **FREE for home projects**.

cdpstudio.com
Tel: +47 990 80 900 • info@cdptech.com
CDP Technologies AS // Hundsværgata 8, 6008 Ålesund, Norway

CDPStudio

HANDHELD GAMING with Raspberry Pi

Retro gaming on the move can be fun and creative. PJ Evans grabs some spare batteries

Maker



PJ Evans

PJ is a writer, software engineer and a dab-hand at Galaxians. When not using the original machinery he can be found 'doing research' for this feature.

@mrpjevans

Whether you're looking for a nostalgia hit or just an authentic way of playing the classics, handheld gaming with Raspberry Pi is fun, fun, fun. Not only can you play retro games galore but also get involved in the creation of 8-bit-style games. With the increasing power of Raspberry Pi Zero and Raspberry Pi Pico (especially with Raspberry Pi Pico 2), there's never been a better time to put down your phone and grab something a bit more tactile. Over the next few pages we'll look at your options for handhelds, setting them up and how to write your own games.



Warning!
Copyright!

All the software discussed in this feature has been made freely available by its respective copyright holders. Please be cautious when finding ROMs for your retro setup that you are not downloading from a site hosting software illegally.

magpi.cc/legalroms

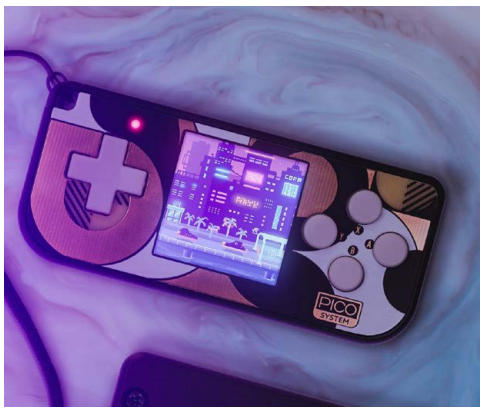


RETROFLAG GPI CASE 2W

£75
magpi.cc/gpicase2w

With more than a passing resemblance to a classic 1990s device, the GPi Case is a stunning little handheld. This version is powered by Raspberry Pi Zero 2W, so it can handle more demanding emulators than earlier versions. A 3in IPS screen and audio jack provide the full experience.

>> Perfect for
The dedicated retro gamer



PIMORONI PICOSYSTEM

£59
magpi.cc/picosystem

Want to go smaller? The cute little PicoSystem is a Pico-based handheld targeting those wanting to try their hand at writing their own games. It's small enough to feature a lanyard hole, and built from solid aluminium so will handle bumps and bruises. Pimoroni provides all the info to get started and loads of sample games.

>> Perfect for
Hacking about and writing your own games



NULL 2

£37 / $49
null2.co.uk

Fancy something a little more hackable? The Null2 is a self-assembly kit in the classic landscape form factor. It's ideal for those who want to customise and endlessly tinker. Powered by a Raspberry Pi Zero 2 it comes with all the parts you need for a tiny handheld experience.

>> Perfect for
Those who love to game and hack in equal measure



KITRONIK ZIP96

£36
magpi.cc/zip96

Here's something a bit different. The ZIP96 is a perfect introduction to coding through game creation. A super-simple LED array powered by Raspberry Pi Pico complete with control buttons. Kitronik has thoughtfully created a series of lesson plans to show how to write simple games like *Snake* for this low-cost device.

>> Perfect for
The younger games coder



PI GRRL 2

Varies
magpi.cc/pigrrl2

How about building your own handheld from scratch? If you have access to a 3D printer and know which end of a soldering iron gets hot then you can have a lot of fun putting this kit together. The result is a cute Raspberry Pi Zero-powered handheld ready to run your favourite games.

>> Perfect for
Retro-crazy makers



RETRO LITE CM4

Varies
magpi.cc/retrolitecm4

If you really want to make a statement, and have some proper building skills, try the Retro Lite project. A beautiful larger handheld in a format similar to the Nintendo Switch and Steam Deck. It requires custom PCBs and a lot of work to build, but the Compute Module 4 powered result will be mighty.

>> Perfect for
The serious retro gamer and maker

> If you have access to a 3D printer and know which end of a soldering iron gets hot then you can have a lot of fun

WHAT'S THE SOFT OPTION?

You've got your hardware but what's the best OS to use?



Recalbox

recalbox.com

Over one hundred systems are supported out of the box and installation is a breeze. Ideal if you just want to get on and start gaming.



RetroPie

retropie.org.uk

For a long time, this was the de-facto standard for Raspberry Pi gaming. It's not updated as often now, but still worth a look.



Batocera

batocera.org

New kid on the block, Batocera supports over 190 systems and is gaining a reputation as an excellent platform.

Build the ultimate retro gaming handheld

Play thousands of games on the move with Retroflag's amazing GPi Case and a Raspberry Pi Zero 2W

You'll Need

- Raspberry Pi Zero 2 (No headers) **magpi.cc/zero2w**
- Retroflag GPi Case 2W **magpi.cc/gpicase2w**



A 3-inch IPS screen is the perfect size and yes, of course it runs *Doom*.

The GPi Case recreates that 1990s handheld gaming feel, with a few extra buttons



▼ Recalbox comes with loads of free (and legal) games for you to play, including this ZX Spectrum scrolling shooter.

Getting started in retro gaming has gotten much easier over the years. More powerful hardware means emulators run better too. Retroflag have been at the forefront of the retro hardware scene with a series of handheld and console cases for Raspberry Pi, some of which bear tribute to some of the legendary devices of the 1980s and '90s. Combine the latest handheld case with the power of a Raspberry Pi Zero 2W and you have something really special. Getting started can be intimidating so here's a short guide to creating the best handheld retro gaming device out there.



Raspberry Pi Zero 2W fits in a cartridge with an adapter board. These can be swapped out, and the SD card is always accessible.

01 Get Recalbox

Recalbox is the leading platform for retro gaming on Raspberry Pi (and other systems too). The developers have excelled in making a true plug-and-play system that removes a lot of the endless config editing and moving strange files around to make things work. In fact, there are over 100 systems supported right out of the box. Better yet, they have created a build especially for the GPi case range. Start by getting a microSD card and writing the Recalbox OS image to it. You'll find it in Raspberry Pi Imager > Emulation and game OS > Recalbox > GPICase2W. *Do not* hook up the Raspberry Pi to a monitor and boot.

02 Assemble the cartridge

The Raspberry Pi Zero 2W fits into a cartridge that can be removed from the main body (you can buy additional carts too). The instructions will ask you to install additional software, but the Recalbox image already has everything already installed. If you boot to a regular HDMI monitor, it will mess things up for later. Instead, remove the microSD card and follow the assembly instructions to attach the Raspberry Pi Zero 2W to the adaptor and then mount both in the cart without the card. Screw the cart halves together so the adapter's pogo pins are married to the GPIO.

03 First boot

Before placing the cart into the back, flip the 'Safe Shutdown' switch to 'On' and make sure the internal battery is fully charged or keep the USB power cable attached. Place the cart firmly in the slot and switch on. The first boot will run through a configuration process but there are no questions to answer. Just let it do its thing (it'll give you some great tips too) and you'll be taken to the systems menu. A number of platforms are already available with games included, so you can start right away. Use the D-pad to navigate, B to select and A to go back. When done with a game, press START and the flag button above it together.

04 Connect to Wi-Fi

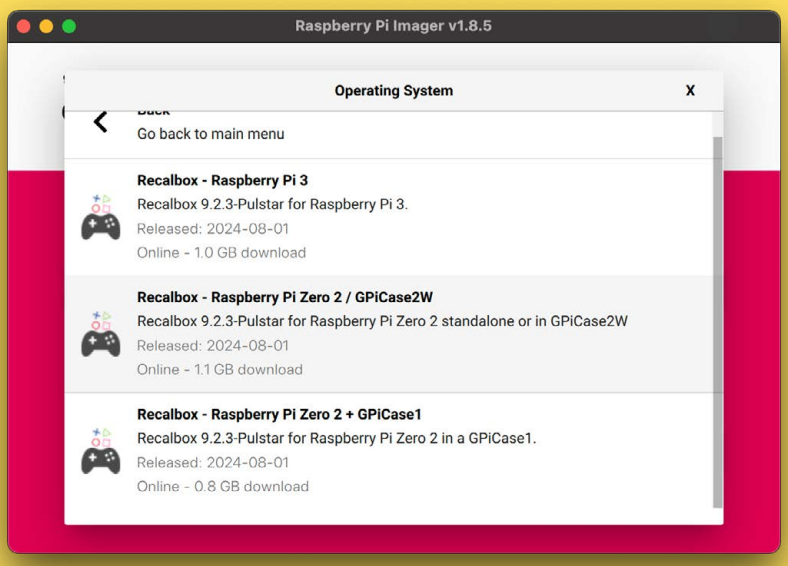
Now you have a base system up and running, you'll probably want to add more games. The sensible option is to use Wi-Fi. On the main system menu, press the SELECT button to access the main menu. Now scroll down to 'Network Settings' and press B. Scroll to 'Enable Wi-fi' and press B. Now you can go to 'Network' and choose your local Wi-Fi network. When selected go to 'Wi-fi Password' and enter your password using the groovy keyboard system. You can also use WPS if your router supports it. Finally, choose a hostname for your new toy and you should be able to find it on your local network.

05 Upload ROMs

If you want to add additional games to your handheld, Recalbox has made it easier than just about any other retro gaming platform. When we connected to Wi-Fi, the device started sharing a directory on the network. All you need to do is connect to that folder just like any other network share. On Windows you can use the network browser or 'Map network drive' option. On macOS, Finder will see the handheld automatically. Raspberry Pi and Linux users can mount the filesystem like any other. To add games for a particular system, navigate to 'roms' and then find the system name you want and drop the files there.

06 Refresh and scrape

You won't be able to see your new games right away. The system needs to rescan and restart first. From the Systems menu, go to the system you want to update. Now press START and scroll down to 'Update games list'. Once the update is complete, you can now automatically add artwork and metadata by using the scraper. From the Systems menu, press START and scroll to 'Scraper'. Starting the scraper will scan all your games and add artwork automatically. It can take some time but you can target individual systems in the menu first. Now, it's time to get playing.



▼ Raspberry Pi Imager contains all you need to install Recalbox onto a microSD card

>>Top Tip<<

Safe shutdown

Recalbox supports the GPi Case's safe shutdown mode. When enabled, using the case's power switch will perform a controlled shutdown, protecting your precious handheld.

>>Top Tip<<

Other GPi cases

If you can't find an image for the combination of Raspberry Pi and GPi case you are using, check Recalbox's own site: **recalbox.com**

Make your own handheld games with PicoSystem

What's better than playing games? Making your own!

You'll Need

- Pimoroni PicoSystem **magpi.cc/picosystem**
- Laptop or desktop computer
- USB-C cable

Live like it's the '90s with your own version of *Snake* on a 120 x 120 display

Pimoroni's MicroPython libraries make reading control input as simple as possible



> "Aimed at those who want to write games as much as play them"

Pimoroni's PicoSystem is a unique and fun little beastie. Comparable only with Panic's PlayDate, PicoSystem is a small handheld gaming platform that's aimed at those who want to write games as much as play them. It's powered by the mini but mighty RP2040 and features a full-colour 1.6in display, D-pad and four buttons. You can write games in super-fast C++ or more friendly MicroPython. Getting started can be daunting, but the excellent documentation and software tools take away a lot of the pain. Here we'll create a simple *Snake*-like game in MicroPython.

01 Set up the PicoSystem

Like any Raspberry Pi Pico, you can change the firmware on the PicoSystem by putting it in bootloader mode and updating the firmware. The first thing we need to do is upload the Micropython firmware, as PicoSystem ships with a C++ stack. You can download the latest version from **magpi.cc/picosysrelease**. You need to download '**pimoroni-picosystem-{version}-micropython.uf2**' (where 'version' is a group of numbers). Connect the PicoSystem to your computer, hold down X and switch it on. A directory will be mounted just like a USB drive. Copy the uf2 file into the directory. It will then automatically unmount. You're ready to go.

02 Create your code

Let's write *Snake*! PicoSystem works on an infinite loop, each iteration of the loop being known as a 'tick'. Every time the loop runs, we move the snake in the chosen direction, check the direction hasn't changed and also check if the snake has collided with food, the wall or itself. To enter the code, we recommend using Thonny (**thonny.org**) which will recognise the PicoSystem when connected and allow you to add files. Create a new file on the PicoSystem called **main.py** and enter the code as shown on p106. You can also download the code from **magpi.cc/picosyssnake**. Save the file onto the PicoSystem and then disconnect.

03 Make it your own

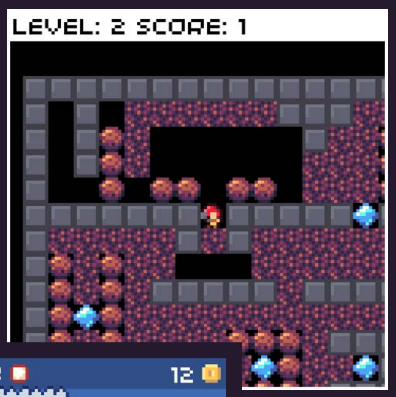
Let's play *Snake*! If a file called **main.py** is present on the PicoSystem, it will automatically run on boot. Switch the PicoSystem on and your game should start immediately. Grow your snake by eating the food (green block) and see how long you can make the snake without hitting the edge of the screen or itself. Now you have a basic game running, how can you make it better? Could speed slowly increase? Multiple food to collect? How about a high-score system or better graphics? *Snake* is a great starting point for your own game-writing adventures.

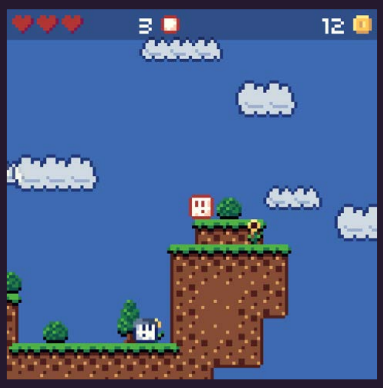
>>Top Tip<<

Read up!

PicoSystem comes with great documentation for both its C++ and MicroPython platforms: **magpi.cc/picosysdocs**

▼ **PicoSystem game:** *Rocks and Diamonds*





▲ **PicoSystem game:** *Super Square Bros*

main.py

DOWNLOAD THE FULL CODE:
magpi.cc/picosyssnake

> Language: **MicroPython**

```
import utime
import urandom

# Reset everything
pen();cursor();camera();clip();alpha()

# Reset so we have a 2-block snake and food
def game_reset():
    global snake, move
    snake = [[55,60], [60,60]]
    move = [5, 0]
    add_food()

# Add new food in a random place
def add_food():
    global food_x, food_y
    food_x = urandom.randint(0, 23) * 5
    food_y = urandom.randint(0, 23) * 5

def update(tick):
    global direction, move, snake

    # Detect a change in direction
    if pressed(UP): move = [0, -5]
    elif pressed(RIGHT): move = [5, 0]
    elif pressed(DOWN): move = [0, 5]
    elif pressed(LEFT): move = [-5, -0]
    head = snake[len(snake) - 1]
    new_head = [head[0] + move[0], head[1] + move[1]]

    # Remove the tail
    snake.pop(0)

    # Check whether the new 'head' will collide with the rest of the body
    for segment in snake:
        if new_head[0] is segment[0] and new_head[1] is segment[1]:
            game_reset()
            return

    # Has the snake reached edge of the screen?
    if new_head[0] is 0 or new_head[0] is 120 or new_head[1] is 0 or new_head[1] is 120:
        game_reset()

    # Has the snake eaten some food?
    if new_head[0] is food_x and new_head[1] is food_y:
        snake.append([head[0] + move[0], head[1] + move[1]])
        add_food()

    # Add the head
    snake.append(new_head)

def draw(tick):
    # Clear the screen
    pen(0, 0, 0)
    clear()
    pen(15, 15, 15)
    flip()

    # Draw each segment of the snake
    for segment in snake:
        frect(segment[0], segment[1], 5, 5)

    # Draw the food
    pen(0, 15, 0)
    frect(food_x, food_y, 5, 5)

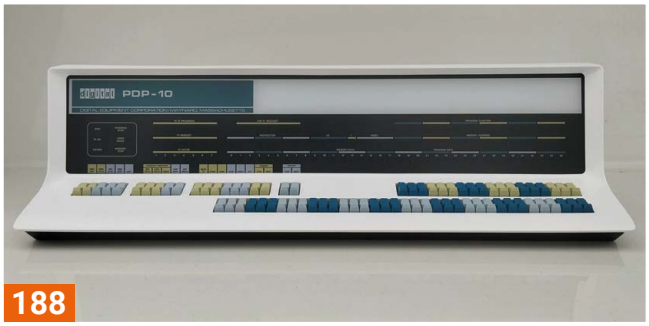
    # Controls the speed of the game
    utime.sleep(0.2)

# Start the game
game_reset()
start()
```

Reviews and Resources



186



188

186 Home Assistant Yellow
Home automation made easy

188 PiDP-10
A modern take on a classic

190 ArmPi FPV AI Vision
A robot arm that can see

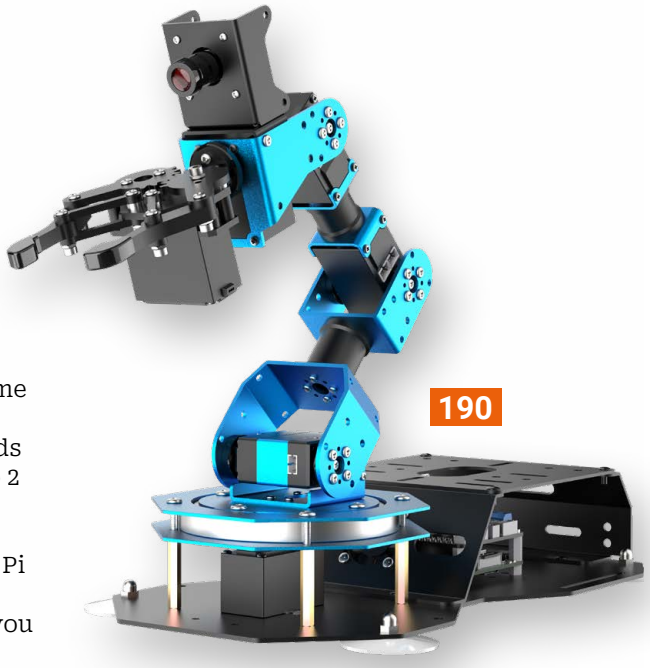
192 Plasma 2350
All-in-one LED control board

194 PiDog
A very smart dog

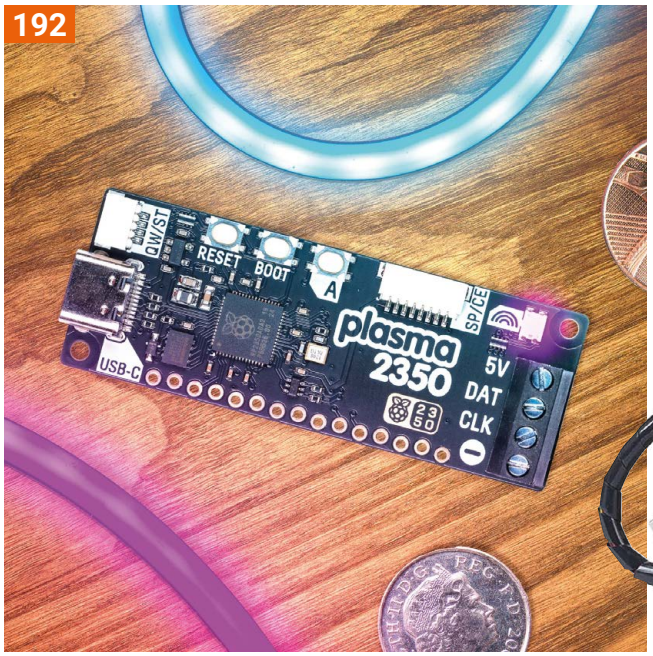
196 10 amazing gaming accessories
Level up your game time

198 10 amazing Pico 2 builds
Showing off what Pico 2 can do

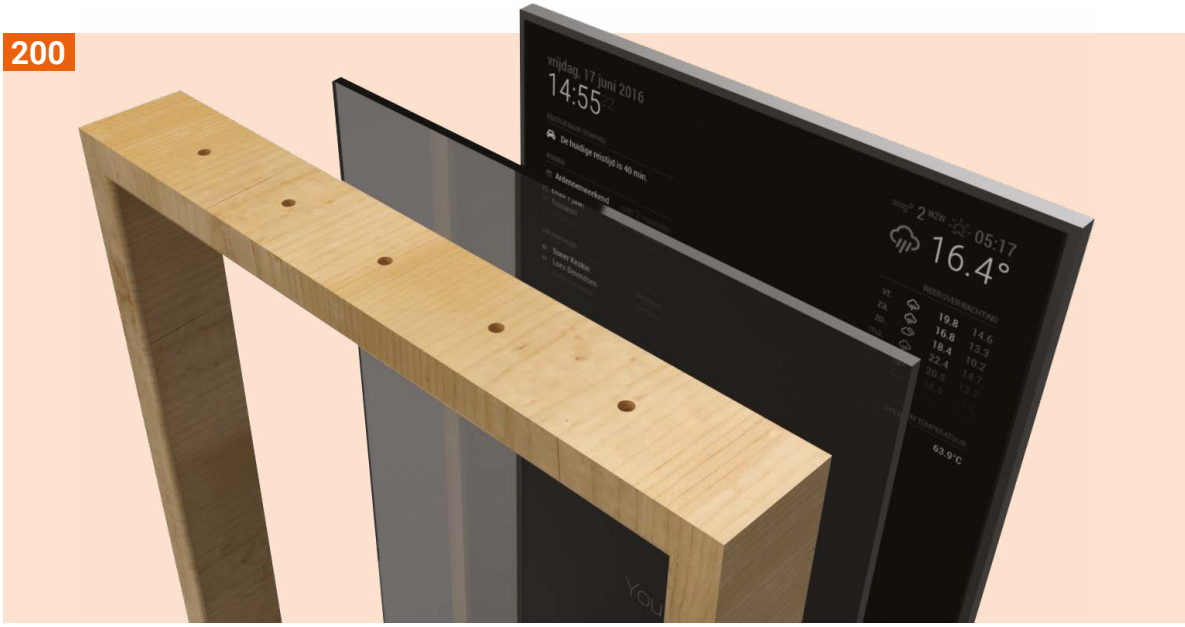
200 10 amazing Raspberry Pi monitors
The best displays for you



190


192
QWIIC
RESET
BOOT
A
plasma
2350
5V
DAT
CLK
USB-C


194


200
vrijdag 17 juni 2016
14:55
05:17
16.4°

Home Assistant **Yellow**

▶ Home Assistant ▶ **magpi.cc/hayellow** ▶ £107 / $135 (without CM4)

Compute Module-powered home automation is only moments away with this powerful kit. By **Rob Zwetsloot**

SPECS

DIMENSIONS:
123mm x 123mm x 36mm

POWER:
12v/2A barrel DC jack, PoE+ IEEE 802.3at-2009 Class 3 or 4

EXTRA FEATURES:
M.2 SSD slot, stereo audio DAC with 3.5mm jack output, enhanced wireless (Silicon Labs MGM210P Mighty Gecko Module), RTC



▲ The case looks great and houses everything neatly inside

Verdict

Extremely easy to set up and use, it's a very compact and practical box that really helps power your home

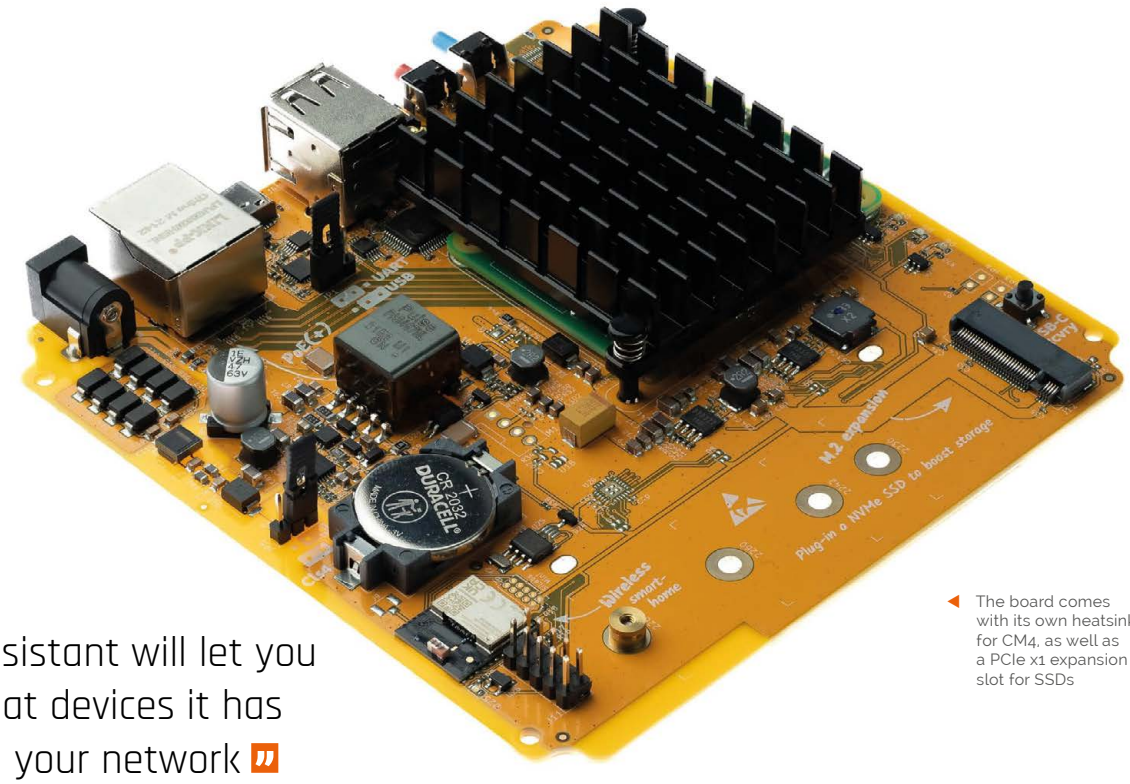
10/10

Raspberry Pi for home automation and other forms of IoT is what a lot of people love to use it for, and thanks to that the hardware and add-ons that work with Raspberry Pi are easy to come by. Software-wise as well, one of the more popular systems is Home Assistant, which has been around for nearly as long as Raspberry Pi has itself. You can even find it in Raspberry Pi Imager.

It's no surprise then that its branded hardware is pretty high quality. Powered by a Raspberry Pi Compute Module 4 (which you can supply yourself to keep the price down), and with PoE (power over Ethernet) capabilities, it's a remarkably competent yet simple device on paper, picking up on any IoT-enabled hardware on your local network and very quickly letting you start controlling it.

Setting up the device is very simple, although depends slightly on the version you get. The kit that comes with a Compute Module 4 already installed is basically ready to go, just requiring you to get it set up for your network and IoT add-ons.

If you're adding the Compute Module, you just need to take the case off using the hand-tightened screws (no screwdrivers involved) and firmly click CM4 in. You can also add an M.2 SSD at this stage too if you want the extra storage. After that, it's just installing the OS via a USB stick (set up with Raspberry Pi Imager), and then doing the usual network setup. The longest part of setting up this way is just letting all the software install – in about 30 minutes we were all ready to go.



The board comes with its own heatsink for CM4, as well as a PCIe x1 expansion slot for SSDs

> Home Assistant will let you know what devices it has found on your network

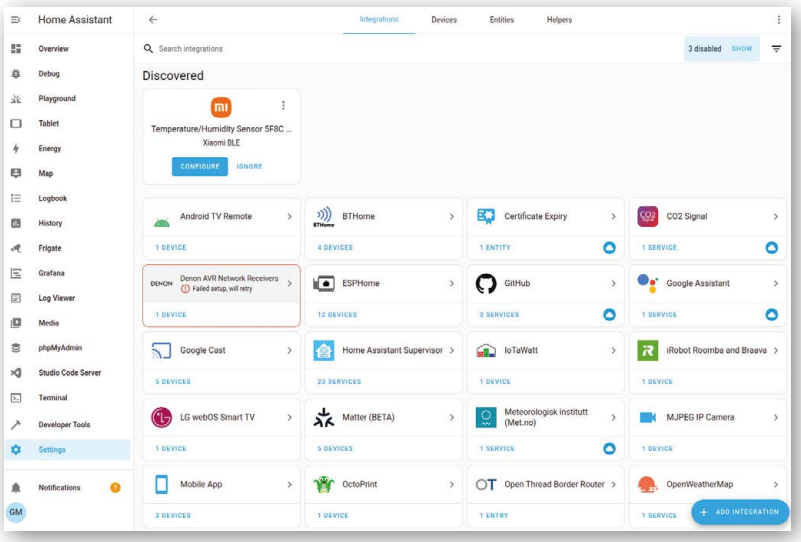
Automated automation

During the last stages of set up, Home Assistant will let you know what devices it has found on your network. It has access to a huge range of services and standards as you'd expect, and puts any found devices on your dashboard for you to configure further. This is accessible via a smartphone app or your browser, and there's an astonishing level of customisability in the software. From the use of general active triggers for actions (including voice control) to different passive 'scenes' that will, for example, automatically lower the lights when watching TV.

As this is positioned as a big hub on your network, you can also add plenty of other software services to it – such as Plex, Sonos, TOR, and a whole variety of extensions that you can easily add from the browser. The SSD slot will come in handy if you use the media server applications.

It's a fantastic piece of kit that we found very easy to use without sacrificing any of the nitty-gritty home automation tools you'd want to use to truly customise your home – to the point that it's inspired us to expand the amount of automated devices in our home.

The dashboard surfaces a lot of information so that you can perfectly tweak your home



PiDP-10

▶ Oscar Vermeulen / CEDS ▶ **magpi.cc/pidp10buy** ▶ From £296 / $370

SPECS

ASSEMBLY TIME
Approx six hours

DIMENSIONS
Approx 56w x 16h x 13d

POWER
Via Raspberry Pi

INTERFACES
HDMI, SSH, RS232

OPERATING SYSTEMS EMULATED
TOPS-10, ITS

Oscar Vermeulen is back with his most ambitious retro kit yet. **PJ Evans** returns to the space age

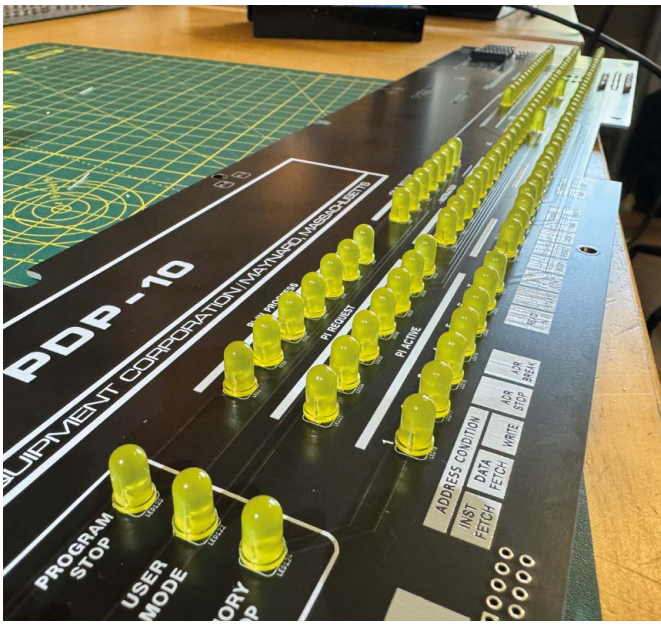


▲ The completed using is 56 cm wide as is an accurate 2/3rd scale reproduction of the original

Following on from his original PiDP-8 kit and the beautiful PiDP-11 Oscar Vermeulen now presents his latest DEC computer recreation: The PiDP-10. Despite the plaudits for his first two kits, Oscar has not rested on his laurels and this new offering is a bit special, not only for the history behind it, but also the sheer ambition of the recreation.

The original PDP-10, of which this is a two-thirds scale reproduction, found a place in the legend and folklore of early computing, mainly to the MIT AI lab, who's residents found the computer to be perfect for hacking about and creating things, amongst which was the first computer game, *SpaceWar!*

These are probably the largest PCBs you'll ever work on at home at around 50 cm long. They will eventually find themselves in a two-piece injection-molded case with a meticulously recreated lamp panel. The result is *2001*-esque. It'll be the best-looking computer in your collection.



▶ There are over 200 components that make up the kit. Patience is rewarded with nearly aligned lamps and switches

Assembly

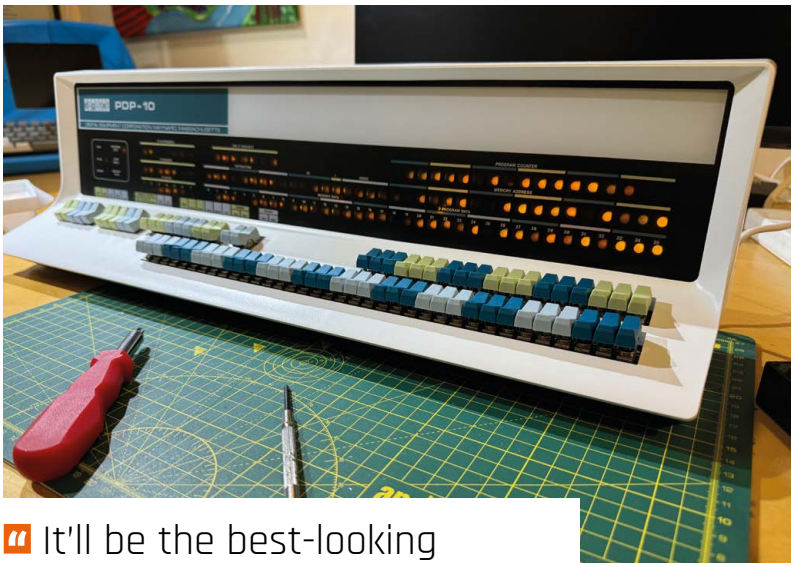
Assembling the kit is not for the impatient. It took your reviewer a total of about six hours over two days. What really made the assembly a pleasure is the solid online documentation, with lots of hints and tips, and a superbly notated PCB, ensuring the builder knows orientation of components at every step. Oscar has been generous with spares and even provided parts for mounting optional 'hacks'.

There are a lot of components to assemble, including over 120 LEDs and 74 switches. The kit is well within the capabilities of anyone who is confident with a soldering iron and there is no SMD soldering to worry about. Patience is a virtue here, and will be rewarded with neatly aligned LEDs and switch banks. Oscar has some great tips along the way to help you achieve a perfectly aligned lamp array.

To run everything Raspberry Pi 5 is recommended, mounted on the rear of the main PCB, but depending on what you want to do, you can go all the way down to a Zero 2 W. The kit comes with a number of optional hardware improvements, including cutouts and mounting points for RS232 adaptors and large cooling fans for an authentic sound.

Software

Once built, generous instructions for its use are provided. Software installation is straightforward, running on top of an existing Raspberry Pi OS install. You have the option of running DEC's own TOPS-10 OS or the more fun ITS from MIT. Documentation and lots of software make this a great tool for exploring computer history.



▲ Once completed, the builder is rewarded with an impressive light show

> "It'll be the best-looking computer in your collection"

A nice touch is the teleprinter software included (you'll need to use HDMI for this). You can also use SSH or even hook up an original terminal or teleprint via the optional RS232 interface. Care has been taken to ensure the main OS is not tampered with, so you can 'double duty' your Raspberry Pi if you wish.

The price may make you wince but this still represents good value for money. The time, care and effort put into the kit design, its instructions and provided software truly impressed us. Fun to build and rewarding to explore. A must for any retro computer enthusiast.



▲ The rear of the kit shows the well-ventilated Raspberry Pi and the optional fans

Verdict

A near-perfect execution of preserving computer history in a fun and creative way. Patience and a steady hand will reward you with an amazing experience and a beautiful object.

10/10

ArmPi FPV AI Vision

▶ HiWonder ▶ **magpi.cc/armpifpv** ▶ From £200 / $300

A sturdy robotic arm with computer vision for an impressive range of AI abilities. By **Phil King**

SPECS

FEATURES:
6DOF (including gripper), HD camera, breakout board, metal base and fittings

CONNECTIONS:
Breakout board screw terminals for power, JST connections for servos

SERVOS:
LX-255 (base) — 25kg torque; LX-15D — 17kg torque; Anti-blocking bus (gripper) — 8kg torque

DIMENSIONS/WEIGHT
277 × 177 × 428mm; 1.2kg



▶ Equipped with a wide-angle camera, the robotic arm has 6DOF including a strong gripper to pick up objects up to 500g in weight

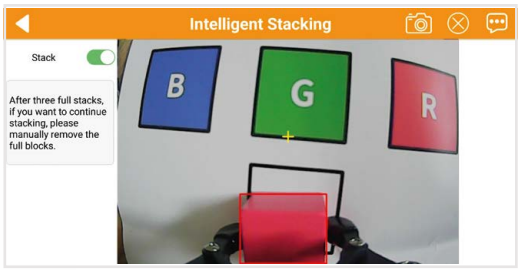
Verdict

Great value for money considering the sturdiness of the arm, built-in camera, and AI vision possibilities

9/10

Equipped with a camera, the ArmPi FPV is a capable robotic arm that uses AI computer vision to help it perform a range of tasks. The kit is available with or without Raspberry Pi 4 or 5 (4GB or 8GB RAM) included.

There are also three editions to choose from: Standard, Advanced and Developer. The Standard kit features the robotic arm, breakout board (one of two versions, for Raspberry Pi 4 or 5), power supply, paper 'map' (more on that later), coloured blocks, plain blocks, coloured balls, and tags. The Advanced kit adds a couple of flat-pack shelving units for 'warehousing' operations, while the Developer kit adds several extra sensors, a dot matrix display and a fan.



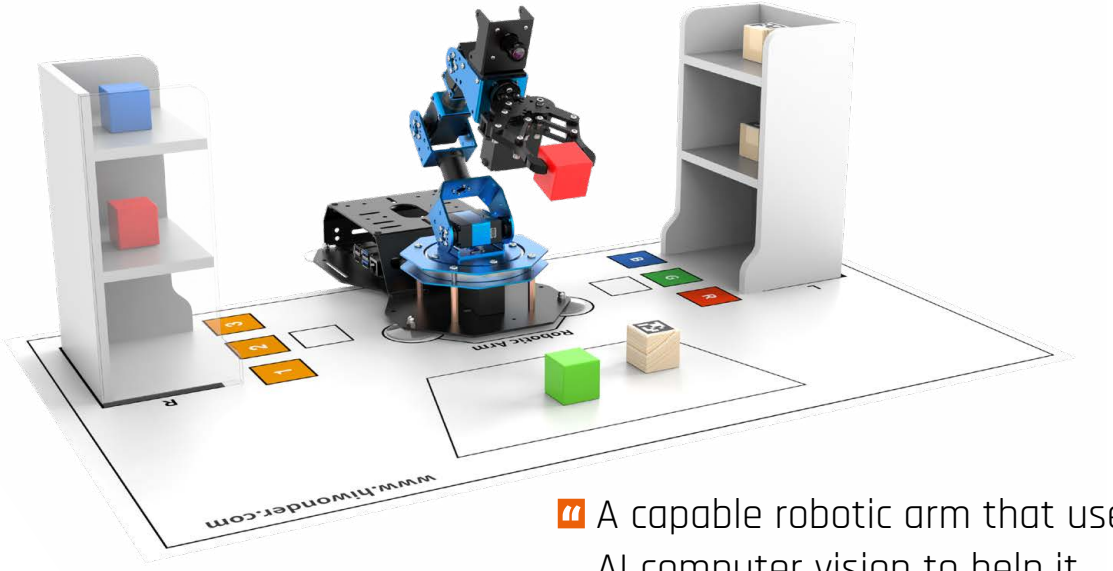
▲ Block-stacking makes use of computer vision and image recognition via Raspberry Pi

Strong arm

We tried out the Advanced kit with Raspberry Pi 5. The arm comes ready-assembled, sitting on a solid black metal base whose rear section holds Raspberry Pi, secured with screws and pillars. Four suction cups stick the base to a desk or the floor – not the most secure of methods – but the unit itself is very sturdy.

The breakout board is mounted on Raspberry Pi and wired from JST connectors to the arm, with some spare servo and SPI sockets. Power – for the arm and Raspberry Pi – is supplied from a 7.5V 6A DC PSU via a barrel adapter with two wires that fit into screw terminals on the breakout board.

The arm itself has six DOF (degrees of freedom) counting the gripper on the end of it, which can be rotated via a 'wrist'. The base servo enables the whole arm to rotate, while three vertical elbow joints, with anodised metal brackets, enable countless possible positions. The servos are of three types/sizes, each with 0.3° accuracy, 0–240° rotation range, and feedback for angle read, temperature, voltage and position. Arm movement is reasonably smooth, and not particularly noisy.



▲ The ArmPi FPV comes with a paper 'map' with block and stacking zones for AI tasks, plus optional shelves for warehousing

> A capable robotic arm that uses AI computer vision to help it perform a range of tasks

A view to a thrill

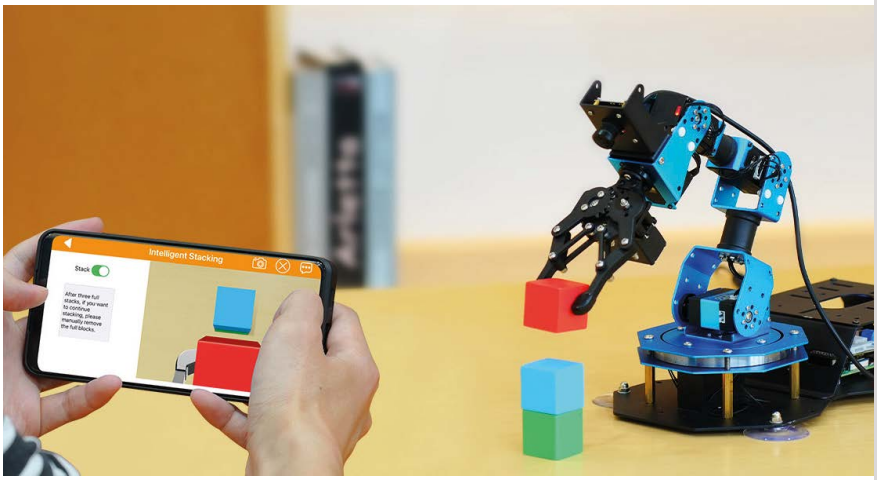
Mounted just behind the gripper, the HD camera offers a wide-angle 120° view. It's connected by a long, loose cable to one of Raspberry Pi's USB ports, with no clips to secure it to the arm, although it does pass through a cutout in the metal base.

The camera is the key to the arm's AI abilities. The simplest way to try these out is with the WonderPi smartphone app (iOS or Android). Once your phone is connected to the arm's automatic Wi-Fi hotspot, you can use the app to control it remotely. The gripper, wrist, and base servos are adjusted by pressing on-screen arrows, while the others are controlled by dragging them on a graphic of the arm.

The app's AI modes are where the fun really starts. Item tracking sees the arm move to track an object of the chosen colour (red, green, or blue) held in your hand. Face recognition is self-explanatory, resulting in a gripper 'wave' to say hello. Item sorting and stacking modes see the arm pick up coloured (or tagged) blocks in turn and either place them on the correct squares on the paper map, or stacked up on a blank square. It's impressive to watch in action and the app gives you an FPV camera view. If you have the optional shelf units, you can get it to do warehousing, delivering, and transferring tasks.

The app is just a showcase for the arm's capabilities, however: a starting point. By following an extensive array of online tutorials, you'll learn how to program it with Python, use OpenCV for image recognition, employ ROS (Robot Operating System) and MoveIt motion planning, use inverse kinematics to reach a desired arm position, and much more.

▼ A smartphone app enables manual remote control and an array of fun AI modes such as block-stacking



Plasma 2350

▶ Pimoroni ▶ **magpi.cc/plasma2350** ▶ From £12 / $13

An LED strip controller with even more processing power. By **Phil King**

SPECS

FEATURES:
RP2350A processor; Boot, Reset, and user buttons; on-board RGB LED

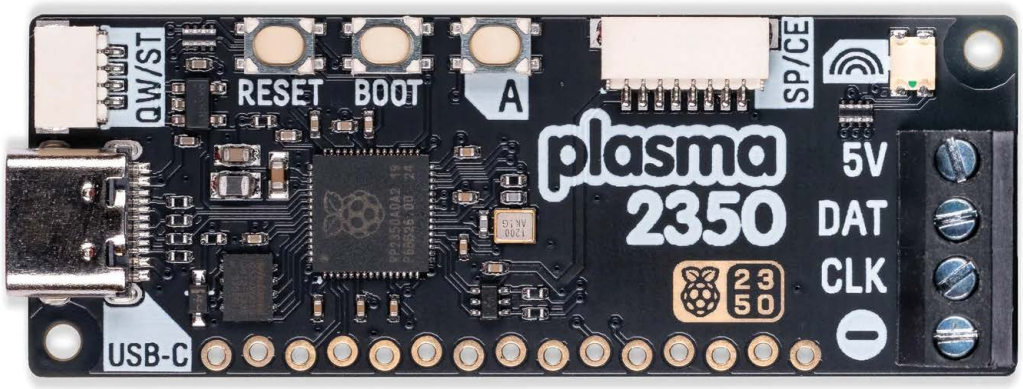
LED COMPATIBILITY:
5V WS2812/NeoPixel, APA102/DotStar

CONNECTIONS:
4 × screw terminals, USB-C port for power/programming, Qwiic/STEMMA QT, SP/CE, unpopulated 15-pin GPIO header

Verdict

An easy way to control NeoPixel/DotStar LED strings with programmable effects, with extra processing power if you need it.

9/10



▲ Only slightly longer than a Raspberry Pi Pico 2, the Plasma 2350 makes use of the same microcontroller chip for fast processing and flicker-free lighting

▶ The Starter Kit includes a 10m string of frosted RGB LED stars that showcase the Plasma 2350's capabilities with some eye-catching effects

Featuring the same RP2350 microcontroller chip as Raspberry Pi Pico 2, the Plasma 2350 can illuminate strings of 5V WS2812/NeoPixel or APA102/DotStar individually addressable RGB LEDs with some eye-catching lighting effects.

Based on a Dual Arm Cortex M33 running at up to 150MHz with 520kB SRAM, the processor is a major upgrade on the RP2040 used in previous Pimoroni products such as the Plasma 2040 and Plasma Stick 2040 W. While lighting LEDs isn't the most demanding of tasks, the extra processing power may come in useful for more advanced projects linked to breakout boards. There's double the amount of QSPI flash storage (4MB) to play with, too.

You can buy the Plasma 2350 board on its own or in a Starter Kit (£34.50 / $38) with a USB-A to USB-C cable and 10m string of 66 individually addressable frosted LED stars. These look superb when lit up, and are a great way of showcasing the capabilities of the Plasma 2350. We also tried out a long 300-LED strip and there was easily enough current (up to 3A) from the USB-C power connection to light them all.

Wired for light

Connecting your LED string or strip to the board is simple. As on the Plasma 2040, there are four screw terminals on one end: for 5V power, data, clock, and ground. While WS2812/NeoPixel LED strips have only three wires, omitting the clock

connection, the latter is needed for DotStar LEDs. A little care needs to be taken to make sure each wire is in the correct terminal and that they're screwed securely.

Despite coming in a slimmer 'gum stick' form factor than the Plasma RP2040, the board manages to cram in many useful features. There's an unpopulated header down one long edge to break out selected GPIO pins, offering access to UART and I2C interfaces, along with analogue inputs, PWM outputs, and PIO state machines. There's also a Qwiic/STEMMA QT connector for breakout boards, as well as Pimoroni's new proprietary SP/CE (Serial Peripheral / Connector Evolution) port – an eight-pin JST-PH connector including four pins for SPI.

> Impressive lighting effects include blinkies, sparkles, snowfall, fire, pulsing and a lovely rainbow

Buttons for everything

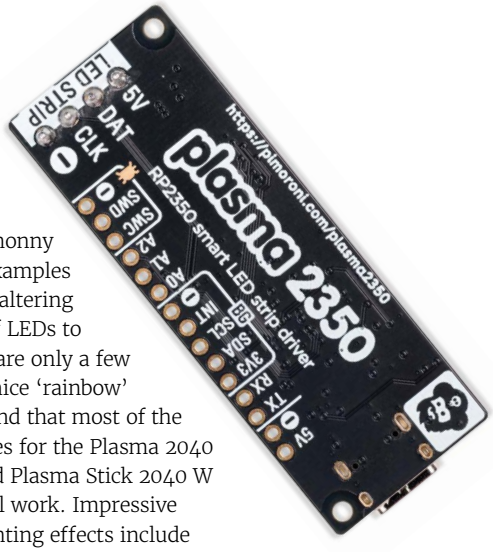
One slight downside of the SP/CE's inclusion is that there's no room for a B user button next to the A one (as on the Plasma 2040), although the Boot button doubles as a user input. There's also a handy Reset button, to save repeatedly disconnecting and connecting the USB-C power. An on-board RGB LED is a nice touch, too.



Before you can start programming some light patterns, you'll need to install MicroPython. In its RP2350 GitHub repo (**magpi.cc/pimoroni2350gh**), Pimoroni provides a custom UF2 file for the Plasma 2350. To install it, connect the board to your computer via USB while holding the Boot button, to mount it as a drive, then drag the file over to it. Alternatively, if you prefer CircuitPython, with which you can utilise Adafruit's excellent LED Animation library, there's also a UF2 image for that: **magpi.cc/plasma2350cp**.

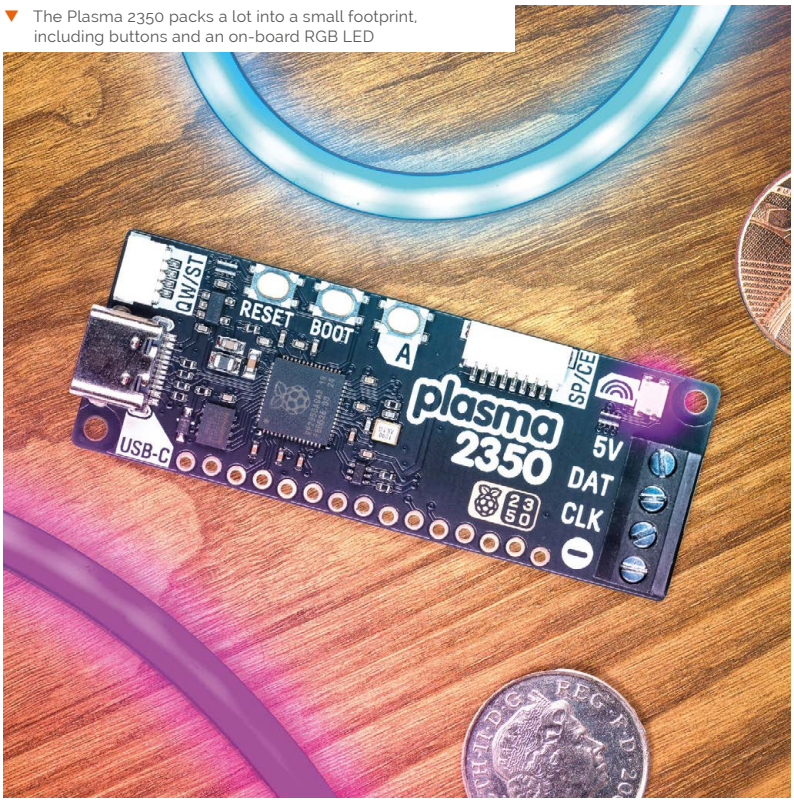
Using MicroPython in the Thonny IDE, we tried out some code examples from Pimoroni's GitHub repo, altering the constant for the number of LEDs to match our string. While there are only a few examples there – including a nice 'rainbow' colour-cycling effect – we found that most of the ones for the Plasma 2040 and Plasma Stick 2040 W still work. Impressive lighting effects include alternating/random blinkies, sparkles, snowfall, fire, pulsing and a lovely rainbow sweeping across the string of LEDs.

Since the Plasma 2350 lacks on-board Wi-Fi, you can't get your LEDs to react to data from the network, but you could always connect a breakout input such as a temperature sensor



▲ The rear of the Plasma 2350 board, showing helpful labels for the LED strip screw terminals and unpopulated GPIO header

▼ The Plasma 2350 packs a lot into a small footprint, including buttons and an on-board RGB LED



PiDog

▶ SunFounder ▶ **magpi.cc/pidog** ▶ £157 / $180

A smart robotic dog packed with features and possibilities. By **Phil King**

SPECS

FEATURES:
12 × metal-gear servos, Robot HAT, camera module, RGB LED strip

SENSORS:
Sound direction, 6-DOF IMU, dual touch, ultrasonic distance

WORKS WITH:
Raspberry Pi 4, 3B+, 3B, Zero 2 W

POWER:
USC-C, rechargeable 2×18650 battery pack

Powered by a Raspberry Pi (not included) and featuring 12 servos, PiDog is a metal marvel that can do (almost) anything a real dog can do. Walk, sit, lie down, doze, bark, howl, pant, scratch, shake a paw…

Equipped with a bunch of sensors, it can self-balance, discern the direction of sounds, detect obstacles, and see where it's going. You can even get a dog's-eye view from its nose-mounted camera via a web page or companion app.

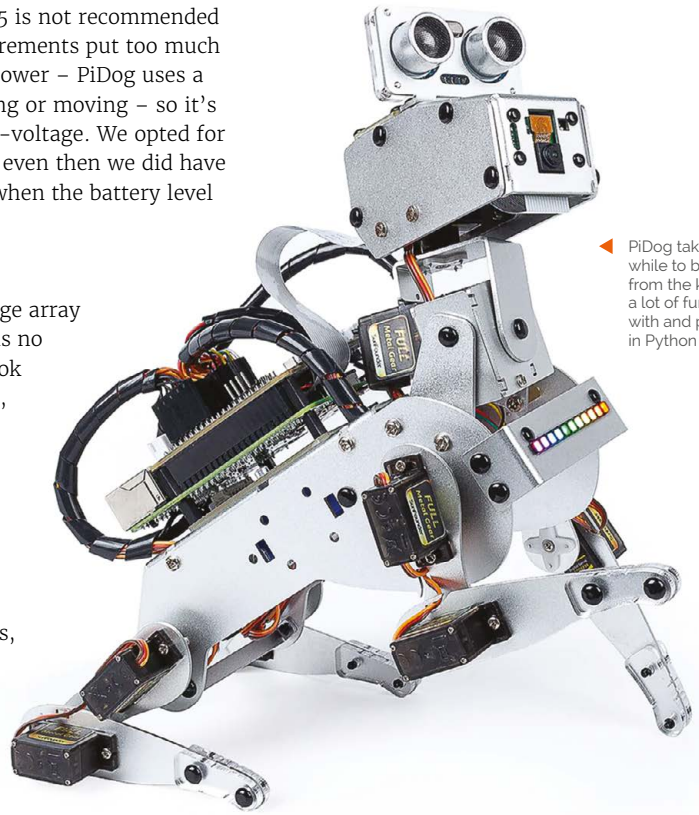
The first thing to decide is which Raspberry Pi model to use before assembling the kit. PiDog will work with Raspberry Pi 4, 3B+, 3B, and Zero 2 W. Using a Raspberry Pi 5 is not recommended since its extra power requirements put too much of a strain on the battery power – PiDog uses a lot of current when standing or moving – so it's likely to suffer from under-voltage. We opted for a Raspberry Pi 4, although even then we did have a few issues with crashes when the battery level was low.

Canine construction

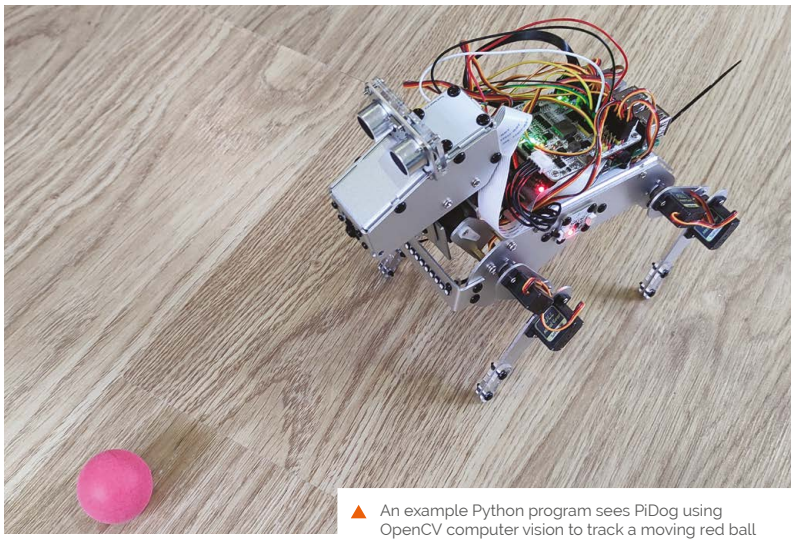
With a kit comprising a huge array of parts, building a PiDog is no mean feat. We reckon it took us around five to six hours, although we were taking our time to get it right. The printed diagram-based instructions are easy to follow, however, and there are online videos if you get stuck. Apart from a few fiddly bits, including manipulating some tiny screws and nuts, it's an enjoyable process. Helpfully, the fixtures and fittings – including numerous sizes of screws and plastic rivets – come in labelled bags. The kit includes a couple of screwdrivers too.

The main chassis is built from aluminium alloy panels, giving this dog a shiny and robust 'coat'. There are also several acrylic pieces, including some to build a stand to place PiDog on when calibrating its leg servos. A nice touch.

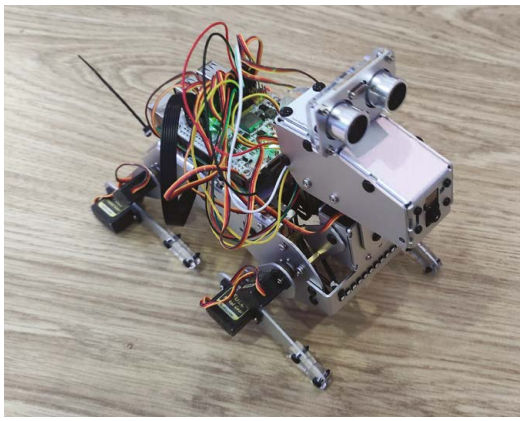
Raspberry Pi sits on a sound direction sensor module and is then mounted with a Robot HAT which handles all the servos (via PWM pins), sensor inputs, and battery management. Portable



PiDog takes a while to build from the kit, but is a lot of fun to play with and program in Python



▲ An example Python program sees PiDog using OpenCV computer vision to track a moving red ball



▲ You'll end up with spaghetti wiring into the Robot HAT, but can use the supplied spiral binding to tidy it up a bit

power is supplied by a custom battery pack comprising two 18650 batteries with a capacity of 2000mAh, which takes a couple of hours to charge fully.

Doggy-do code

Once you've assembled the kit, it's time to fine-tune the calibration of the servos with a script. You'll have used a zeroing script during assembly to get the rough positions right, so will have already installed the PiDog libraries and software in Raspberry Pi OS.

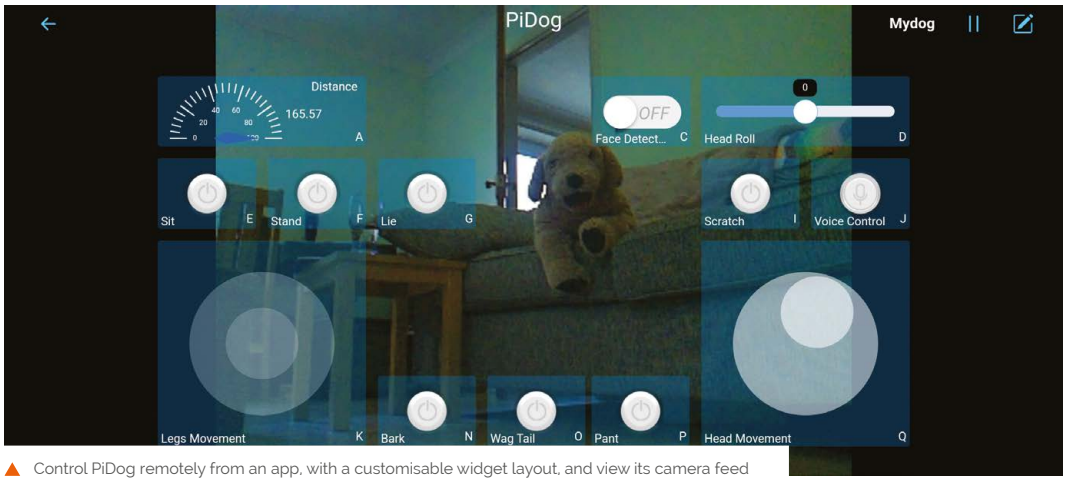
Detailed online documentation guides you through everything, including running a script to enable I2S sound from the robot's speaker. It also covers a good range of Python example programs that showcase what PiDog can do.

In patrol mode, for instance, PiDog walks forward and stops to bark when it detects something ahead. The react demo sees it rear up and bark when approached from the front, but roll its head and wag its tail when you pet the touch sensor on its neck. There's also a balance demo to showcase its 6DOF IMU module that enables PiDog to self-balance when walking on a tilting tabletop.

There are a few examples using the camera module with OpenCV computer vision. A face-tracking demo generates a web server, enabling you to see the camera view on a web page. There's also the option to control PiDog with an iOS or Android app, complete with live camera feed.

> You can even communicate with your PiDog via GPT-4o AI, using text or spoken commands

You can even communicate with your PiDog via GPT-4o AI, using text or spoken commands – with a USB mic (not supplied) equipped. It takes a bit of setting up, using an API key, but the online guide takes you through the process.



▲ Control PiDog remotely from an app, with a customisable widget layout, and view its camera feed

Verdict

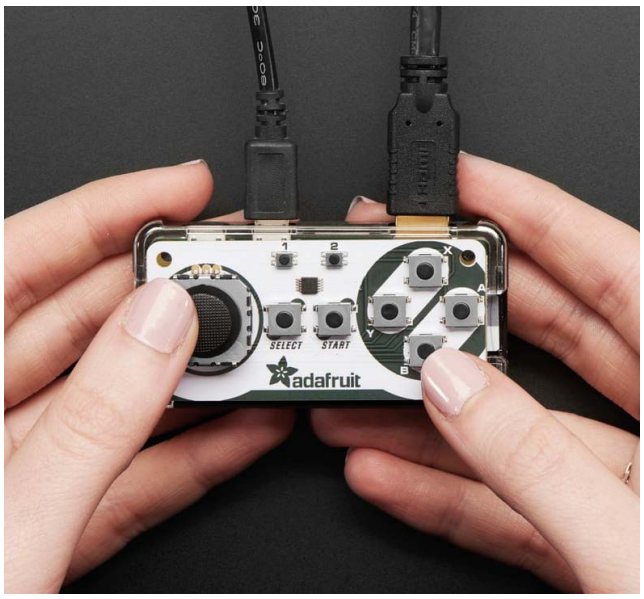
Great fun to play with, this smart canine companion has an impressive feature set and lots of possibilities for further training.

9/10

10 amazing: Gaming accessories

Enjoy your Raspberry Pi games more with these excellent upgrades

We meet a lot of people who use Raspberry Pi for gaming. Whether on the go or in their living room, there's so many ways to play with Raspberry Pi and even Pico. We've put together a list of some items that are sure to improve your experience.

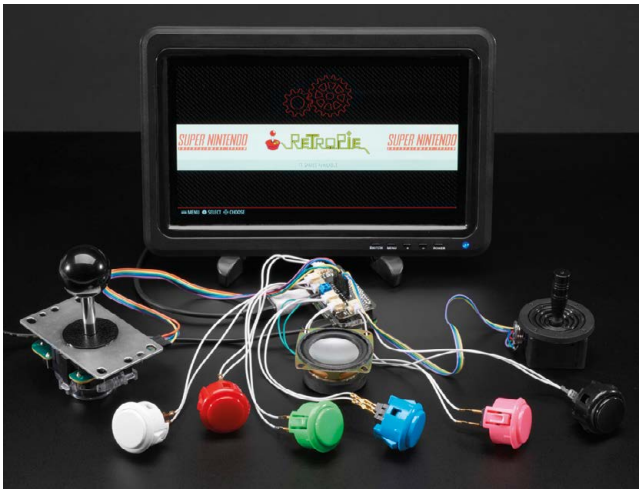


▲ Adafruit Joy Bonnet

Miniature console

Turn your Raspberry Pi Zero into the tiniest plug-and-play console ever – all you need is a screen to plug it into!

magpi.cc/joybonnet | £12 / $15



▲ Adafruit Arcade Bonnet

Stripped down arcade

Create a small yet powerful arcade machine out of Raspberry Pi Zero with this minimalist add-on for JST connectors

magpi.cc/arcbonnet | £12 / $15



◀ Pico Dongle Lite

Custom input

If you've made custom input devices for games with a Pico, this is another great way to interface that Pico with the device you're gaming on

magpi.cc/picodongle | £2 / $3

▼ Game 5Pi Retro Gaming Case

Classic enclosure

Upgraded to the latest Raspberry Pi 5 but still want to rock a retro case? Game 5Pi allows you to sneakily camouflage your Raspberry Pi 5 as something resembling a NES. It also comes with a heat sink fan kit.

magpi.cc/game5pi | £17 / $21





▲ Classic wired joypad

Nostalgic control

Sometimes the best way to play old games is with a controller you remember. No fancy analogue sticks, just eight buttons and a D-pad

magpi.cc/classicpad | £14 / $17

▼ PiStation Case + LCD



Portable console

A throwback to the '90s, this console-plus-screen combo is definitely more powerful than the machine it's emulating, but that just makes it cooler

magpi.cc/pistation | £81 / $101



◀ 8BitDo Wireless Adapter 2

Wireless gaming

Connect all manner of Bluetooth controllers to your older Raspberry Pi (or any other system!) thanks to this powerful dongle – it also supports gyro controls

magpi.cc/8bitdongle | £19 / $24



▼ GPi Case 2

Handheld power

This case turns your Raspberry Pi into a handheld console that feels like a top quality official product. Very little assembly required too!

magpi.cc/gpicase2 | £69 / $94

▼ 8BitDo Pro 2 controller

Wireless gaming

Our favourite retro-styled controller got even better with the Pro 2. Not only will it sync with a Raspberry Pi but also your Nintendo Switch too

magpi.cc/pro2 | £42 / $52



▼ Picade X HAT

Arcade heart

If you're planning to build an arcade based on Raspberry Pi, the Picade X HAT is the ultimate way to connect it all together

magpi.cc/picadex | £16 / $20



10 Amazing:

Raspberry Pi festive light projects

Light up your home this holiday season with a little help from Raspberry Pi

Whether you celebrate Christmas, Yule, Hannukah, Festivus, or anything else during December, there's plenty of ways to decorate your home this festive season. We've got a selection of ten amazing light projects to help inspire you along the way.



▲ Raspberry Pi Fireplace Emulator

No chestnut roasting

Unable to build a real fireplace, maker Peinador decided to make their own out of a Raspberry Pi and an LED matrix. It's not as warm but it's just as festive.

magpi.cc/fireplace



▲ NeoPixel Menorah

No oil needed

Celebrate the nights of Hannukah without needing candles permanently lit in your home. Just press the button to light the next candle each night.

magpi.cc/neomenorah



◀ Christmas Tree Lights 1

Simple NeoPixel tree

The simplest way to create Christmas tree lights with Raspberry Pi – and it even makes use of Node-RED for the code block enjoyers.

magpi.cc/treelights1

▼ Johnson Family Christmas Light Show

Garden display

This very custom lightshow changed many times over the years but always lit up in sync with the music, and you could listen in on your radio.

magpi.cc/johnsonlights





Holiday Light Show

House display

A slightly simpler but no-less spectacular way of creating a music-synced light show for your home – it uses very few components too.

magpi.cc/holidaylightshow



Christmas Tree Lights 2

Festive Energenie automation

Automating your Raspberry Pi-powered Christmas tree lights couldn't be easier with an Energenie and Pi-mote, as Stewart Watkiss shows us.

magpi.cc/treelights2

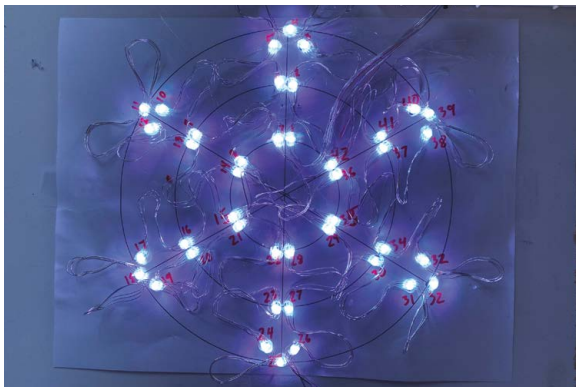
Cheap LED display matrix

Lights on a budget

From a distance you don't need a dense concentration of LEDs – with just 96 you can create excellent festive matrix that can display colourful low-res animations.

magpi.cc/cheapled





LED snowflake

Non-denominational decoration

This simple project from Codeacademy is mostly code and a lot of LEDs, but it's a cool decoration to put behind a window.

magpi.cc/ledsnowflake



Audio Reactive Holiday Lights

Fa-lah-lah-LED

Having your lights react to your Christmas songs is a great way to make the festive atmosphere much more immersive.

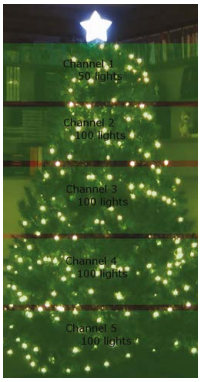
magpi.cc/audiolights

Christmas Tree Lights 3

Tree light show

This tree light show goes the extra step and has lights that flash to the music. Be extra careful if you attempt this build though – it uses relays and mains power. We suggest integrating the code into a similar project.

magpi.cc/treelights3

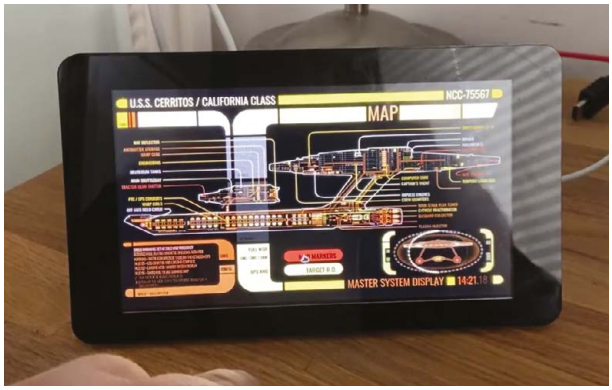


10 Amazing:

Raspberry Pi monitor projects

Use a screen and Raspberry Pi to do incredible things

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



▲ PiRitos

Cali-class LCARS

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

magpi.cc/piritos



▲ PC resource monitor

Gaming gauges

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

magpi.cc/resourcemon



◂ Possessed Portrait

Halloween horrors

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

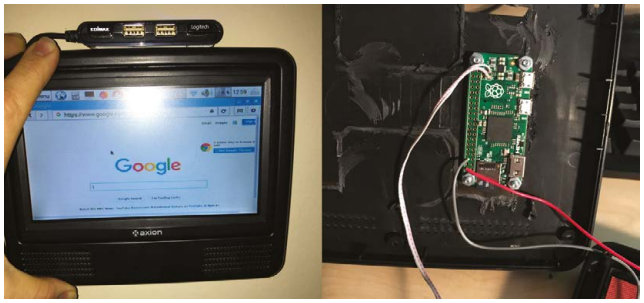
magpi.cc/possessedpic

▼ Raspberry Pi Zero Recipe Kiosk

Kitchen komputer

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

magpi.cc/recipekiosk





Digital information screen

Data kiosk

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

magpi.cc/digiinfo

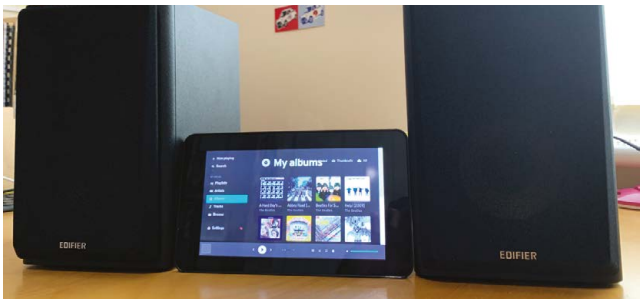
Train time display



Departures and delays

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

magpi.cc/traintimes



Home music system

See your songs

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

magpi.cc/homemusic



Home automation

Home health

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

home-assistant.io



Alternative flight simulator

Window browsing

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

magpi.cc/alexairvideo

Magic Mirror

Vanity project

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

magicmirror.builders




PROJECTS FOR MAKERS & HACKERS
BUILD A CUSTOM KEYBOARD WITH RASPBERRY PI PICO
CUSTOM CONTROLS WITH A 3D PRINTED BIG BUTTON
BOOK OF
MAKING
2026
CONTROL PROGRAMMABLE LEDS FOR DAZZLING LIGHTING
EVERYTHING YOU NEED TO KNOW ABOUT BATTERY POWER
FROM THE MAKERS OF RASPBERRY PI OFFICIAL MAGAZINE

BOOK OF MAKING 2026

STEP INTO THE WORLD OF MAKING!





- DISCOVER YOUR NEW FAVOURITE HOBBY
- LEARN THE DIGITAL SKILLS THAT MAKE THE WORLD GO ROUND
- TRY YOUR HAND AT 3D PRINTING, ELECTRONICS, PROGRAMMING, AND MORE
- DISCOVER PROJECTS THAT YOU CAN DO IN AN HOUR, AFTERNOON, OR WEEKEND

rpimag.co/BookOfMaking2026

The official

Raspberry Pi Handbook

2026

Dive into the world of Raspberry Pi with this huge book of tutorials, project showcases, guides, product reviews, and much more!

Raspberry Pi 500 and Raspberry Pi 500+ are here, taking Raspberry Pi to new heights. It's the power of Raspberry Pi 5 in a full desktop experience and we have all the specs and details.

That's not all - we have plenty of Raspberry Pi Pico 2, Raspberry Pi Zero 2, Raspberry Pi 5, and Raspberry Pi 4/400 content squeezed into the book as well. There's something for every user.



200 PAGES OF RASPBERRY PI

Get started guide covering every Raspberry Pi

Everything you need to know about the brand new Raspberry Pi 500+

Inspiring projects to give you your next project idea

Build a Raspberry Pi 5-powered media player

Explore the world around you with roving robots

Play retro horror games on Raspberry Pi 5

Raspberry Pi PRESS

raspberrypi.com

ISBN 978-1-916868-48-9

UK £14
US $24.99