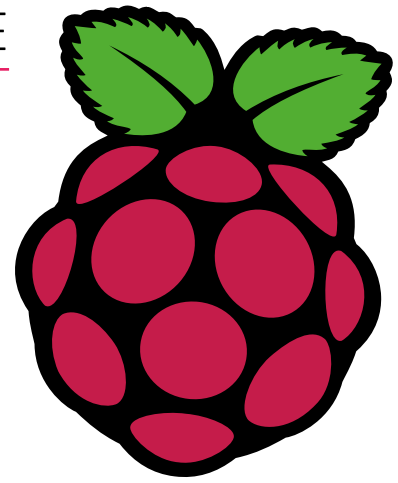




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Issue 101 | January 2021 | magpi.cc

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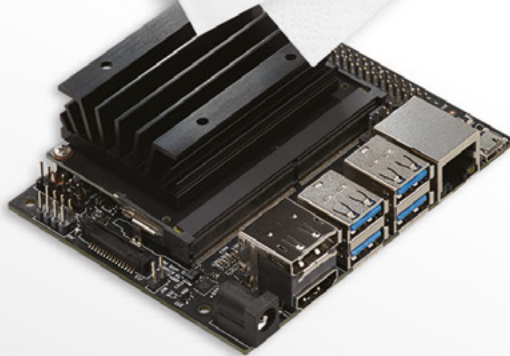
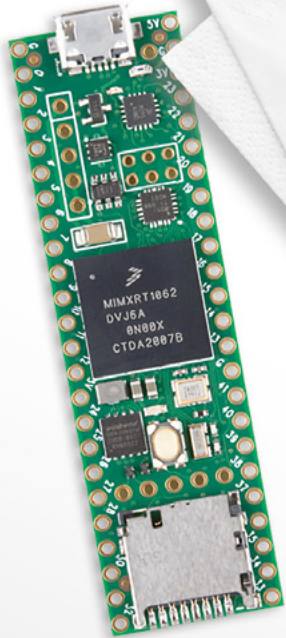
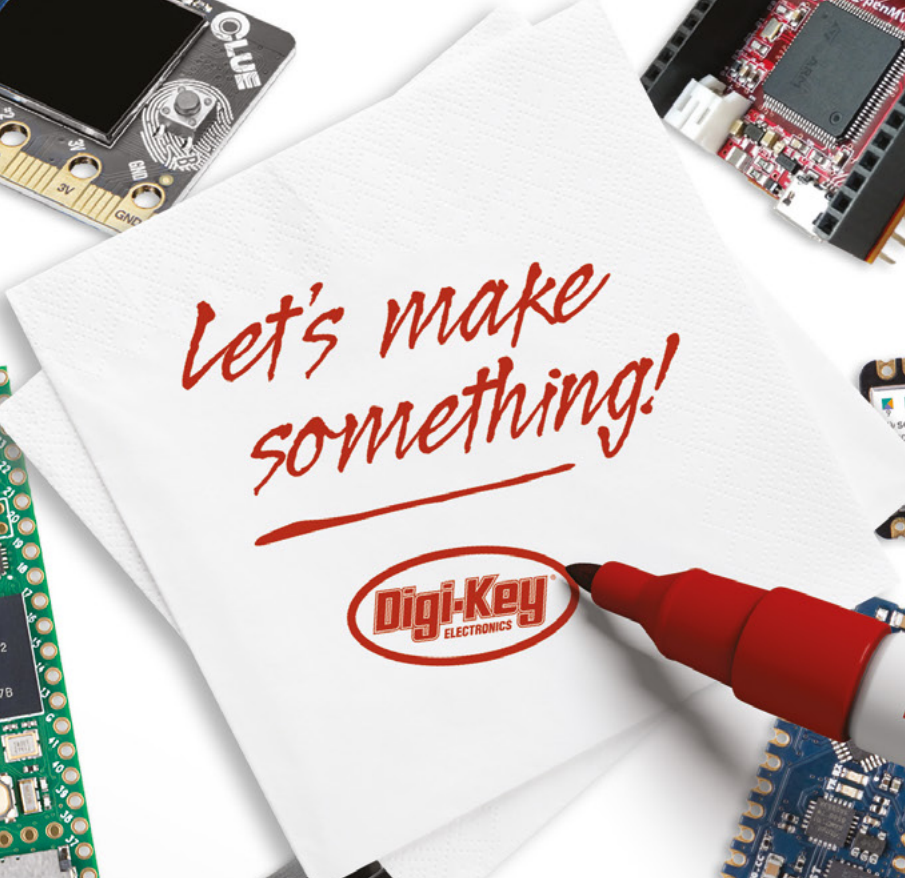
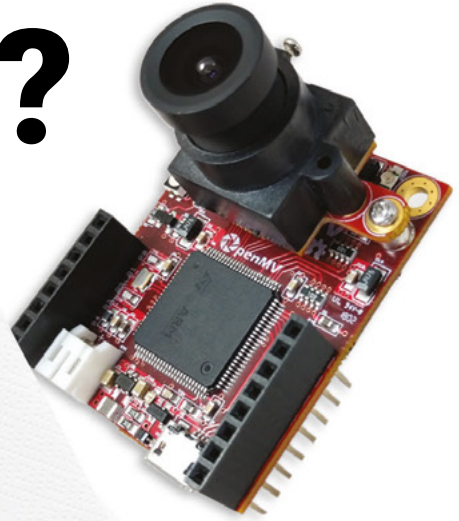
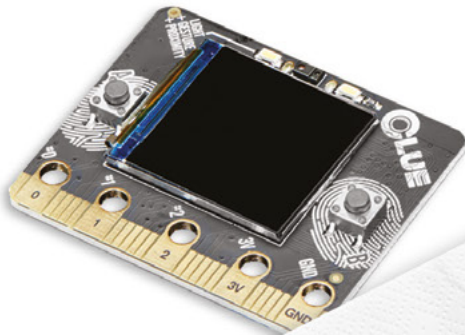
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to *The MagPi* 101

Raspberry Pi 400 is the most exciting computer released in years. Packed with a 1.8GHz ARM processor and running Raspberry Pi OS, it's a capable work machine that's just bursting with potential. It doesn't matter if you want an ultra-light computer for office work, a powerful coding and development tool, or a handy electronics workstation for your lab: Raspberry Pi 400 is the all-in-one that does it all.

So where to start? Our Raspberry Pi 400 Projects and Guides feature (page 36) is packed with advice to help you on the way. Whether you're looking for a light Linux desktop or want to explore electronics, we've got the information you need.

If you are absolutely new to Raspberry Pi, you'll find our QuickStart guide on page 46; and if you're looking for a first-rate electronics tutorial, then hook up an old DB9 retro joystick to Raspberry Pi 400 (page 52). There's also a fantastic guide to using Raspberry Pi for arts and crafts (page 72) this month. All that's on top of some of the best Raspberry Pi projects around. Who would have thought you could cook food with a Raspberry Pi robot (page 22)?

This issue is packed with information for Raspberry Pi newcomers and seasoned hands alike. So jump in and discover something wonderful to make.

Lucy Hattersley Editor



EDITOR

Lucy Hattersley

Lucy has the biggest bottle of champers she's ever seen and absolutely no idea what to do with it. Hope you all enjoy the holidays.

@LucyHattersley





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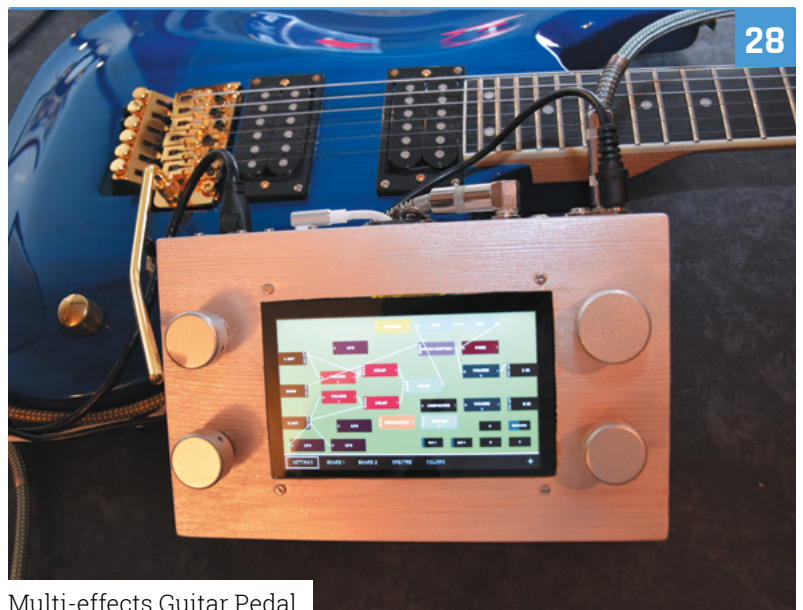
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OnionBot Sous Chef



Multi-effects Guitar Pedal

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DB9 joystick on Raspberry Pi 400



Build a Home Assistant: part 3

The Big Feature



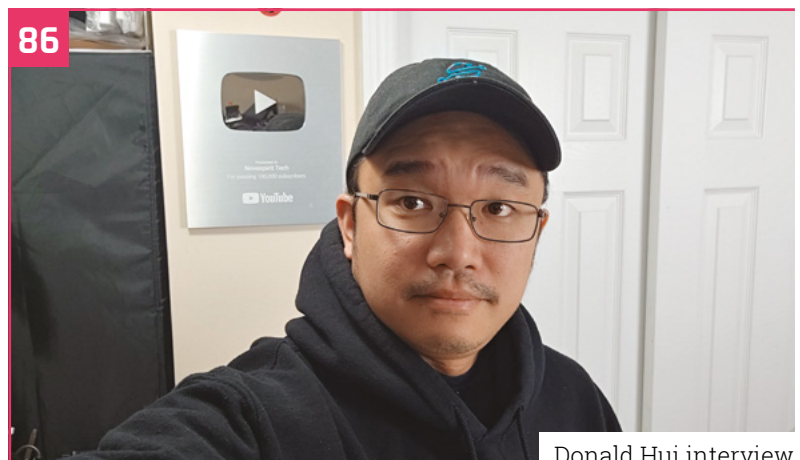
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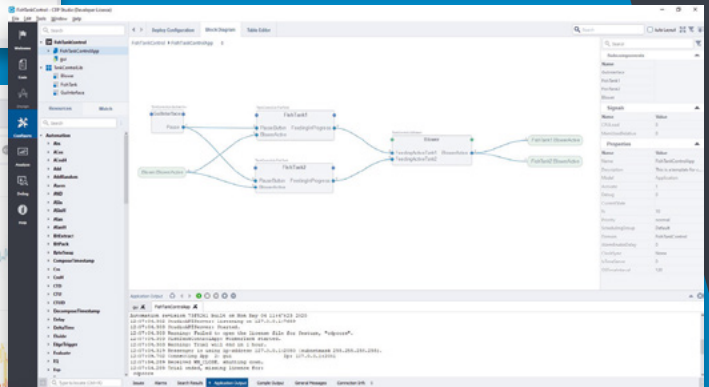
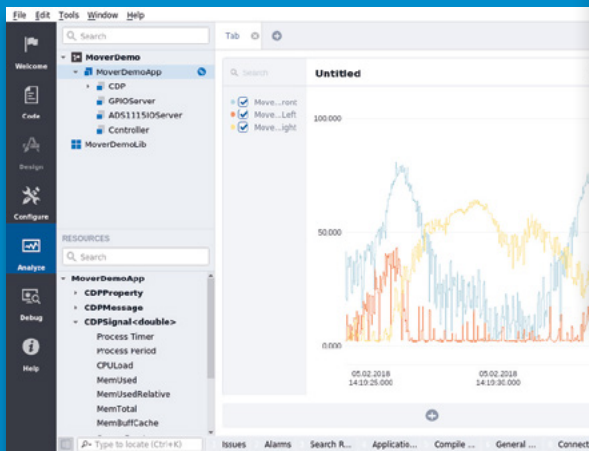
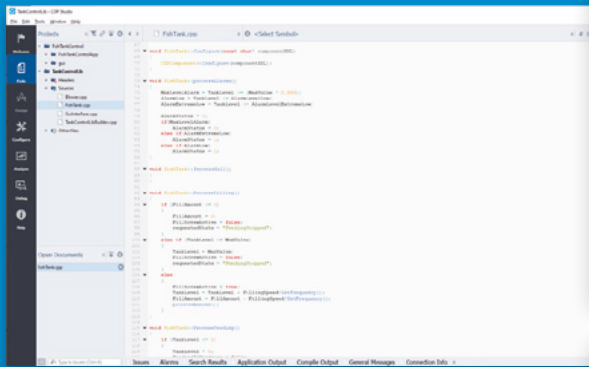
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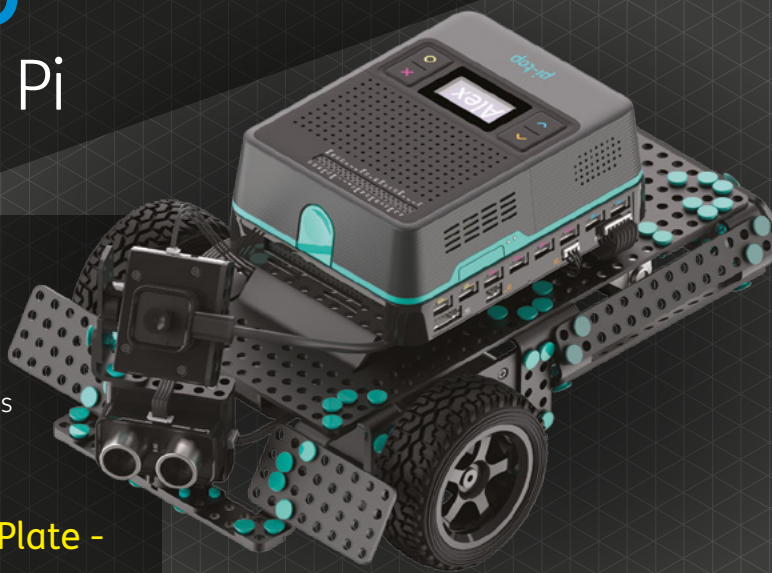
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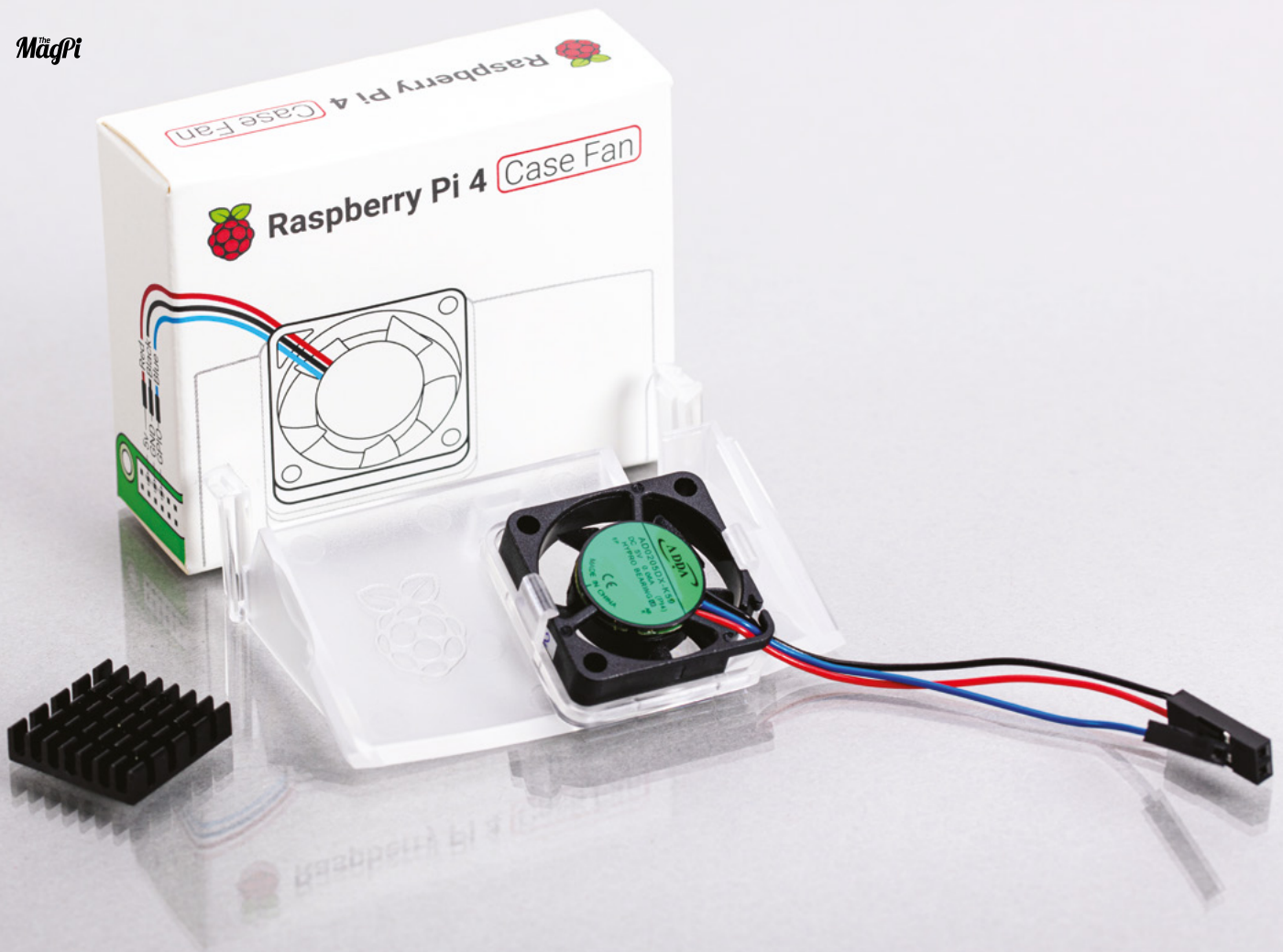
Emotion Mapping



Interaction

Raspberry Pi is a trademark of the Raspberry Pi Foundation.*Not photoshopped. We really did make a pi-top drone! †pi-top [4], Expansion Plate and Robotics Kit sold separately.

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Raspberry Pi 4 Case Fan released

Add extra cooling to Raspberry Pi 4 with this accessory for the official case, reports **Rob Zwetsloot**

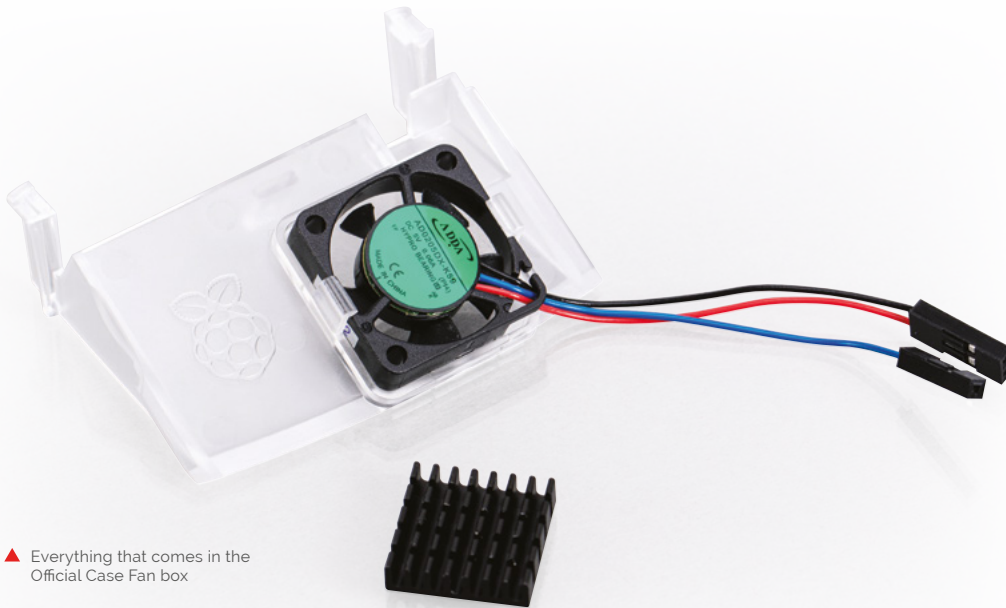
Since Raspberry Pi 4's launch in June 2019, improvements to the thermal efficiency of the CPU through numerous firmware updates have helped reduce the heat output of this Raspberry Pi model (see more details on this in *The MagPi* #88, magpi.cc/88). Some folks still like to add their own thermal management as well, such as heatsinks and active case fan cooling. However, there hasn't been anything for the official case – until now.

The Raspberry Pi 4 Case Fan (magpi.cc/casefan) is a brand new official product for the official case of Raspberry Pi 4 that gives a huge active cooling boost, perfect for those folks really pushing the limits of what Raspberry Pi 4 can do.

Installing the Case Fan is very easy – it comes as one piece that clips into the top of the official Raspberry Pi 4 case, and a trio of flying jumper leads are then plugged into specific GPIO pins to power it. There's even an included heatsink if you really want to help heat escape from the CPU. This does mean it only currently works with a Raspberry Pi 4 case, though.

Cool down

How does it work? Well, the fan draws in air through gaps in the Ethernet and USB port holes which then moves over the heatsink. The extra surface area that the heatsink adds to the CPU allows for more heat to be transferred into the



▲ Everything that comes in the Official Case Fan box

air. This heated air then vents out of gaps around the microSD card slot, allowing more cool air from outside to come in.

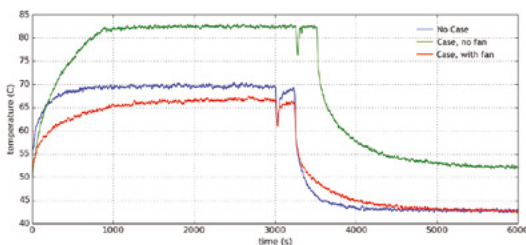
Tests have shown that this completely negates the effect on internal heating that the case causes (see **Figure 1**), with temperatures returning to the much cooler levels normally seen from a naked Raspberry Pi 4 board – albeit now with more protection from the elements.

“There’s even an included heatsink if you really want to help heat escape from the CPU”

Where to get it

The Case Fan is available right now for only \$5 from Raspberry Pi Approved Resellers such as Pimoroni, The Pi Hut, and Adafruit (find a full list on the product page: magpi.cc/casefan). It’s also available from the Raspberry Pi Store in Cambridge, but check in advance whether it’s open or operating as click and collect.

As Eben says, it’s a great stocking-filler for fans of Raspberry Pi in your life.



▲ **Figure 1** Temperature change over time with and without the case fan installed, compared to a Raspberry Pi 4 without a case

Speed holes



Concerned that you may need more air flow in the case? While designing the case, Gordon Hollingworth, Director of Software Engineering at Raspberry Pi Trading, tested it out and found it wasn’t essential. “After running the tests with additional holes in both the lid and the base, I concluded the issue wasn’t really getting air unrestricted in and out of the case (although the holes did make a small difference),” Gordon wrote on a blog post regarding its design: magpi.cc/casefandesign.

So if you do fancy drilling some small ventilation holes into the case, feel free but a) be careful and b) don’t expect it to do much.



BOSEBerry Pi



David Hunt

A radio enthusiast and lecturer who has been playing with radios since a young age.

magpi.cc/boseberrypi

Upcycling and recycling is a great way to keep an aesthetic while making use of updated tech. **Rob Zwetsloot** listens in on this latest effort

“I use my radio daily,” David Hunt, creator of BOSEBerry Pi tells us. “It informs me of world news as I have my breakfast, keeps me company on a long car drive, and provides some background noise as I am tinkering away on a new project in my workshop.”

David has been a radio enthusiast since he was a kid, and was wrestling with a DAB radio in his kitchen with spotty reception.

“I thought it might be time to replace this radio and started to wonder if I could build my own connected to the internet,” he explains. “I know this can easily be achieved using a smart

speaker setup, but I wanted a radio that just played radio stations. In support of the United Nations sustainable development goal (magpi.cc/un12) which aims for sustainable consumption, I decided to reuse a traditional radio and build my own system inside it.”

During David’s search for a suitable radio housing, he came across old BOSE SoundDocks (from the days where iPod docks were all the rage) which were listed as faulty.

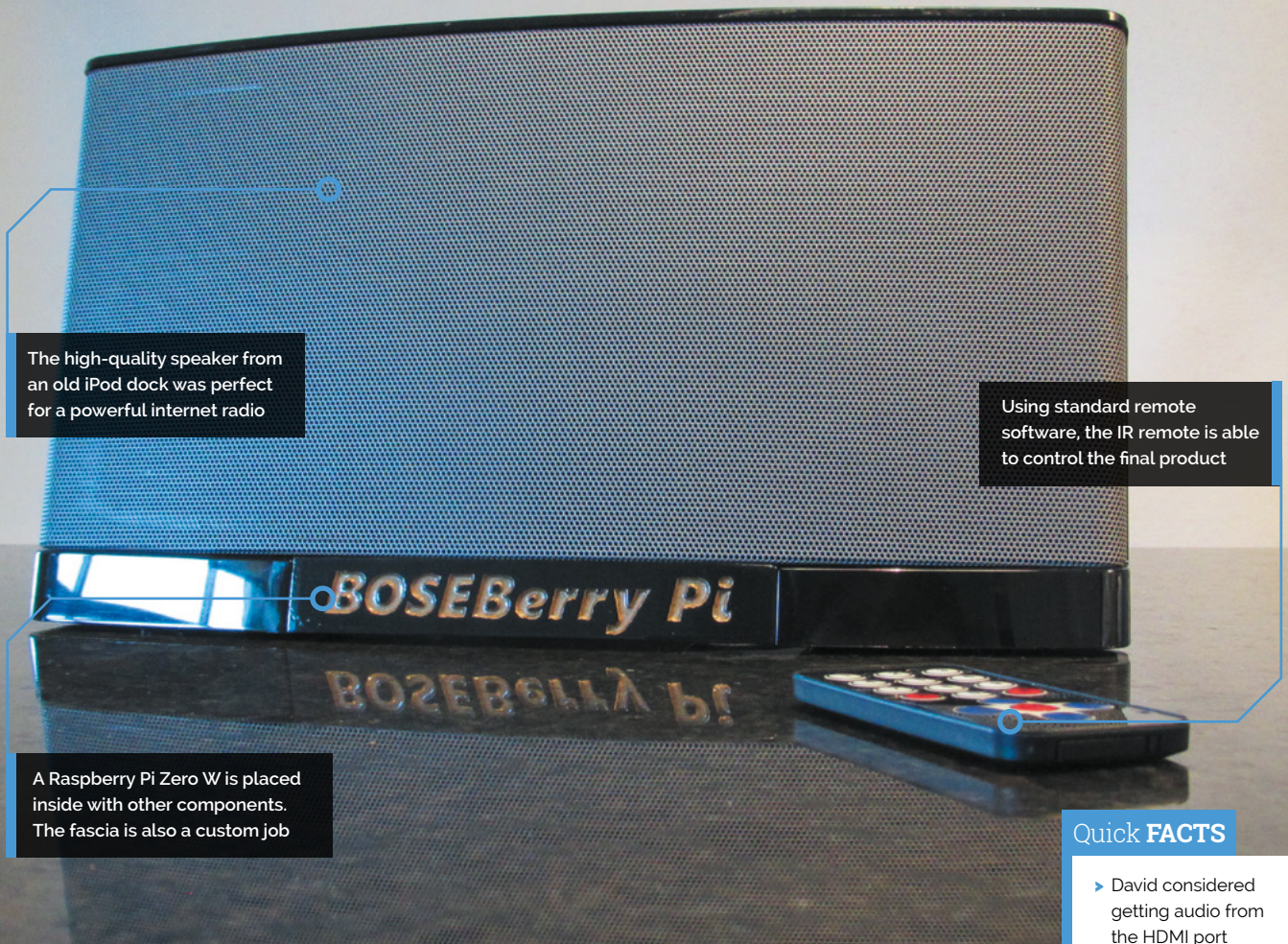
“I suspected that these devices fail from the repeated insertion of the iPod into the docking connector,” he says. “But as I was not going to use that, it would seem a good option to use as the base for my project.”



▲ As the dock is not very deep, it fits nicely in many places



▲ Washing away several years' worth of grime



The high-quality speaker from an old iPod dock was perfect for a powerful internet radio

Using standard remote software, the IR remote is able to control the final product

A Raspberry Pi Zero W is placed inside with other components. The fascia is also a custom job

Quick FACTS

- ▶ David considered getting audio from the HDMI port
- ▶ He used a PCM5102A DAC
- ▶ The DAC can deliver a 24-bit, 192kHz audio signal
- ▶ The system stays on 24/7 so radio can be used instantly
- ▶ The PAM8403 class D amplifier board cost 18p

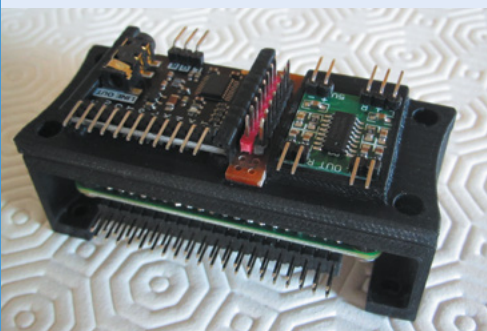


- ◀ David had to experiment a bit with paints on his 3D-printed fascia

Upcycling a speaker



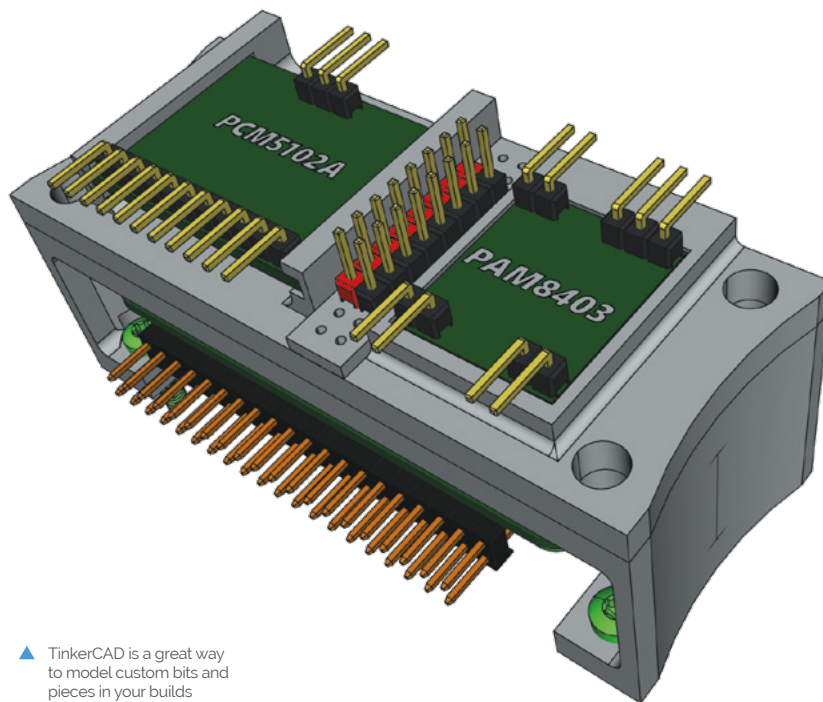
01 Carefully gut your 'faulty' iPod dock. Retain the "Vans off the wall" sticker if you really want a slice of 2011 remaining.



02 Build a custom mount for your Raspberry Pi, DAC, and amplifier now that there's a load more space inside your old dock.



03 Slot inside, wire it up, and create a custom face plate to make sure you know that your hard work is sitting proudly in your kitchen.



▲ TinkerCAD is a great way to model custom bits and pieces in your builds

Like a lot of upcycling projects, David went with a familiar solution: "I decided to use a Raspberry Pi Zero W for this project as it had plenty of processing power for the task and a very small physical footprint which could fit inside the case with ease."

He decided to use a full-on DAC to provide the audio he needed from his Raspberry Pi Zero, delivering audio quality higher than internet radio could ever deliver. After removing the internals of the BOSE system, he found a good space to mount Raspberry Pi Zero and other components, using a custom cradle designed in FreeCAD. He also added a small class D amplifier, and installed an adapter so he could use a 5 volt power supply.

“ I decided to use a Raspberry Pi Zero W for this project as it had plenty of processing power for the task ”

Keeping it simple

Out of a choice of music player and radio software for Raspberry Pi, David decided to keep it simple. "As the radio was not going to use a screen of any kind, I downloaded the latest version of Raspbian [Raspberry Pi OS] Buster Lite and installed it on an SD card," he says. "All the installation was done through the command line. I installed the music player daemon and music player client, which

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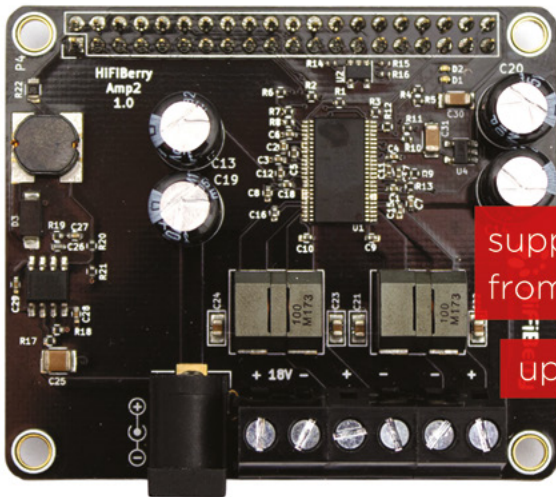


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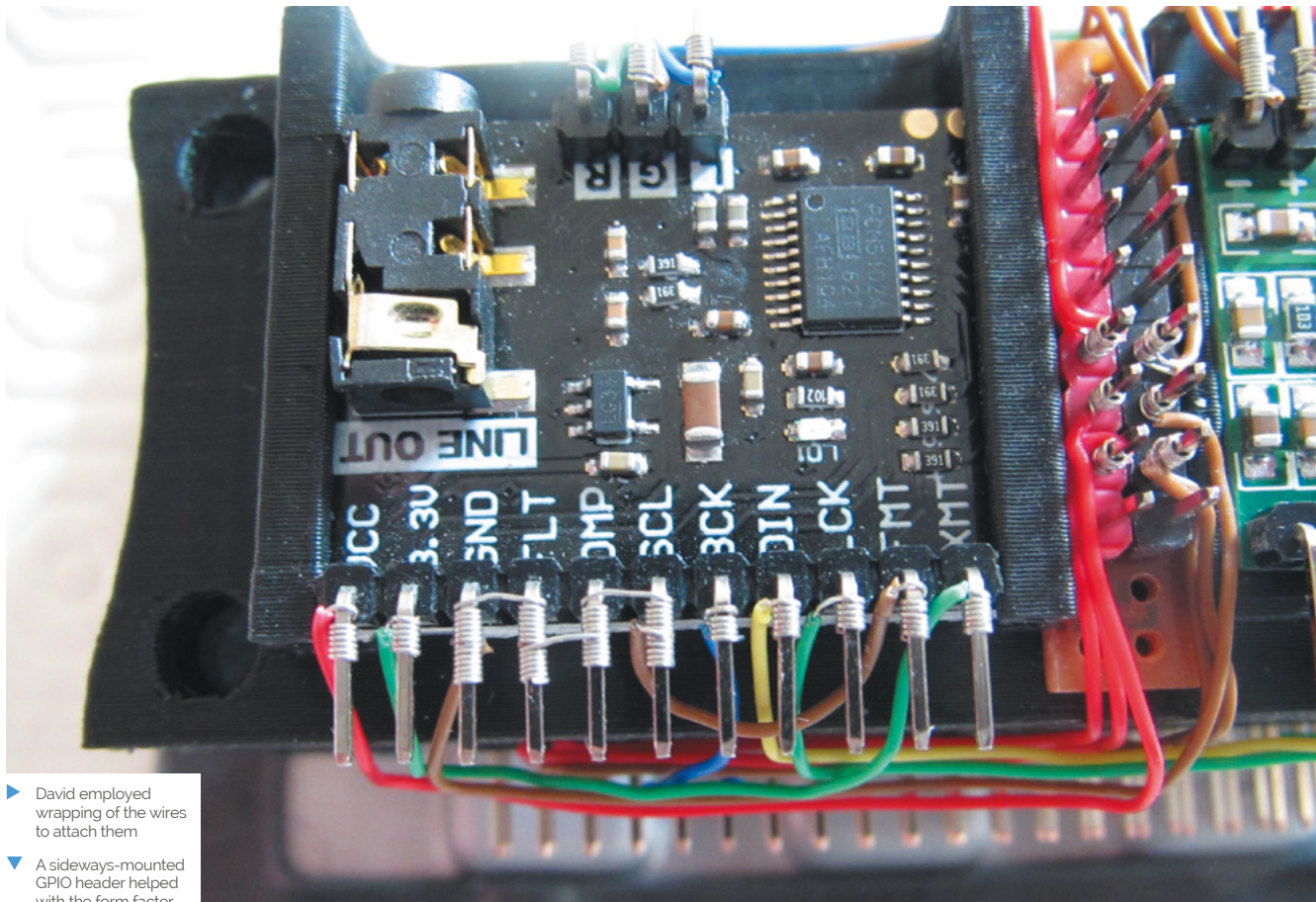
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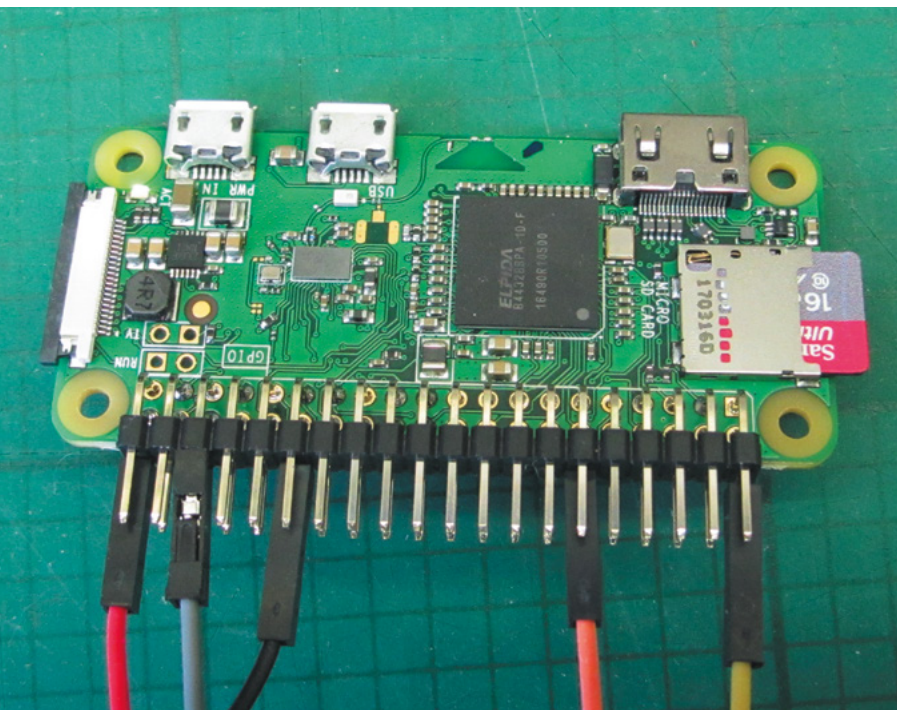
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- ▶ David employed wrapping of the wires to attach them
- ▼ A sideways-mounted GPIO header helped with the form factor



allowed me to check that the hardware was able to play the music stream.”

He added remote control abilities, programmed in specific stations, and was done.

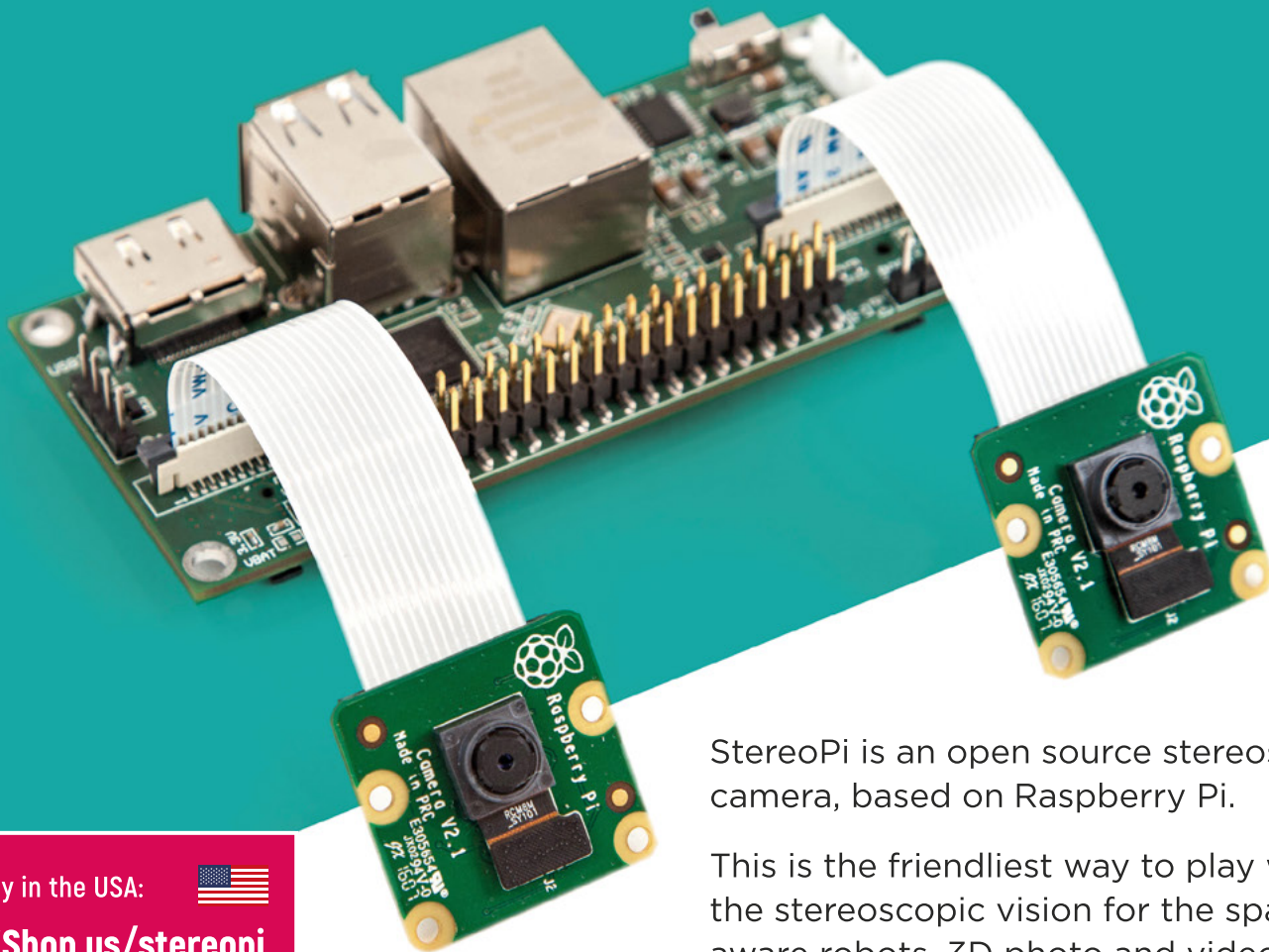
Final touches

Well, nearly. David decided to go a few steps further with a custom fascia with an updated logo.

“Although this front fascia was now complete, I decided to experiment with the style of it,” he tells us. “I started with an understated panel with embossed letters, but then thought the wording should be highlighted as a feature. This was achieved with some enamel paint to fill the depressions made by the letters.”

A test piece revealed that the enamel paint was being drawn up along the filaments of PLA printer thread by capillary action. “This was solved by first sealing the whole face with a clear acrylic spray, then painting the detail, finishing with some wet and dry paper on the top surface. A final coat of acrylic spray provided the finishing touch of a gloss surface to match the rest of the speaker body. I give you the BOSEBerry Pi.” [M](#)

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LinuxGizmos.com

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MickMake

"With it you can do things like, stream stereoscopic 3D video to YouTube, build real-time depth maps using OpenCV, create panoramics using Hugin and even a 3rd person view of real life. Cool."

Raspberry Pi Blog

"There are some excellent community efforts too, of which our current favourite is this nifty dual camera board."

Hackster News

"You can hook this up to YouTube, to Oculus Go, you can use it with OpenCV.. I cannot wait to start messing around with these because it's basically a dream come true."

Korg Monotron MIDI

Zack Scholl wanted to play his Korg Monotron using a keyboard, so he added MIDI using a Raspberry Pi computer, as **David Crookes** explains



Zack Scholl

Zack lives in Seattle and has created many open-source MIT-licensed projects. His interests include transferring data, automation, and the open-source programming language Go.

magpi.cc/monotron

The Korg Monotron is a tiny analogue synthesizer capable of producing great sound and wonderful effects. It's also something of a musical bargain given that it can be picked up for less than £50. But, because it uses a linear potentiometer, or ribbon controller, rather than a keyboard, it's not the easiest of devices to operate.

Recognising that, musician and engineer Zack Scholl got to work on a solution, using a Raspberry Pi to add MIDI functionality. The end result is music to our ears since it not only makes the synthesizer infinitely more playable, but has allowed Zack to record an entire music album.

"The ribbon controller made it near-impossible to play multiple notes in tune because moving your finger just a few millimetres changes the pitch," he explains. "That's where adding MIDI functionality comes in handy." Indeed, it means a wide variety of electronic musical instruments and computers can now be added. "The easiest modification is to get a keyboard that speaks MIDI

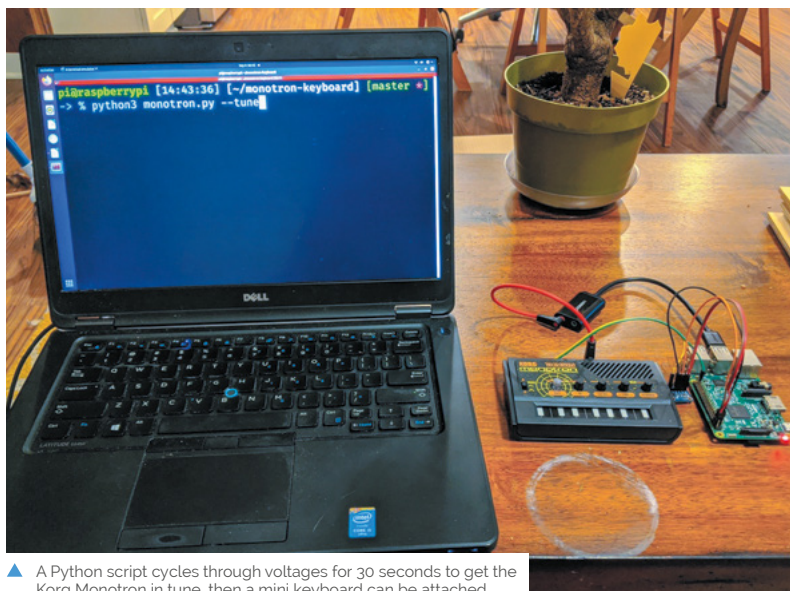
and convert the MIDI notes into voltages that the Korg Monotron understands."

Tuning in

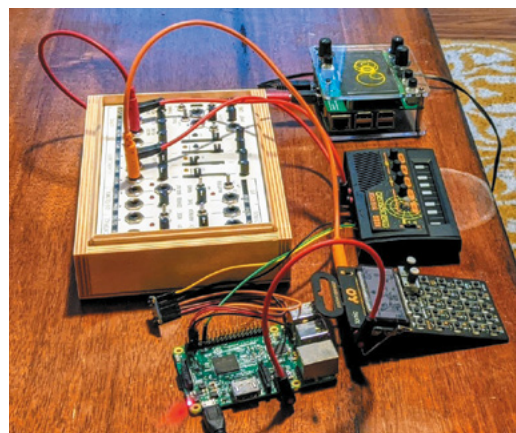
By choosing a Raspberry Pi for the project, Zack was able to avoid the pitfalls of similar mods which tend to require lots of components and PCBs. "The biggest drawback of other projects is that they have had no way of automatically tuning the Monotron – that is, they can't determine exactly which voltage corresponds to which frequency on the unit," he notes.

“ The biggest challenge has been to keep the Monotron in tune ”

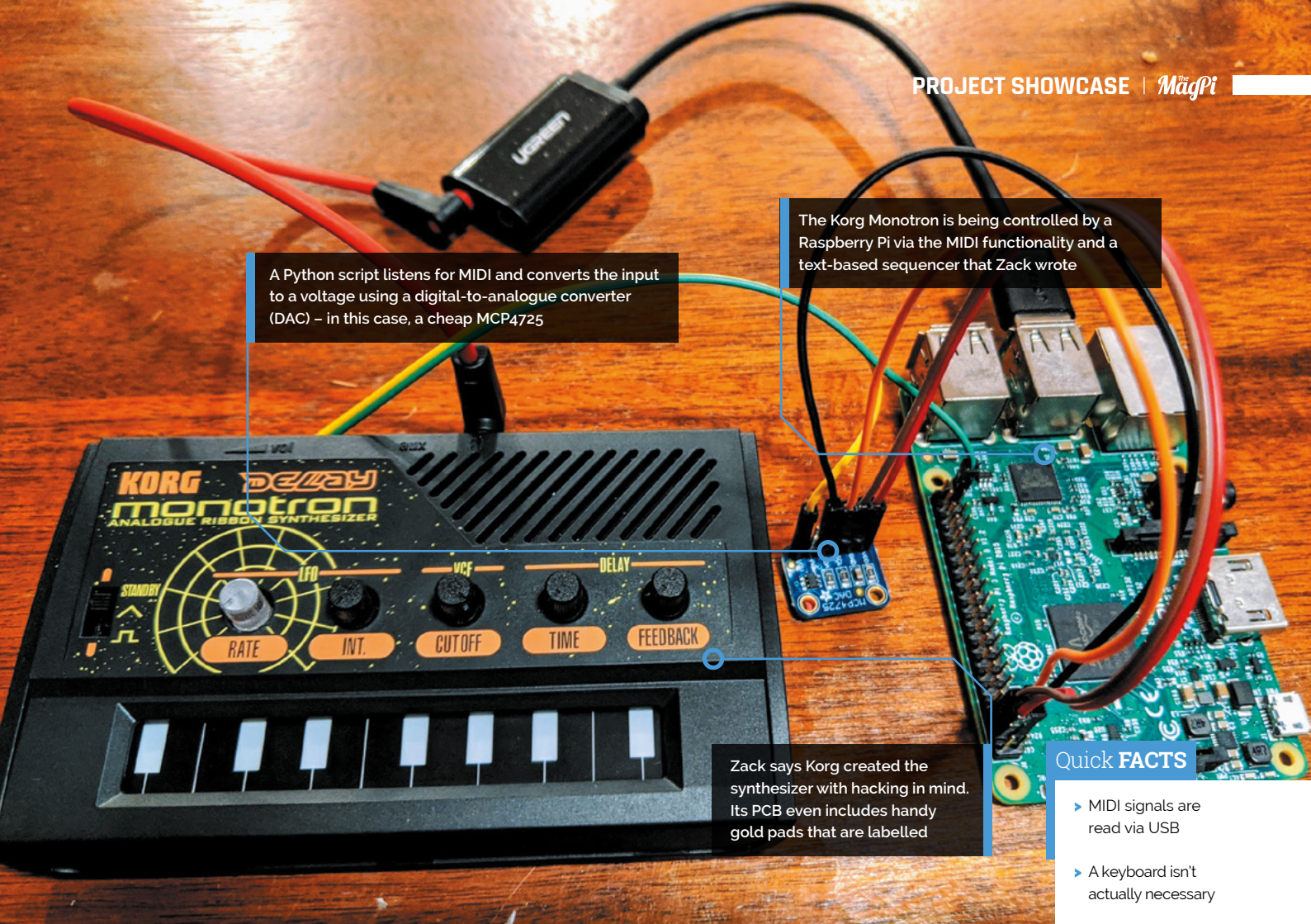
Zack's approach provided the ideal solution and it means he can play the Monotron with itself and other instruments. "Raspberry Pi can easily understand MIDI via USB, and the MIDI input can be converted to a voltage using a DAC [digital to analogue converter] plugged directly into the external pins," he says.



▲ A Python script cycles through voltages for 30 seconds to get the Korg Monotron in tune, then a mini keyboard can be attached



▲ Zack's mini studio includes a PO-32 drum machine, Koma Field Kit, and Monome Norns running a looper script on another Raspberry Pi



A Python script listens for MIDI and converts the input to a voltage using a digital-to-analogue converter (DAC) – in this case, a cheap MCP4725

The Korg Monotron is being controlled by a Raspberry Pi via the MIDI functionality and a text-based sequencer that Zack wrote

Zack says Korg created the synthesizer with hacking in mind. Its PCB even includes handy gold pads that are labelled

Quick FACTS

- ▶ MIDI signals are read via USB
- ▶ A keyboard isn't actually necessary
- ▶ A sequence of notes can be programmed
- ▶ The project uses a 5V to 3.3V regulator
- ▶ Listen to Zack's album at magpi.cc/attheplace

Indeed, the build was relatively straightforward. “The biggest challenge has been to keep the Monotron in tune. The cheapness of the synthesizer means it doesn't have any circuits to keep the pitch locked into a certain scale or tuning, but by routing the audio from the Korg Monotron into the recording input of the USB audio device, Raspberry Pi is able to ‘learn’ which voltage corresponds to which frequency.”

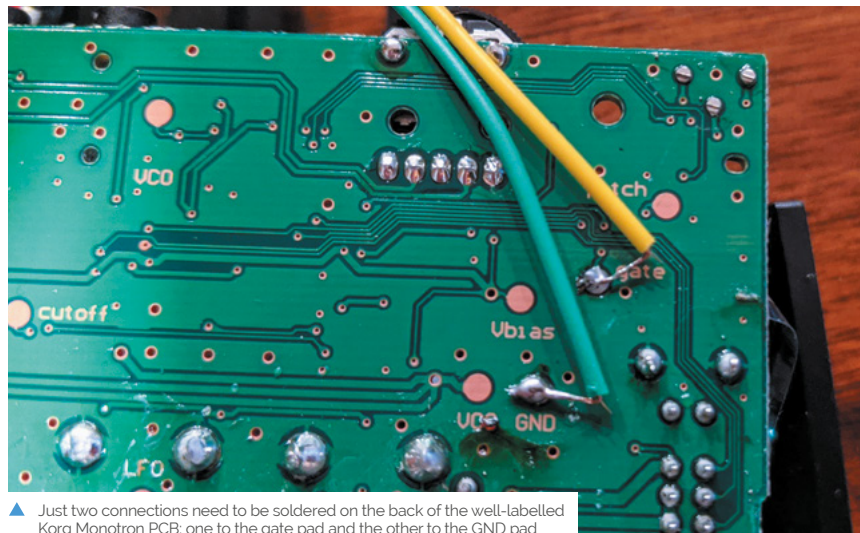
A star is born

To achieve this, Zack wrote a custom Python script that could adjust the voltage and frequency, making use of two modes – tune and play – with the former sending out voltages and listening to the USB audio input to calculate the voltage-frequency relationship. “When you put it into play mode it will listen to MIDI and use the calculated voltage-frequency relationship to figure out which voltages to send out to the Korg Monotron, which changes its pitch according to the incoming voltage,” he reveals.

It's also possible to play the Korg Monotron without a keyboard at all. A text file can be run instead and Zack wrote the program to do this before he even created the Monotron project. “The software lets me connect to Raspberry Pi via a

Secure Shell and directly write notes into a file that will be played by the Korg Monotron,” he explains.

“This was great because it turned Raspberry Pi into a self-contained musical instrument. Essentially you can just connect it to the synthesizer and it will play whatever you want. It frees up my hands to modulate the effects and it makes for some really impressive-sounding music.” [M](#)



▲ Just two connections need to be soldered on the back of the well-labelled Korg Monotron PCB: one to the gate pad and the other to the GND pad

The Stargate

Fans of the Stargate SG-1 series, prepare to be inspired: a fellow aficionado has fashioned his own model of the show's iconic portal. **Nicola King** takes an interstellar trip



Kristian Tysse

MAKER

Kristian is 39 years old and lives in Norway. He is married and has four children. He works at a hosting company – proisp.eu.

thestargateproject.com

When Kristian Tysse began making some projects on his new 3D printer, he soon became aware that the possibility of printing his own ‘working’ Stargate SG-1 model was within his grasp at last. “I suddenly realised I might now have enough knowledge about 3D printing, Raspberry Pi, motors, and programming to actually make a Stargate model of my own,” he tells us. “I wanted people who are familiar with the show to immediately know what it was, and tried to make it work as best I could, while staying as true as possible to the feeling and essence of the TV show.”

Kristian also wanted to use a Raspberry Pi within this fully interactive, light-up, moving-parts project as “it is a powerful device with lots of flexibility. I do like that it functions as a full computer with an operating system with all the possibility that brings.”

Model minutiae

You only have to look at the model to see just how much 3D printing was needed to get all of the parts ready to piece together, and Kristian created it in segments. But one of the key parts of his model



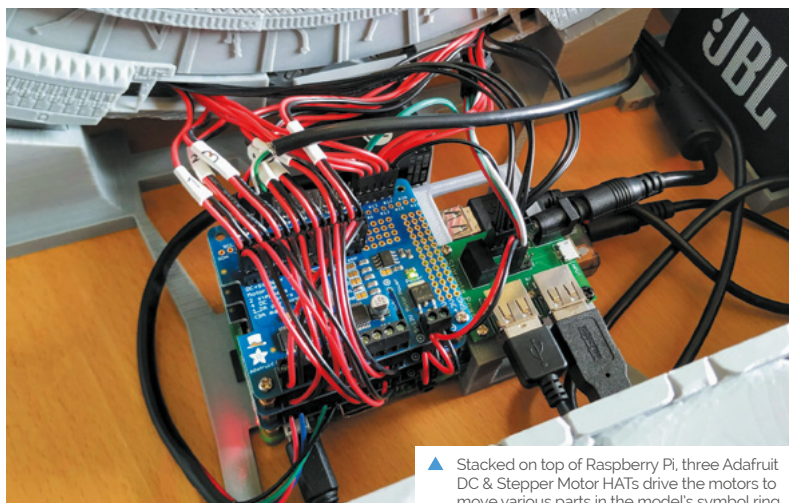
▲ For the DHD, Kristian designed a custom PCB for the 39 tactile buttons, housed in a layered, 3D-printed case

is the DHD or Dial Home Device which viewers of the series will be familiar with. “The DHD functions as a USB keyboard and, when the keys are used, it sends signals to the (Python) program on Raspberry Pi that engages the different motors and lights in a proper Stargate way,” he enthuses. “If a correct set of keys/symbols are pressed on the DHD, the wormhole is established – illustrated on my Stargate with an infinity mirror effect.”

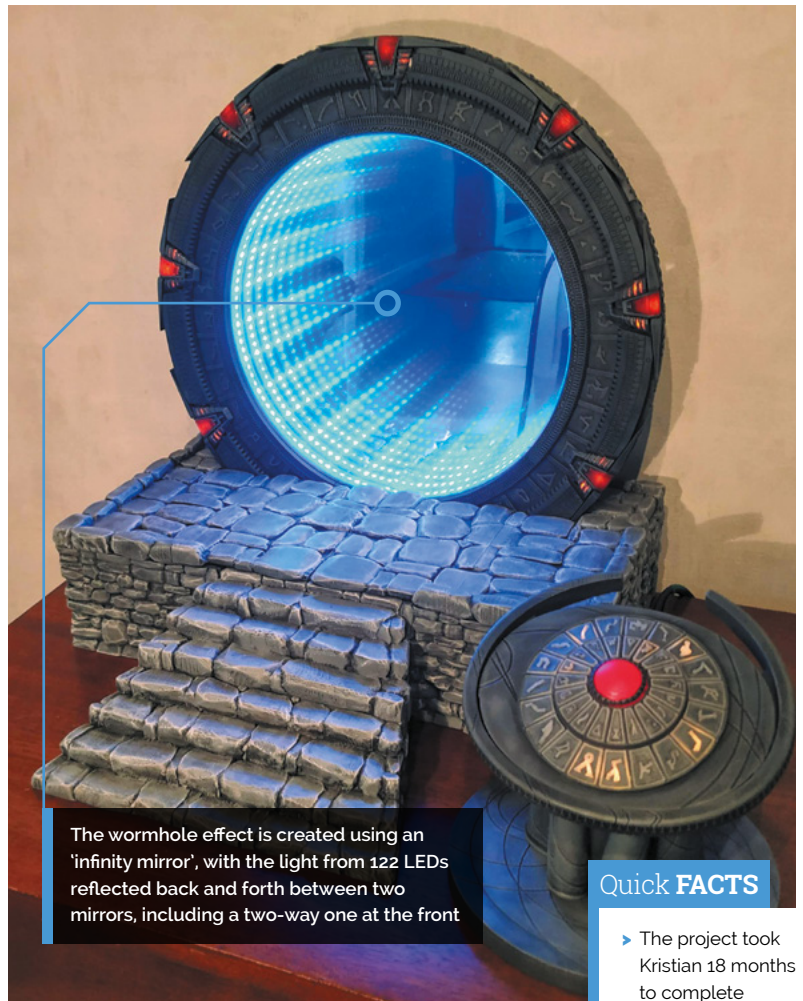
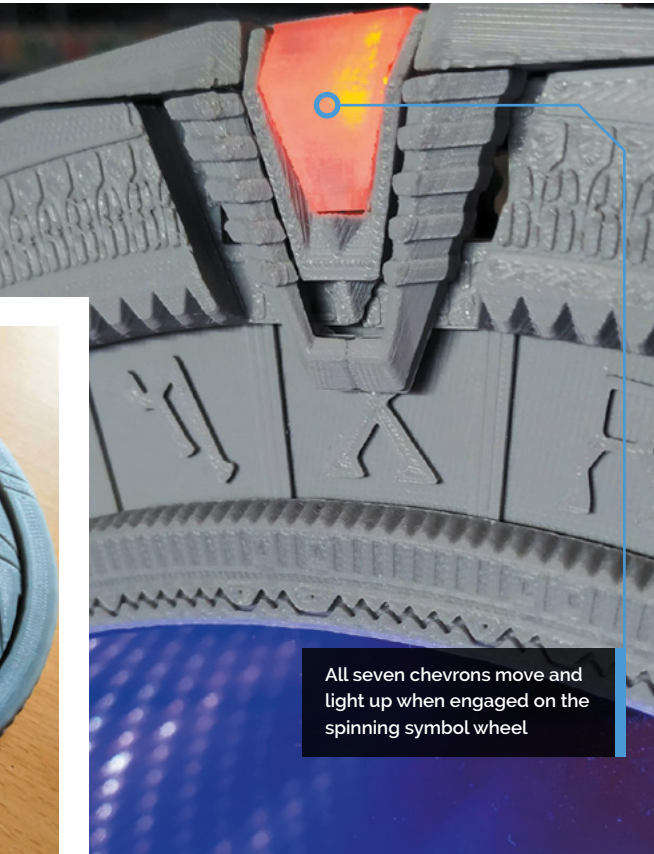
However, the DHD was a challenge, and Kristian is still tweaking it to improve how it works. He admits that writing the software for the project was also tricky, “but when I think back, the most challenging part was actually making it ‘functional’, and fitting all the wires and motors on it without destroying the look and shape of the Stargate itself.”

Dazzling detail

Kristian admits to using a little artistic licence along the way, but he is keen to ensure the model replicates the original as far as possible. “I have taken a few liberties here and there. People on the social media channels are quick to point out



▲ Stacked on top of Raspberry Pi, three Adafruit DC & Stepper Motor HATs drive the motors to move various parts in the model's symbol ring



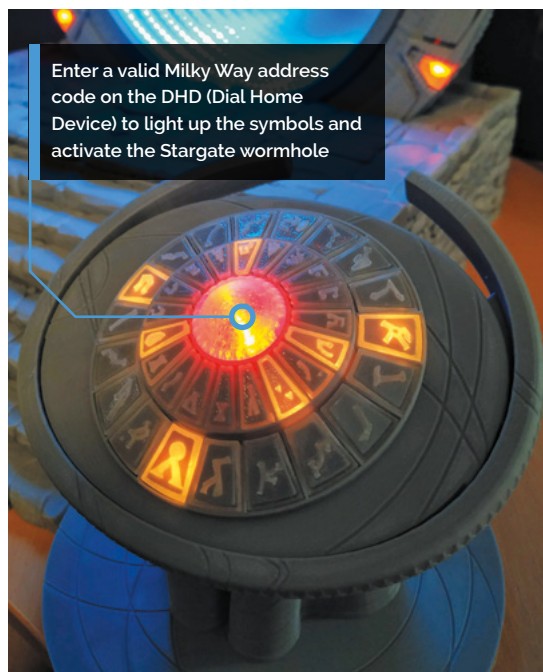
Quick FACTS

- ▶ The project took Kristian 18 months to complete
- ▶ The model is about 39cm in diameter
- ▶ The Stargate even has sound effects from the TV show!
- ▶ Kristian's other Raspberry Pi projects include motorised roller blinds...
- ▶ ...and a GPS-based garage door opening system

“I wanted people who are familiar with the show to immediately know what it was”

differences between my Stargate and the one in the series. I have listened to most of those and [made] some changes. I will implement some more of those changes as the project continues,” he says. He also had to redesign the project several times, and had a number of challenges to overcome, especially in creating the seven lit, moving chevrons: “I tried many different approaches before I landed on the right one.”

The results of Kristian's time-intensive labours are truly impressive, and show what you can achieve when you are willing to put in the hours and the attention to detail. Take a look at Kristian's extremely detailed project page (thestargateproject.com) to see more on this super-stellar make. [M](#)



OnionBot Sous Chef

Too many cooks spoil the broth, but too few can mean culinary disaster. **Rosie Hattersley** hears how a Raspberry Pi bot provides a helping hand



Ben Copley

Design engineer Ben undertook this project for his master's thesis at Imperial College London. It's the most complex – and tastiest – of his many Raspberry Pi projects to date.

magpi.cc/onionbotgit

Stir-frying the onions, chopping the veg, adding seasoning, checking on what's roasting in the oven. These day-to-day cooking tasks are complex because they're performed simultaneously.

Keen cook Ben Copley found himself pondering how to automate such tasks when considering what he could usefully invent for his master's thesis at Imperial College London. His response was the OnionBot – “a Raspberry Pi 4-based sous-chef robot that supports me in the kitchen”.

Ben says he loves cooking, but never seems to have as much time as he'd like. “That got me thinking about how a robot might help take over some of the easy tasks.” He envisaged “a device that can automate the easier pan-cooking tasks so the head chef (me!) can focus on culinary creativity. Thus started my quest to completely over-engineer cooking a bowl of pasta.”

Home cooks

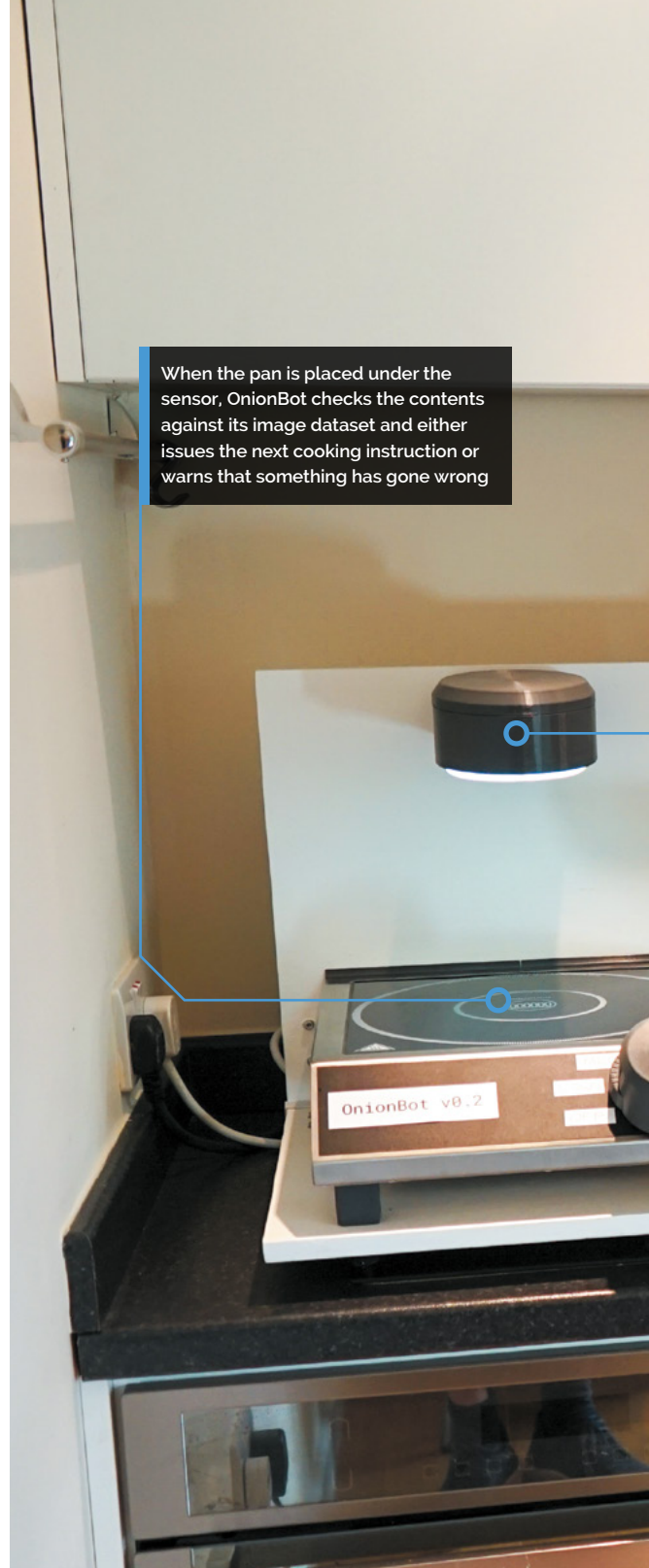
Ben wanted a counter-top device, ideally a robot with AI capabilities and a camera that could be used as a sensor. He decided to use Raspberry Pi with two cameras (one thermal) “to watch the pan and give me intelligent assistance while I focus on other things!” He says Raspberry Pi 4 was an obvious choice as it provides the processing power, I/O, and small size needed to bring these components together. “The best thing about Raspberry Pi is there's so much support and documentation online. Someone's always fixed your unfixable bug before!”



Warning!
Hot surface

Ensure Raspberry Pi and components are kept away from the hot surface, and don't leave any pans unattended.

When the pan is placed under the sensor, OnionBot checks the contents against its image dataset and either issues the next cooking instruction or warns that something has gone wrong



A 7-inch Raspberry Pi touchscreen displays instructions, reminders, and alerts. Ben designed the robot's parts in Fusion 360 and 3D-printed them on a Prusa i3 MK3. He wrote the firmware in Python and a web interface based on HTML, CSS, and JavaScript. Overall, the project cost around £400.

AI was a major challenge of the project as Ben needed a huge number of food images. With no available pan cooking datasets, he set about

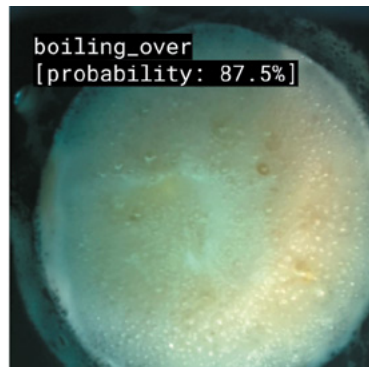
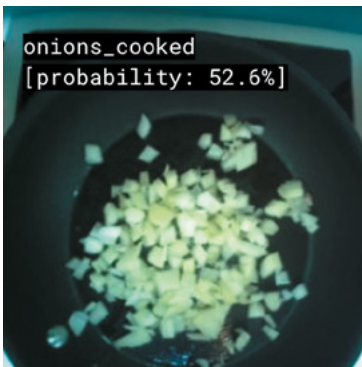
The wide-angle nature of the cameras means they don't need to be positioned very high above the pan. A 12V blower blows air over them to stop the lenses from steaming up due to condensation

OnionBot v0.2

The touchscreen acts as the sous-chef, displaying and following recipe instructions and prompting the human chef to stir the pot if they haven't done so for several minutes

Quick FACTS

- ▶ Ben previously designed a Tamagotchi-style pet: magpi.cc/gizmo
- ▶ Don't forget to feed it! (Pasta, of course)
- ▶ Ben promised his tutor other robot recipes would follow
- ▶ So, he's encouraging others to help him succeed: magpi.cc/onionbotpaper
- ▶ He recommends Google's Teachable Machine for a first ML project: magpi.cc/teachablemachine



- ◀ Ben ate nothing but pasta for a week while perfecting the recipe that OnionBot follows and collecting related images

OnionBot is so named because "the idea came to me when looking for an automated way to perfectly soften onions in a pan while I get on with the rest of the dish"

“ OnionBot was able to follow along the entire recipe, giving the head chef instructions and reminders ”



▲ Ben wanted to use computer vision to act as a chef's watchful eye over the pan. Based on what it senses, the OnionBot then tells the human chef what to do next

creating his own, along with an interface for the robot to access them for comparison. The method involves training a robot for each new recipe. As each milestone in the cooking process is completed, the user clicks a button on the web interface to save an image that is then labelled and stored in Google Cloud for use as a classifier.

Know your onions

Ben chose a simple pasta with tomato sauce recipe as a repeatable experiment to test the system. Since machine learning models need large, varied datasets, Ben ate a lot of pasta and collected around 500 labelled images for each action in the recipe. He trained the classifiers using Google AutoML, which makes it extremely easy to make image classifiers, even without any machine learning experience. He recommends Google Coral AI USB Accelerator – “a great piece of kit that is plug and play straight into Raspberry Pi, and which speeds up machine learning models.”



He started simple, teaching the OnionBot to bring a pan of water to the boil. Harder challenges included: Are these onions cooked? Is the pan on the hob? Is the pan being stirred?

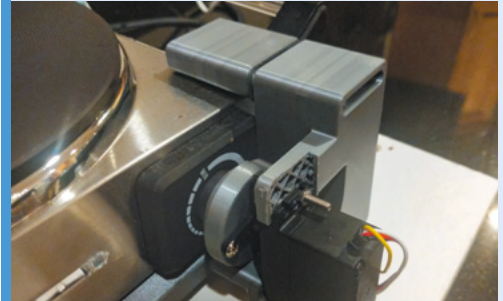
Multiple models were added to the final pasta recipe, which Ben converted into a robot-friendly version that uses the thermal sensor data and computer vision results to make decisions. “With a bit of tweaking, OnionBot was able to follow along the entire recipe, giving the head chef instructions and reminders on the touchscreen as it went along!”

The robot was able to advance through the instructions, making use of Ben’s image classification system. It autonomously controlled the pan temperature using PID feedback, detecting whether the pan is boiling over and, if so, turning down the heat. [M](#)

▲ Ben had to deliberately ruin some of his cooking in order to get images showing things going wrong

Taste test

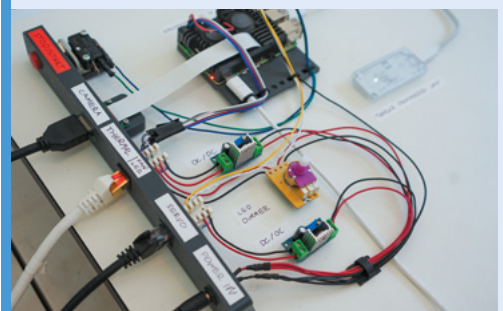
To replicate the OnionBot, you need a portable stove that can be controlled by a servo along with Raspberry Pi 4, camera, and thermal sensor. Full details and code are at magpi.cc/onionbotgit.



- 01** Measure the dial on your stove and add an adapter that allows it to be controlled by the servo hooked up to your Raspberry Pi. A 360-degree servo motor is ideal.



- 02** Connect a wide-angle camera and thermal camera/sensor to Raspberry Pi, and position them above the stove top. Add a computer fan or blower to prevent condensation build-up.



- 03** Python Flask server runs on Raspberry Pi and makes system controls accessible over the local network. A web interface streams the cooking images in real-time and sends commands to Raspberry Pi.

PiTubeDirect

David Banks has used Raspberry Pi to expand the capability of one of retro computing's most iconic machines, as **David Crookes** discovers



David Banks

MAKER

David is a recently retired computer engineer, having worked at HP Labs for 28 years. He lives in Bristol with his wife Liz and dog Jack. You can find him as hoglet67 on the Stardot forums and on GitHub.

magpi.cc/pitubedirect

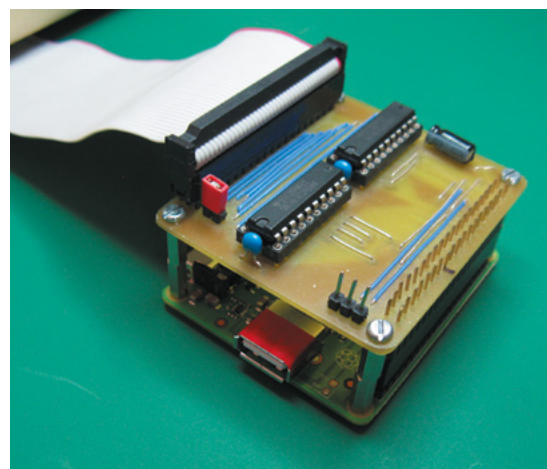
The creators of Raspberry Pi owe much to the BBC Micro – the first computer owned by Raspberry Pi co-creator Eben Upton, and the one that taught children to code in schools across the UK.

The 1980s gem inspired the affordable microcomputer we've come to know and love, so we adore how this project brings both together, using Raspberry Pi to enhance the BBC Micro by allowing another external CPU to be added.

This idea is not new. BBC Micro maker Acorn included a port called Tube for this very purpose and it released a range of second processors to expand a machine with limited RAM. But Acorn's original set of second processors can be expensive and tricky to find, so PiTubeDirect recreates them on Raspberry Pi.

As such, BBC Micro enthusiasts can enhance their computers by adding a second 6502 or they can add external Z80, 32016, and ARM1 second processors – the latter was used to develop the Acorn Archimedes range.

“The second processors would take responsibility for running the current language and the user's programs, leaving the BBC Micro



host responsible for the keyboard, screen, and file system,” says project originator David Banks. “The Tube architecture was unique and very innovative at the time.”

Timing it right

To enhance a BBC Micro in this way, users need a level-shifter HAT connected to Raspberry Pi's GPIO interface which, in turn, is hooked to the BBC Micro's Tube port using a 40-pin IDC cable. After installing the PiTubeDirect software to a microSD card, you simply plug and play.

Yet, getting to this point has been a challenge. “We were brainstorming what it would take to connect Raspberry Pi Zero to the Tube port with the absolute minimal amount of hardware,” recalls David, who began tinkering with the BBC Micro again in 2013 after discovering people were preserving the computer and developing new hardware and software.

“The BBC Micro's Tube interface is just an extension of the 6502 microprocessor bus and it uses 5V signal levels. Raspberry Pi uses more modern 3.3V signal levels, so the minimum hardware is just a couple of off-the-shelf level-shifter chips.



▲ The original BBC Micro Model B had 32kB, but Acorn's originally released 6502 second processor included a 50 percent faster 3MHz 65C02 CPU, as well as 64kB of RAM

The PiTubeDirect build plugs into the Tube port of a BBC Micro, allowing a second processor and extra memory to be used by the host computer

A level-shifter HAT connects to the GPIO connector on Raspberry Pi. PiTubeDirect supports 6502, Z80, 80x86, ARM, 32016, 6809, PDP11, Ferranti F100, OPC 5/6/7, and native ARM second processors

One of the original BBC Micro developers, Steve Furber, shared the original documentation for the Tube ULA custom chip incorporated within Acorn's second processors, allowing the team to more effectively emulate it on Raspberry Pi

Quick FACTS

- ▶ The first prototype took six weeks to develop
- ▶ Releases are named after ships from the game Elite
- ▶ The Z80 second processor runs CP/M
- ▶ David began learning bare-metal coding online: magpi.cc/baremetalc
- ▶ The forum at stardot.org.uk has supported the project

“ We dispensed with the operating system and engaged in 'bare metal' programming ”

“But such a solution is only feasible if Raspberry Pi, in software, can do everything else, including responding to Tube requests in real time.” Achieving that was tricky.

To the bare metal

The wizardry used to interface the BBC Micro to a second processor was originally encapsulated in the Tube ULA custom chip. “Every second processor that Acorn produced contained one, providing a set of four bidirectional FIFOs that allow the ‘host’ and ‘parasite’ processors to communicate via a series of well-defined messages, called the Tube Protocol,” explains David.

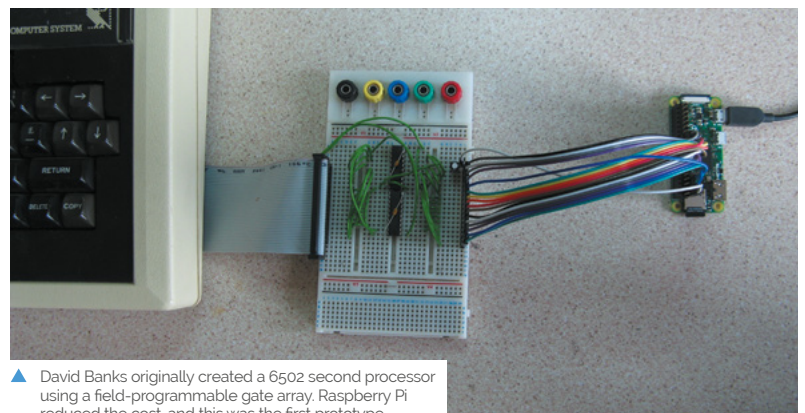
Emulating this entailed using software running on Raspberry Pi and it needed to meet the hard real-time constraints of the 2MHz Tube interface.

“We knew running a conventional operating system like Raspberry Pi OS would not yield the required guaranteed response time,” David says. “So, we dispensed with the operating system and engaged in ‘bare metal’ programming, developing software by directly accessing the hardware of Raspberry Pi Zero.”

To further resolve time-related problems, Dominic Plunkett joined the team and suggested

moving the Tube ULA emulation code on to the GPU. Dominic also optimised the emulation speed of the 6502 to 292MHz, thus making it nearly 150 times the speed of the original 2MHz BBC Micro.

One thing’s for sure, it’s been an education. “One of the more satisfying aspects of developing PiTubeDirect has been learning about programming at the lowest bare metal level,” notes David. “And that’s very much in the same manner that we would really get to know machines back in the 1980s.”



▲ David Banks originally created a 6502 second processor using a field-programmable gate array. Raspberry Pi reduced the cost, and this was the first prototype

Multi-effects Guitar Pedal



Raphaël Isvelin

Raphaël is a 24-year-old software engineer. In January, he quit his job in Paris to travel around the world; after only a couple of months, he had to come back to his hometown and used that time to play music and work on programming pet projects.

magpi.cc/raphael

Create some scintillating sounds with this versatile digital multi-effects unit complete with touchscreen. **Phil King** turns it up to 11

Most makers build something simple for their first ever Raspberry Pi project. Raphaël Isvelin, on the other hand, opted to create something impressive-sounding – literally. His DIY guitar pedal unit offers serious sonic capabilities with its innovative method for combining effects (see magpi.cc/guitarpedalyt for a demo).

After buying some commercial guitar pedals, Raphaël noted that they’re normally run in series, but wondered what would happen if they could be run in parallel. “It makes a pretty big difference,” he tells us. “Suppose you have two distortion pedals: if you run them in series, you’ll hear the cumulated effect of both, while if you provide your ‘dry’ (unmodified) signal to each pedal separately and add up their outputs, you’ll then preserve the specifics of each and create a sound impossible to create when running the pedals in series.”

Unlike off-the-shelf multi-effects units which run their effects in series internally (apply Octaver, then Fuzz, then Delay, for instance), the DIY guitar pedal he built is able to digitally create a complex



parallel signal chain: “Something like the modular synth version of guitar pedals.”

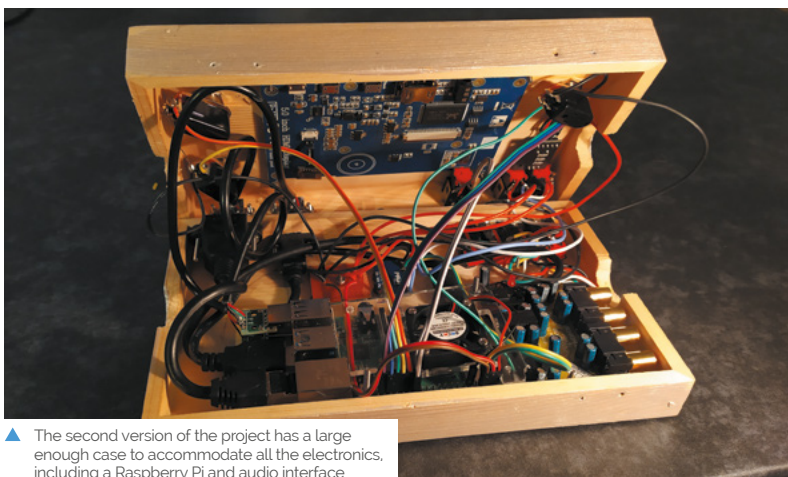
Connecting effects

With a Raspberry Pi 3 and all the other components crammed into a handmade wooden case, the unit features six jacks (two inputs, two outputs, two for expression pedal), a USB port, three push-buttons, and a rotary encoder to control effects.

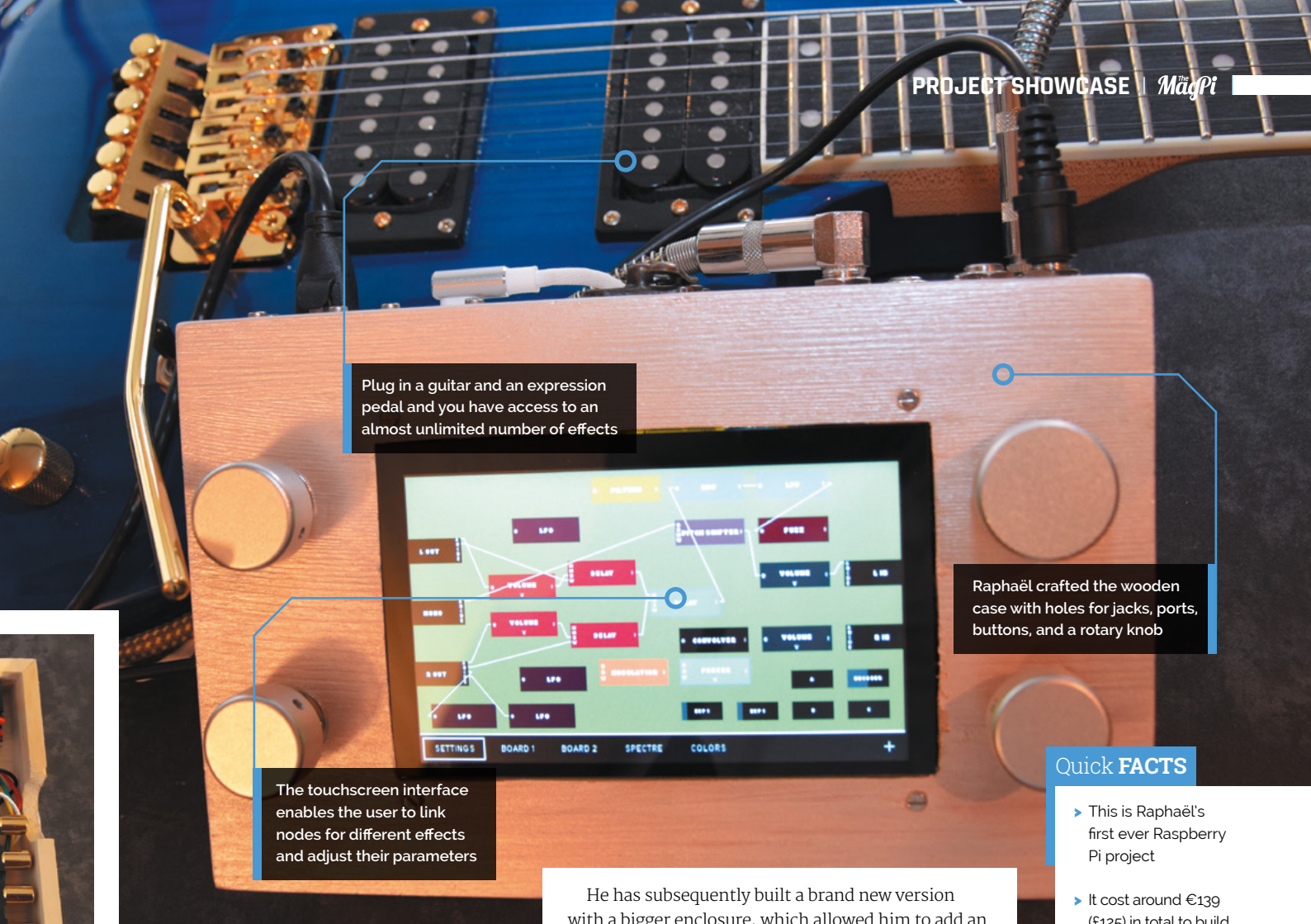
A touchscreen interface (made using the SFML software library) enables the user to create and link multiple nodes for different effects to combine them. There’s also a live board view where you can adjust their parameters of each effect to get exactly the sound you want.

“The centrepiece is what I call the ‘audio pipeline’,” says Raphaël. “It’s moving the audio from node to node (essentially a DFS graph traversal); visually, a node is one brick in the GUI.”

At the moment, he’s made about 25 individual effects (bricks), each having from two to five input and output slots: “You can pretty much add as many bricks as you want and connect them however you want [for] a lot of potential effects.



▲ The second version of the project has a large enough case to accommodate all the electronics, including a Raspberry Pi and audio interface



Plug in a guitar and an expression pedal and you have access to an almost unlimited number of effects

Raphaël crafted the wooden case with holes for jacks, ports, buttons, and a rotary knob

The touchscreen interface enables the user to link nodes for different effects and adjust their parameters

Quick FACTS

- ▶ This is Raphaël's first ever Raspberry Pi project
- ▶ It cost around €139 (£125) in total to build
- ▶ Most of the software is built from scratch, in C
- ▶ The PortAudio library is used for sound input/output
- ▶ For his next project, he plans to make a guitar theremin

“My goal is to provide enough building blocks to recreate the effects of any off-the-shelf pedal, and more, by combining filters, modulation, delays, etc.,” he says.

“ Something like the modular synth version of guitar pedals ”

He has subsequently built a brand new version with a bigger enclosure, which allowed him to add an Ethernet port, another USB, and finally close the box.

“Also, I used another audio interface, which is better suited as it can be torn apart, resoldered, and screwed directly to the enclosure; clearly better than a USB dongle flying around with bulky audio jacks connected to it.”

Quite a few people have told him they'd love to buy his pedal, as a product or as a kit, which he is considering. “One way or another, I plan on making everything open-source relatively soon; I'd love to see people building their own effects!”

We can rebuild it

The project took Raphaël around half his time over a four-month period. While the software aspect was in his comfort zone, “the real hard part for me was cutting wood and soldering things. Seriously, before this project, hardware was pretty much magic to me, and wood wasn't even a thing!”

His reasoning for using a Raspberry Pi in the build was simple: “I want to make a pedal. I've got a tiny computer and a USB audio card. If I put them both in a box, that's a pedal, right?”

For the first version of the pedal, as used in his YouTube demo, he reveals that the wooden enclosure was too small: “There's a 5 mm gap; that's why I shot the video from a 90° angle.”



▲ The rear of the unit features jacks for inputs, outputs, expression pedal, plus USB, Ethernet, and power ports

Car Head Unit

Retro-fitting safety sensors to an older vehicle is a fiddly task. **Rosie Hattersley** finds out how one Raspberry Pi fan customised his own car



Levi Bishop

MAKER

Levi is studying mechanical engineering and computer science in Colorado. He really enjoys maker culture and has even automated several items at work – with his boss’s blessing.

Safety features are standard on most new vehicles, but older vehicles lack the cameras and sensors we’ve begun to take for granted. Student Levi Bishop wanted to add a reversing camera to his existing car without having to fork out over the odds. After all, he was already working several part-time jobs. Having previously tackled several Raspberry Pi projects, Levi decided to design a bespoke car head unit to fit in his vehicle’s stereo slot.

“My eyes lack depth perception, so I really wanted a backup camera for safety,” he explains. Off-the-shelf options were expensive, so he decided to put his engineering skills to the test. The parts ended up costing him “a fraction” of a ready-made product.

Looking back

Originally, he wanted a backup camera and a large screen to display the camera view, much like the home security setup he’d created previously to keep an eye on his house while he was on holiday. He chose a Raspberry Pi 4 as the basis since he knew that model well and it offers good camera support. “The low cost was a major advantage, as well as being able to replace my plain old radio with a big, beautiful 7-inch touchscreen,” he says.

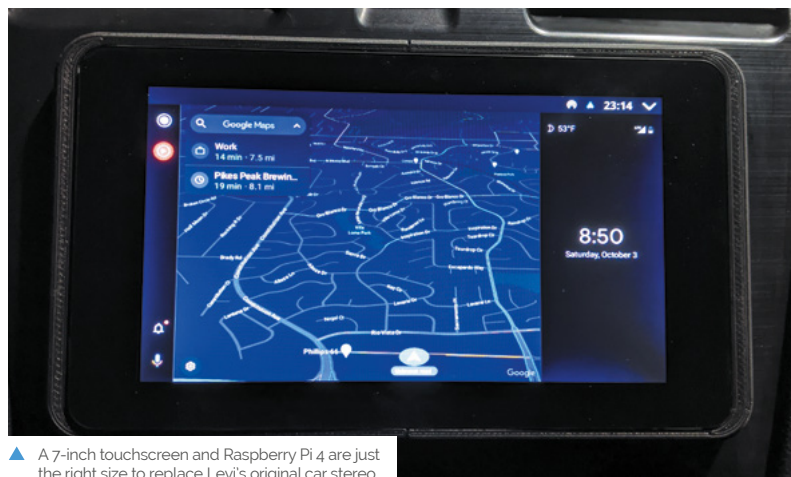


▲ A voltage divider and signal wire to the reverse lamp circuit in the rear light connect to a GPIO pin on Raspberry Pi. The reversing camera is summoned whenever the car is put into reverse

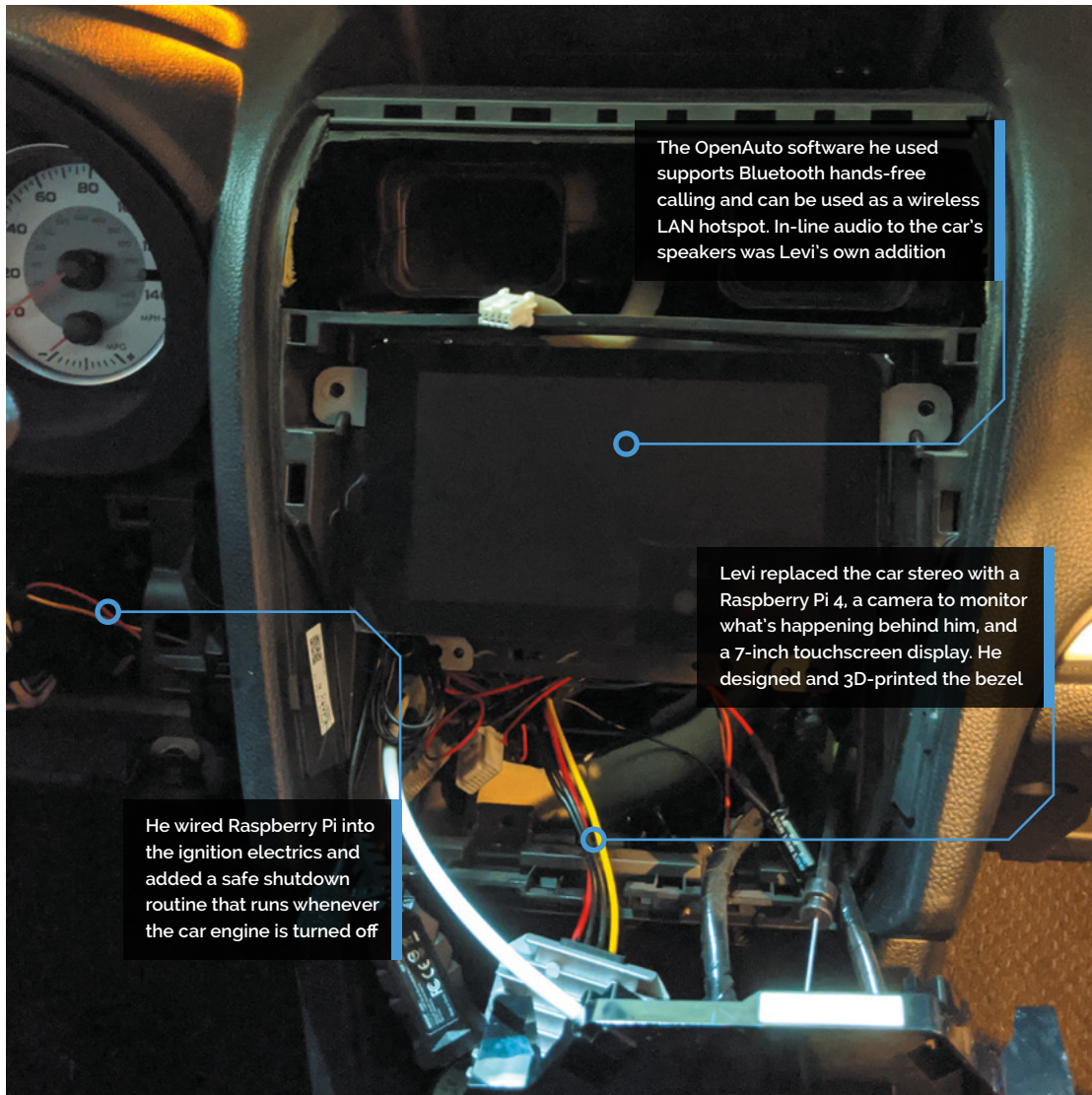
Levi then discovered a company called Blue Wave (bluewavestudio.io), which makes open-source head unit software for Raspberry Pi called OpenAuto. “I flashed my Raspberry Pi with their OS. [This provided] a graphical interface and a full suite of apps and other features you would commonly find in many stock infotainment systems, including Android Auto,” he says.

Powering ahead

Powering it was to prove a challenge as the 12V connections in his car didn’t match that of Raspberry Pi. He used a 12 to 5 volt buck converter to step-down the power supply to Raspberry Pi, though on the first attempt he got his wires mixed up, destroying his Raspberry Pi. To prevent the microSD card corrupting when the power was switched off, Levi cleverly tapped into the ignition wire behind the car dashboard, then soldered a PC817 opto-coupler between it and Raspberry Pi. “I used a Python script I found online that told Raspberry Pi to look for a falling edge on the opto-coupler,” he reveals. “When you turn off the



▲ A 7-inch touchscreen and Raspberry Pi 4 are just the right size to replace Levi’s original car stereo



The OpenAuto software he used supports Bluetooth hands-free calling and can be used as a wireless LAN hotspot. In-line audio to the car's speakers was Levi's own addition

Levi replaced the car stereo with a Raspberry Pi 4, a camera to monitor what's happening behind him, and a 7-inch touchscreen display. He designed and 3D-printed the bezel

He wired Raspberry Pi into the ignition electrics and added a safe shutdown routine that runs whenever the car engine is turned off



Warning! Voltage mismatch

You need a buck converter to make Raspberry Pi work alongside your vehicle electrics.

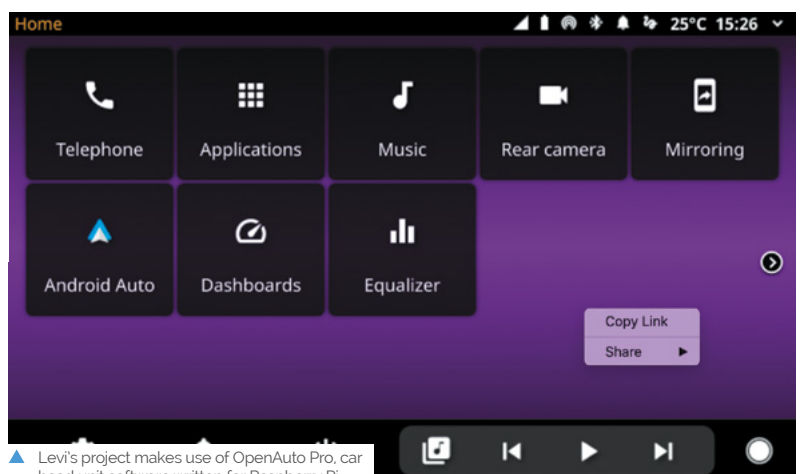
Quick FACTS

- ▶ Raspberry Pi's audio now plays through his car stereo
- ▶ OpenAuto can act as a hotspot, meaning...
- ▶ ...road trip online music playlists are go!
- ▶ There's a useful how-to guide to OpenAuto at magpi.cc/androidauto
- ▶ Levi says the build takes around a week to complete

“ Nothing makes an old car feel like new like a giant touchscreen in the dash ”

ignition, the opto-coupler instructs Raspberry Pi to run a shutdown script, ensuring a safe power-off.”

For others wanting to tackle such a project, Levi warns that the electrical work involved is quite challenging. “You’re splicing into electrical harnesses in your car, building voltage dividers, and doing a lot of stuff to your car that wasn’t meant to be done, so you have to be careful and know what you’re doing so you don’t damage things.” But it’s fair to say he’s pleased with how his project turned out: “Nothing makes an old car feel like new like a giant touchscreen in the dash,” he beams. [M](#)



▲ Levi's project makes use of OpenAuto Pro, car head unit software written for Raspberry Pi

Walking Robot

Hanheum Cho has created a robot that can get around on two legs. But, as **David Crookes** discovers, it also has one eye on targets



Hanheum Cho

MAKER

Hanheum is a 15-year-old student who lives in South Korea. He's a self-taught programmer who learned robotics alone in his bedroom.

magpi.cc/hanheum

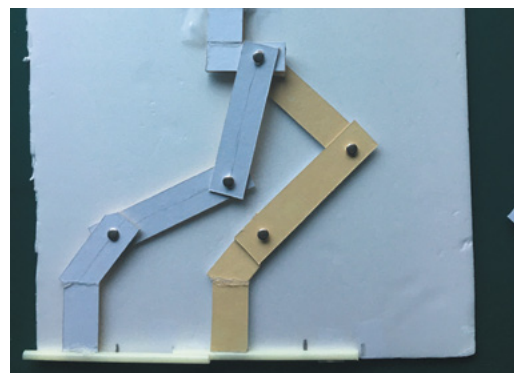
From R2-D2 and Optimus Prime to T-1000 and Johnny 5, TV and film have thrust many cool robots in front of our eyes. Hanheum Cho has enjoyed watching many of them. “Since I was a little kid, I would enjoy shows about robots such as *Transformers*,” he recalls. And now, aged 15, he’s built his very own.

This robot has no name but it does have two legs. It doesn’t talk but it walks, albeit tentatively. “I actually built my first two-legged robot when I was 13 and many people told me it would be difficult to do,” he tells us. “They were correct – it has been hard. But I found a way to make a robot walk and this one is the third version.”

The first two were physically weak. “The robots kept falling, legs were getting crossed and they couldn’t walk well, so I decided to make a new one,” he says. “A few months ago, I upgraded the robot with metal parts. I also wanted it to detect targets using a camera and artificial intelligence.”

Walking with robots

Getting this far has been a steep learning curve for Hanheum. “Since I’m 15 years old, my knowledge



▲ To work out how the legs should move, Hanheum produced a paper model to record the degrees of movement before manually coding the data

of maths and physics isn’t too high, so I couldn’t have many difficult calculations to make the robot walk,” he reveals.

“At first, I experimented to see if the robot could stand on one leg and then I made paper legs to simulate a walking pattern. This allowed me to find the appropriate degree changes that were required which I could then apply to the robot. When the weight is moved to one side, the other leg can move freely and this is the most important concept of my walking robot, with the weight centre of the grounded leg being heavier than the free one.”

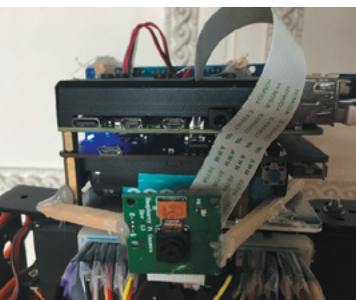
Movement is controlled by an Arduino Mega microcontroller board and a MG995 servo motor. The robot is powered by a couple of LiPo batteries, and a Raspberry Pi 4 computer is used for target detection. “I want it to target like the Terminator,” Hanheum says. But don’t worry, the targets are merely 3D models that look like stick people.

Need more input

To assess the immediate environment and figure whether a target is in sight, Raspberry Pi 4 is connected to a Camera Module. Hanheum has coded a program in Python which is made to call upon hundreds of pictures of the intended target in order to assess whether or not something in front of the robot should be targeted.

▶ The two metallic legs of the robot have hinges at the knees, lending it the flexibility it needs to walk

▼ A Camera Module mounted on the top is used to assess targets



Checking the input from a Raspberry Pi Camera Module against a database of images allows the robot's AI to work out if an object is friendly or hostile

Hanheum has written his own code in Python for Raspberry Pi which draws upon three AI models

The short legs of the robot and its slow pace mean it noticeably moves from side to side when it walks

Quick FACTS

- ▶ The robot is built using metal parts
- ▶ It makes use of Raspberry Pi 4...
- ▶ ...to detect targets using a Camera Module and AI
- ▶ Making it walk required much manual experimentation
- ▶ This is Hanheum's third robot attempt in two years

“ I made paper legs to simulate a walking pattern ”

“It takes an image and analyses it using three AI models,” he explains. “This allows it to work out the proper steps such as turn right, go forward, attack.” Again, this involved some trial and error.

“I experimented with target detection when I built a robot that moved on four wheels,” he says. “That robot could recognise the target with a single camera and it would move towards something with its thin arms. But this robot is more advanced. The walking process is almost complete and the AI code is ready. It’s now just a matter of time.” [M](#)

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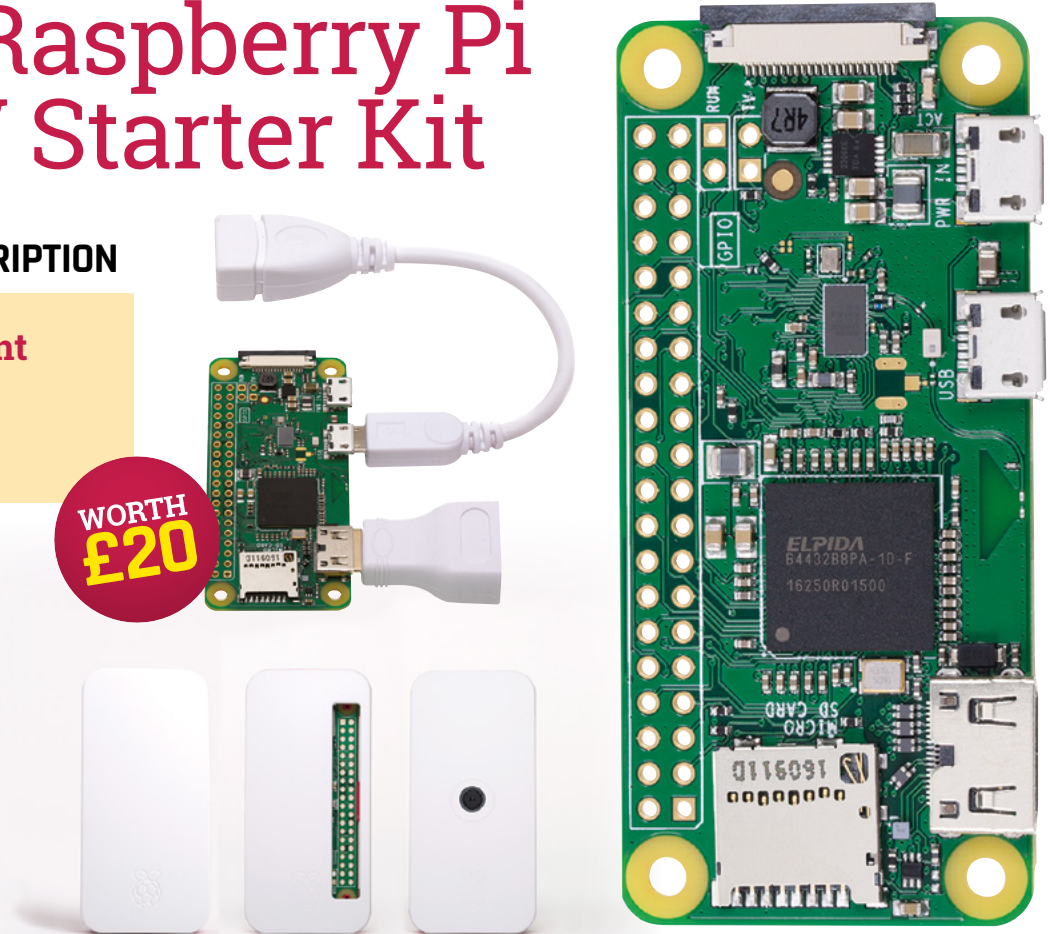
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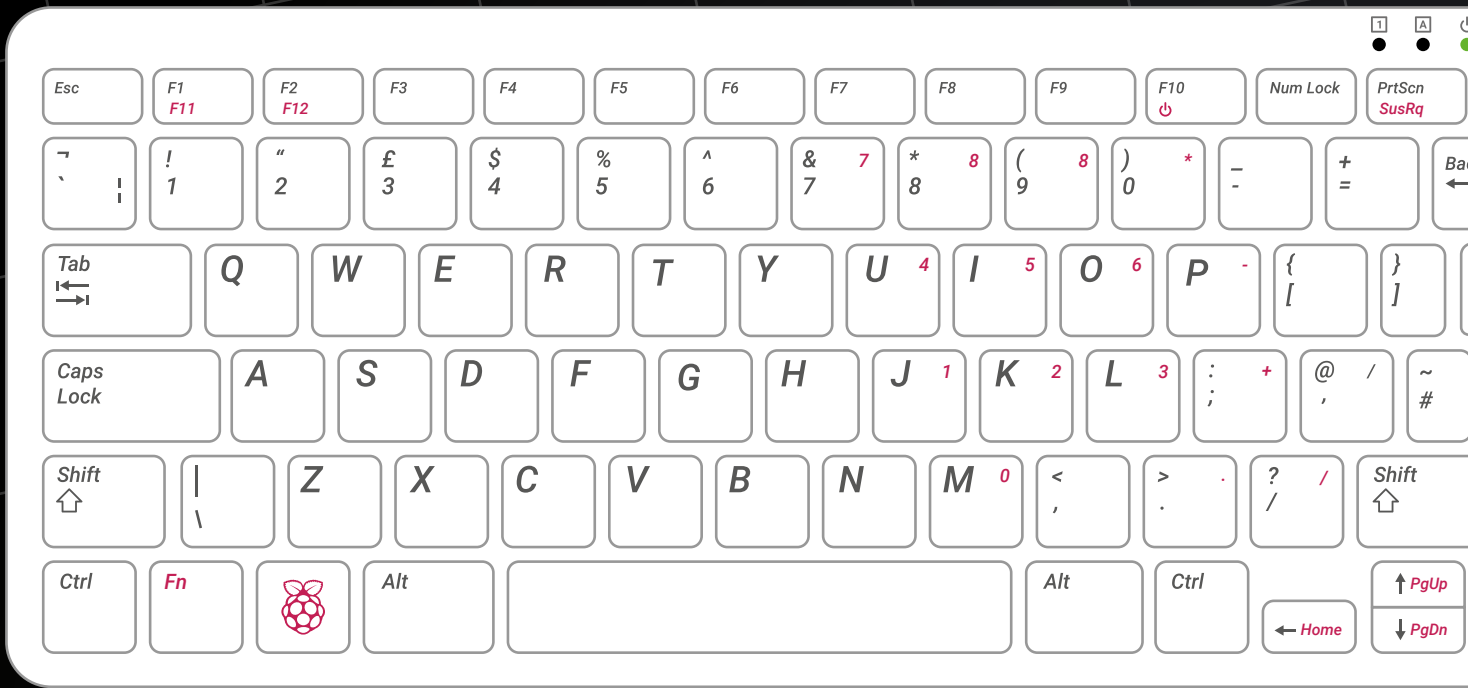


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RASPBERRY PI 400

PROJECTS & GUIDES

Put your new Raspberry Pi 400 to work, and learn to code and make with computers. By **Lucy Hattersley**

Raspberry Pi 400 is the greatest computer we've encountered in years. The seemingly simple act of fitting Raspberry Pi hardware inside the official keyboard has had a profound effect.

Raspberry Pi 400 is an all-in-one computer that's incredibly powerful, extremely low-cost, easy to use, packed with help and advice, and provides an incredible work and learning environment.

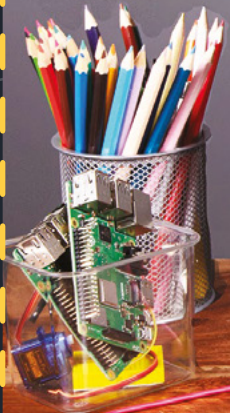
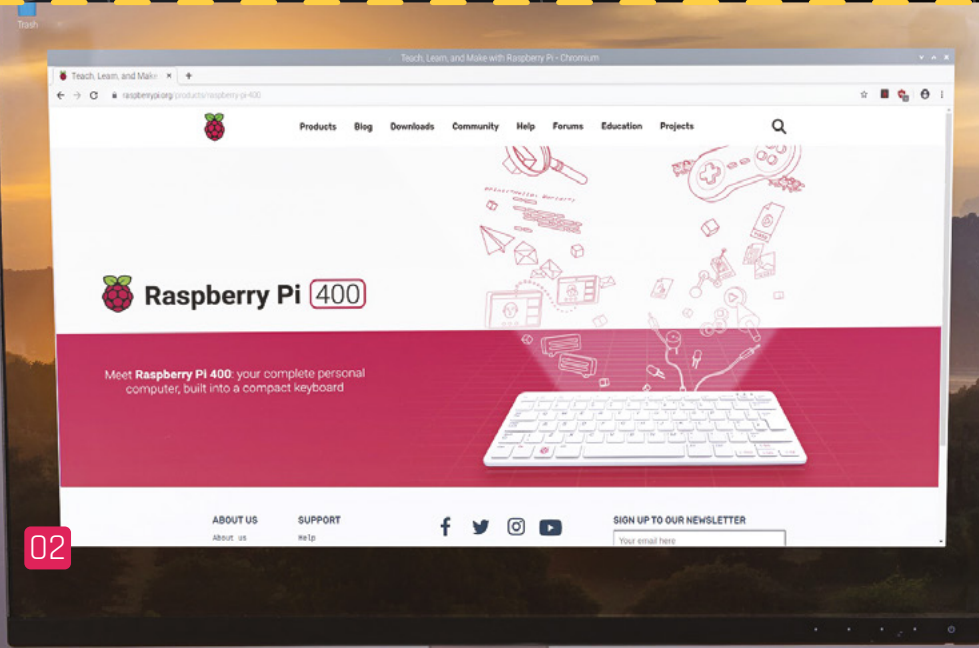
In this feature, we're going to look at using Raspberry Pi 400 for work, coding, and making. Its unique construction makes Raspberry Pi 400 an ideal tool for office work and code development, and the GPIO (general-purpose input and output) pins enable you to add new hardware and build your own electronics projects.

Powered by Raspberry Pi OS, a flavour of Linux, this all-in-one computer has a lot more

functionality than many new users imagine. If you are new to Linux, then you are in for a real treat. This popular operating system is used by office workers, developers, data scientists, and system administrators throughout the world. It's packed with office software every bit as good as you'd find on more expensive computers. And best of all, most of this software is free.

And because Raspberry Pi is designed to help people develop computer skills, you'll find Raspberry Pi OS is packed with beginner-friendly coding tools and advice.

We're going to turn Raspberry Pi 400 into a functional working tool to keep on your desk. We'll help you set it up for the office, then delve into coding tools, before looking at retro computing and electronics projects. Let's put your Raspberry Pi 400 to work.



01 Raspberry Pi 400 contains a powerful 1.8GHz ARM-based computer inside its keyboard

02 Raspberry Pi OS is a powerful Linux-based operating system packed with free software and tools for you to use and explore

03 Raspberry Pi Press provides a wealth of documentation for its computers, enabling you to learn everything from coding to electronics

RASPBERRY PI 400

AS A DESKTOP COMPUTER

Get to work with Raspberry Pi 400 with these tools and programs

Raspberry Pi 400 is a great work computer. In a short space of time, Raspberry Pi 400 has quickly become the default Raspberry Pi used by *The MagPi* team.

We produce a lot of words for this magazine and much of it we write in Google Workspace software tools. This article is being written on a Raspberry Pi 400 with Google Docs (docs.google.com).

Google Docs is a web-based suite of software with Microsoft Office-compatible word processing, spreadsheeting, and presentation software. You can import and export documents

on Raspberry Pi and work on them directly in the web browser.

Many folks prefer to use dedicated office software, and LibreOffice fills the Microsoft Office-shaped hole rather nicely. If it's not already installed, open Recommended Software (menu > Preferences), click the Office category, place a check next to LibreOffice, and click Apply. You'll then find the LibreOffice apps – Base, Calc, Draw, Impress, Math, and Writer – in the Office section of the Applications menu.

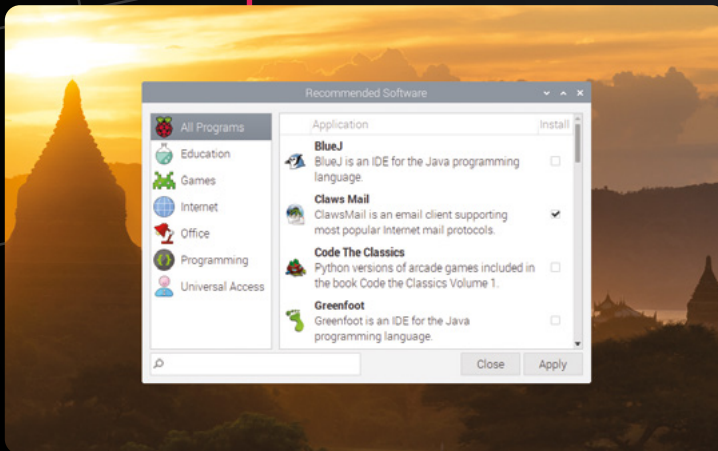
This suite of LibreOffice programs function in much the same way as their more commonly known Microsoft Office counterparts, and you can open, work on, and save Word, Excel, and other Office-suite documents.

Communication

Most email services can be accessed via the Chromium web browser, or you can install Claws Mail with Recommended Software. Other email programs can be found in Add / Remove Software. In *The MagPi* magazine issue #85 'Your next Desktop PC' feature, PJ Evans decided to use Evolution email (magpi.cc/85).

Open Add / Remove Software (menu > Preferences) and search for 'evolution' and it'll display the latest version, currently 'evolution-3.30.5-1.1'. Above this will be the description: 'groupware suite with mail client and organizer'. Place a tick in the checkbox next to it and click Apply.

You'll find the programs in the Applications menu under the Office and Internet submenus. Both have a Welcome Wizard that will guide you through the setup process (you may need to look up the Server and Username information from your email provider).



Recommended Software

Raspberry Pi OS comes with a program called Recommended Software that can quickly install a range of good software you might want. Click the Applications menu icon and choose Preferences, then Recommended Software. Place a tick next to any programs you want to install and click Apply.



Back issues

In *The MagPi* magazine issue #85 (magpi.cc/85), we looked at using Raspberry Pi as a desktop PC. That feature is packed with information on using Raspberry Pi for work. In *The MagPi* #93 (magpi.cc/93), we looked at using Raspberry Pi to work from home; the feature has great information on messaging and communication apps. All of our back issues are available as free PDFs, or you can buy them from our store: magpi.cc/issues.

Many communications programs have web interfaces, including Skype (web.skype.com) and Slack (app.slack.com) that can be used for instant messaging.

Photos and graphics

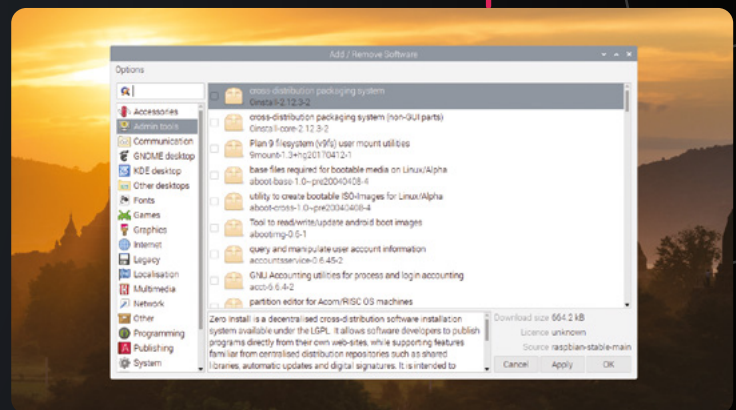
When it comes to editing images and photographs, your first port of call is the built-in Image Viewer program (menu > Graphics). A more complex graphics option is GNU Image Manipulation Program, which has a feature set similar to Adobe Photoshop. It is found in Add / Remove Software.

Management and to-do list software is often used via a web browser

Productivity tools

Management and to-do list software is often used via a web browser, and you may well be best served with an online service such as To-Do (todo.microsoft.com) or Keep (keep.google.com). However, if you prefer a native app then take a look at Planner (planner-todo.web.app).

Another program PJ Evans advocated in *The MagPi* is NextCloud (nextcloud.com), a fork of the popular open-source solution ownCloud. NextCloud enables you to set up your own productivity and file-sharing cloud solution,



Add / Remove Software

A huge range of software can be added to Raspberry Pi OS using the Add / Remove Software program. Click on the Applications menu icon and choose Preferences, then Add / Remove Software. Search for programs using the search bar or by clicking on the categories on the left. Place a tick next to any items you want and click Apply to install them.

similar to services like Dropbox, OneDrive, and Box. You can sign up for a NextCloud hosted provider, or set up your own server.

With the right software, Raspberry Pi 400 becomes a powerful home desktop computer, capable of handling office and work-related tasks.

LEARN TO CODE

WITH RASPBERRY PI 400

Raspberry Pi 400 is the ideal computer for learning to code and making digital projects

One reason many people pick up Raspberry Pi is to develop coding skills and learn about digital making (thanks to those juicy GPIO pins on the back that can be hooked up to jumper cables and a wide array of hardware).

Raspbian OS is built on top of Debian Linux, which is the ideal operating system for coding and making. Thanks to eight years of solid development, Raspberry Pi has a huge range of documentation, tutorials, and advice for budding programmers.

Everything you need to get started is included right out of the gate. Click the menu and choose the Programming tab and you'll discover IDE (integrated development environment) apps ready and waiting: Geany and Thonny.

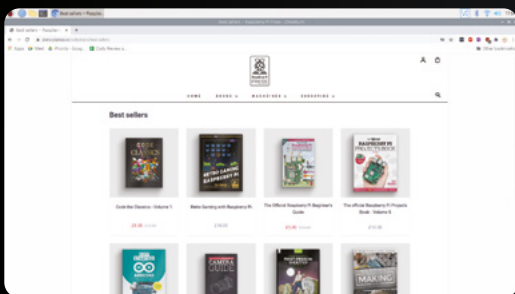
Thonny is our tool of choice. Designed exclusively for the Python programming language, it's set up to be as easy to use as possible, with powerful step-by-

step tools that enable you to walk through code and see exactly what each variable and object is doing.

Absolute beginners

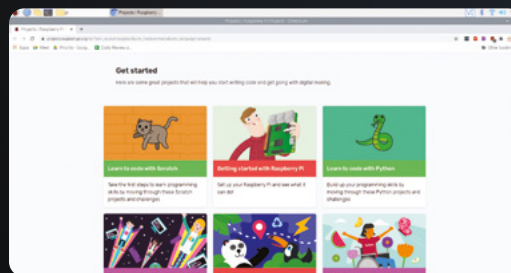
If you are completely unfamiliar with programming, then Scratch (scratch.mit.edu) is a good place to pick up basic concepts. You learn by dragging and dropping characters (known as 'sprites' and blocks of code onto a canvas. These code blocks work in the same way as text programming, but you don't have to worry about writing it all out correctly.

LEARN TO CODE RESOURCES



Raspberry Pi Press

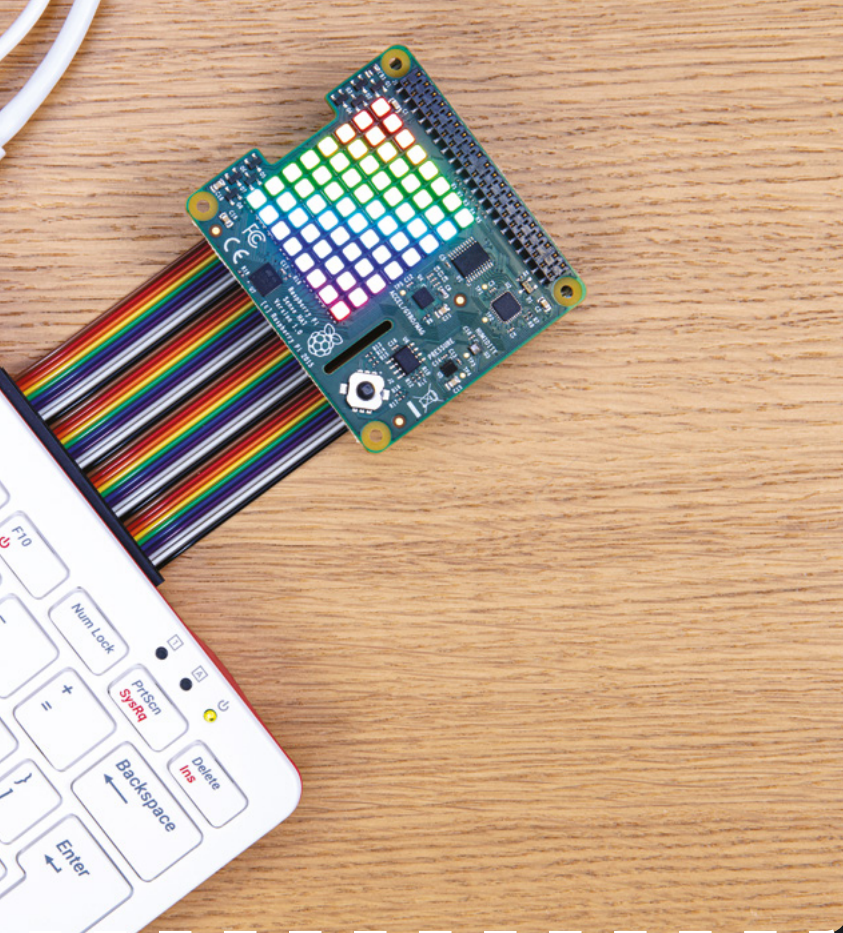
The Raspberry Pi Press store is packed with books and magazines. Open the web browser and visit magpi.cc/store to find a range of useful books.



Projects

Choose menu > Help > Projects to discover a wealth of online resources provided by Raspberry Pi. Learn to Code with Scratch and Learn to Code with Python are easy-to-learn courses packed with useful information for starters.





Scratch is designed for kids, but don't be put off. It's a great way to pick up the nuances of coding without getting lost in the syntax. Open Recommended Software and click on the Programming tab. Place a tick next to Scratch 3 and click Apply. There are other tools here worth looking at, including Mathematica, Sonic Pi, and Sense HAT Emulator. All of which will be handy on your coding journey.

▣ Scratch is designed for kids, but don't be put off ▣

How to get help

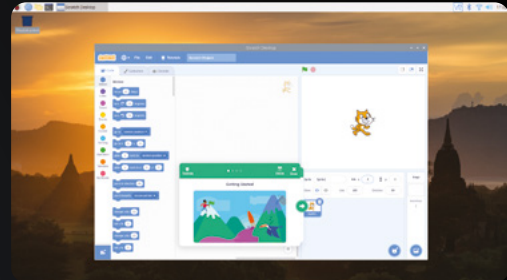
With software installed, you can start the learning process. Everything you need to learn coding with Raspberry Pi 400 is at your fingertips. Click on menu > Help > Projects and you'll find a range of starter guides for various coding languages.

Raspberry Pi Press has a huge selection of magazines and books to help you on your journey, and you can read them for free (magpi.cc/books). If you'd prefer to read these books in print, then most can be picked up for a reasonable cost directly from Raspberry Pi Press (magpi.cc/store): *Code the Classics*, *Create Graphical User interfaces with Python*, and *Simple Electronics with GPIO Zero* are just three books that will help you get started.

Learning to code is a life-changing experience, and Raspberry Pi 400 will help you on your way. Good luck!

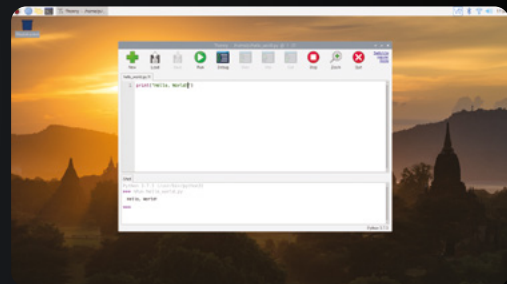
THREE TOOLS

Here are three programming tools you'll want to use with Raspberry Pi 400:



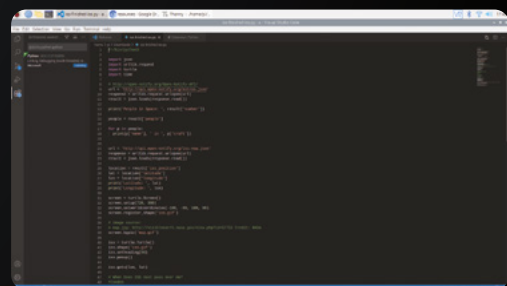
Scratch

For absolute beginners, Scratch enables you to explore coding ideas without messing up with text and having to debug syntax errors. Add Scratch 3 to Raspberry Pi OS using Recommended Software. Click the Tutorials button and choose Getting Started to begin learning.



Thonny

When you start learning to code with Python, this IDE enables you to explore code in a highly visual and easy-to-use manner. Run code one line at a time and explore the changes code is having on variables and objects. Thonny is installed by default, click on menu > Programming > Thonny IDE.



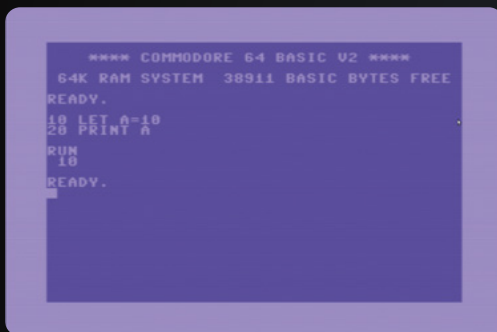
Visual Studio Code

Microsoft's Visual Studio Code (code.visualstudio.com) is a recent addition to Raspberry Pi and is a powerful coding environment packed with support and features for advanced coders. Visit magpi.cc/vscode and click download on ARM (or ARM64) on the .deb row.

RASPBERRY PI 400

PROJECTS

Build something amazing with Raspberry Pi 400



Go retro with Raspberry Pi 400

The all-in-one design of Raspberry Pi 400 brings to mind classic computers from the 1980s such as the BBC Micro, Commodore 64, Commodore Amiga, and Sinclair Spectrum.

The modern innards of Raspberry Pi 400 are so much more powerful than these computers, which means it can quickly emulate the functionality of any of the machines. So if you have a hankering to rediscover BBC BASIC, or to PEEK and POKE the memory address of a C64, then emulation is the way forward.

RetroPie is the most popular way to turn a Raspberry Pi into a range of classic computers, such as the Commodore 64, Spectrum, and Amiga. It's mostly designed for the running of ROM files (typically video games). You can flash a microSD card with the RetroPie software using Imager (magpi.cc/imager) and we have a guide to setting up the software (magpi.cc/retropie). A detailed guide to RetroPie can be found in *The MagPi* magazine #95 (magpi.cc/95). Meanwhile, *The MagPi* #88 (magpi.cc/88) has a guide to Retro Computing packed with information. For a more detailed guide to retro computing with Raspberry Pi 400, see KG Orphanides' tutorial on page 52.



Alert! Copyright

Many ROMs (video game files) are protected by copyright. Be mindful of copyright laws in your area, and stick to legal ROMs and homebrew games. magpi.cc/legalroms

Rediscover RISC OS

Fancy a flashback to the past with an ultra-modern flavour? RISC OS was the original operating system for the Acorn Archimedes system released in 1987. Imagine a divergent timeline where RISC OS had been upgraded and improved and was still around.

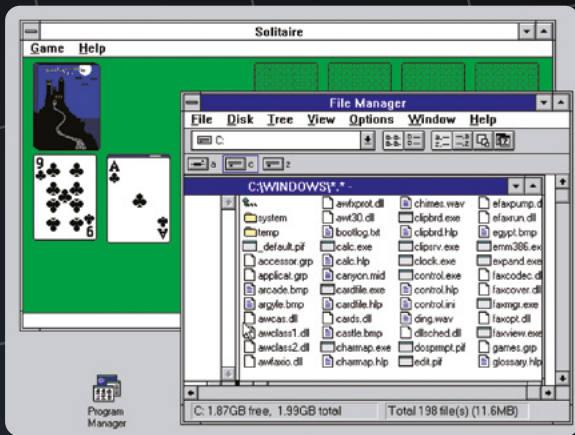
Good news! That world exists. RISC OS Open is an operating system for ARM-based computers (like our Raspberry Pi 400). It's ultra-light, ultra-fast, and packed with modern features like networking and internet. It's not without a few faults, though; wireless LAN support for Raspberry Pi is still lacking, for example. But as an experience in what could have been, RISC OS is a fun diversion.



Retro Gaming with Raspberry Pi

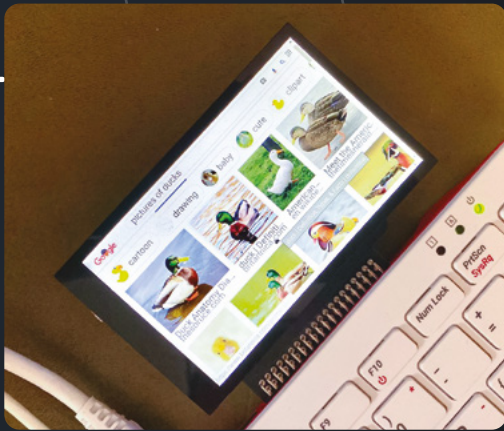
Take a look at our retro gaming book for more information on running retro games on your Raspberry Pi 400.





Run Windows on Raspberry Pi

KG Orphanides has been looking at DOS emulation and classic PC gaming with Raspberry Pi using DOSBox-X, GOG, and Innoextract. It's a great project for Raspberry Pi 400 that enables you to explore classic Windows systems and play retro games from earlier decades. Start with *The MagPi* magazine issue 95 (magpi.cc/95).

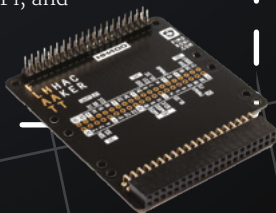


Play around with HATs

HATs (hardware attached on top) are a type of electronic board specially designed to work with Raspberry Pi. They typically work as soon as you plug them in without any additional setup.

Most HATs are designed to fit Raspberry Pi 4 and Raspberry Pi Zero-style hardware. You can connect them to Raspberry Pi 400, but they stand vertically and face backwards, so it's not ideal.

One solution is a ribbon cable (magpi.cc/ribboncable), or you can buy a device such as Pimoroni's Flat HAT Hacker (magpi.cc/flathathacker). This is used to attach HAT hardware to Raspberry Pi, and Pimoroni suggests using it with a HyperPixel display (magpi.cc/hyperpixel).



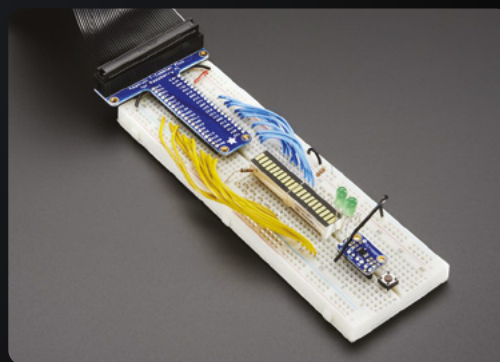
Discover electronics with GPIO

You can attach jumper cables directly to the GPIO (general-purpose input and output) header of Raspberry Pi 400 (just as you can any other Raspberry Pi).

GPIO is one of the things that makes Raspberry Pi a capable computer. With the GPIO pins, you can use Raspberry Pi to control electronic devices, add buttons and screens, and control motors. Learn GPIO and you can turn Raspberry Pi into a robot or a home security system, or just about anything you put your mind to.

There are 40 pins in total, and look closely at the GPIO pins and you will see 'PIN1' and 'PIN40'. You can attach jumper cables directly to the pins on Raspberry Pi, and use the other end to hook up to electronic components.

It is also possible to use a device known as a T-Cobbler with a breadboard to practise electronics. This can be used to extend and protect the GPIO pins on Raspberry Pi (magpi.cc/tcobbler). Check out *Simple Electronics with GPIO Zero* (magpi.cc/gpiozerobook) to start learning electronics.



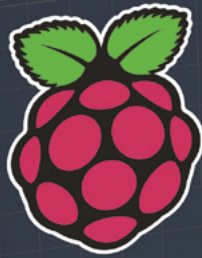
Alert! Power Down

Make sure you switch off Raspberry Pi before connecting HAT hardware or cables to the GPIO pins

magpi.cc/gpio

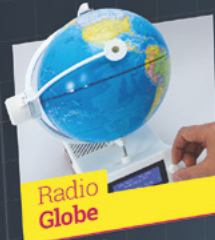
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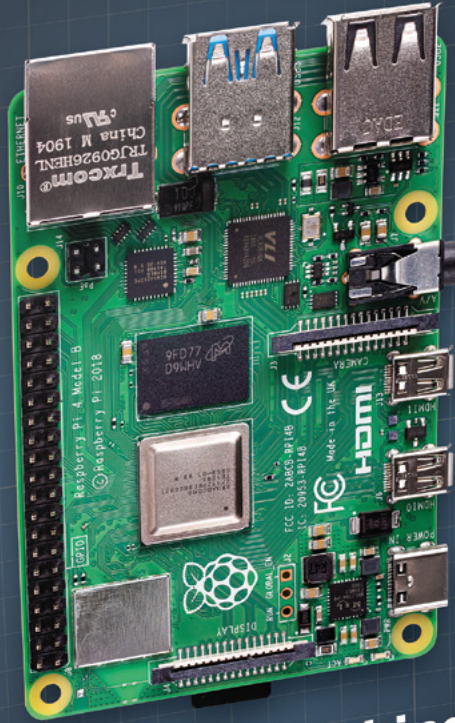
Magic Mirror



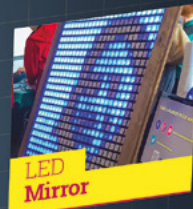
Reachy Robot



Hot Spotter Drone



High Quality Camera



LED Mirror



Dual-screen Instaclock

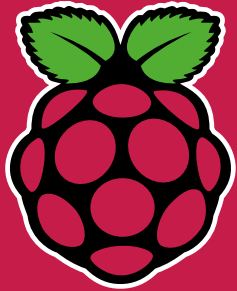


Introducing RASPBERRY PI 400

Make amazing things with Raspberry Pi

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

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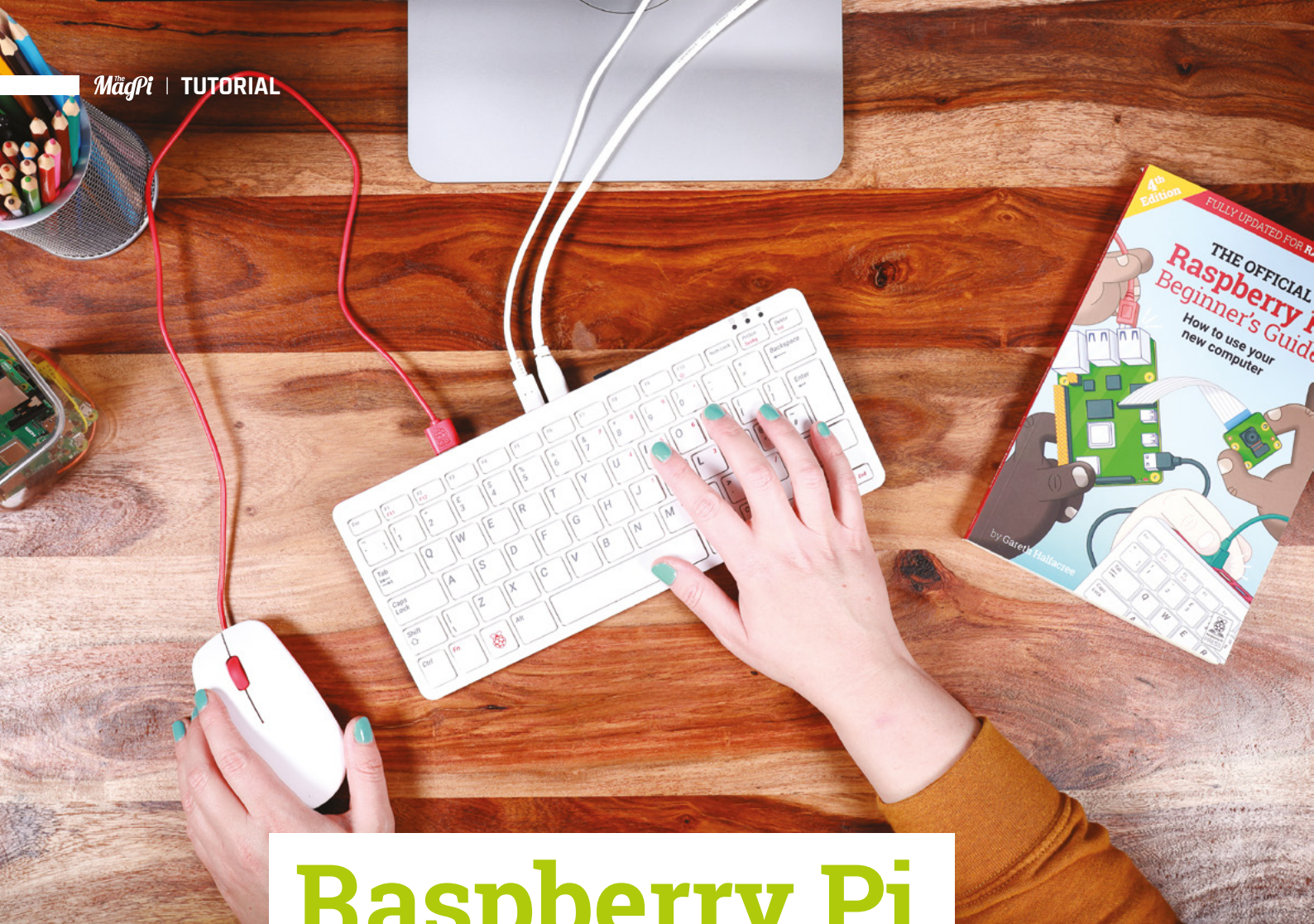
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Raspberry Pi QuickStart Guide

Setting up Raspberry Pi is pretty straightforward. Just follow the advice of **Rosie Hattersley**

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

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

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

What you need

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

A Raspberry Pi

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

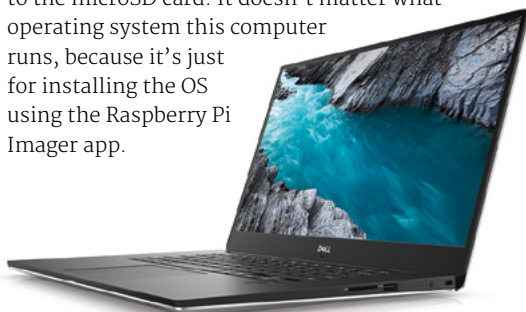


8GB microSD card

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

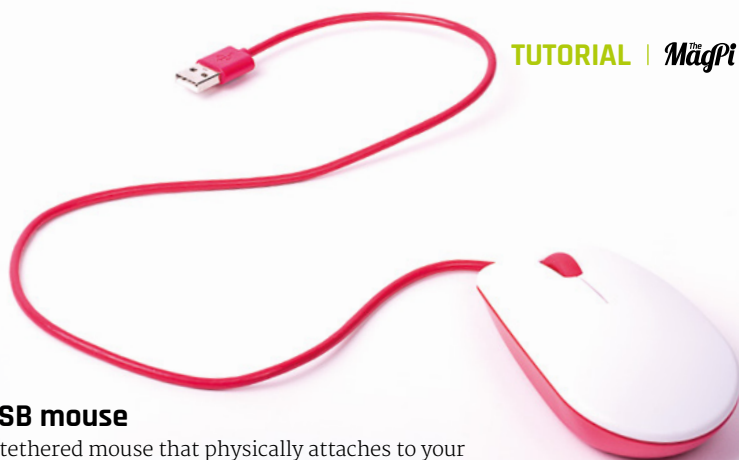
Windows/Linux PC or Mac computer

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



USB keyboard

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



USB mouse

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

Power supply

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



Display and HDMI cable

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



USB hub

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



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

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



Set up Raspberry Pi 400

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

01 Connect a mouse

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

02 Attach the micro-HDMI cable

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

03 The microSD

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



Set up Raspberry Pi

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

01 Hook up the keyboard

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

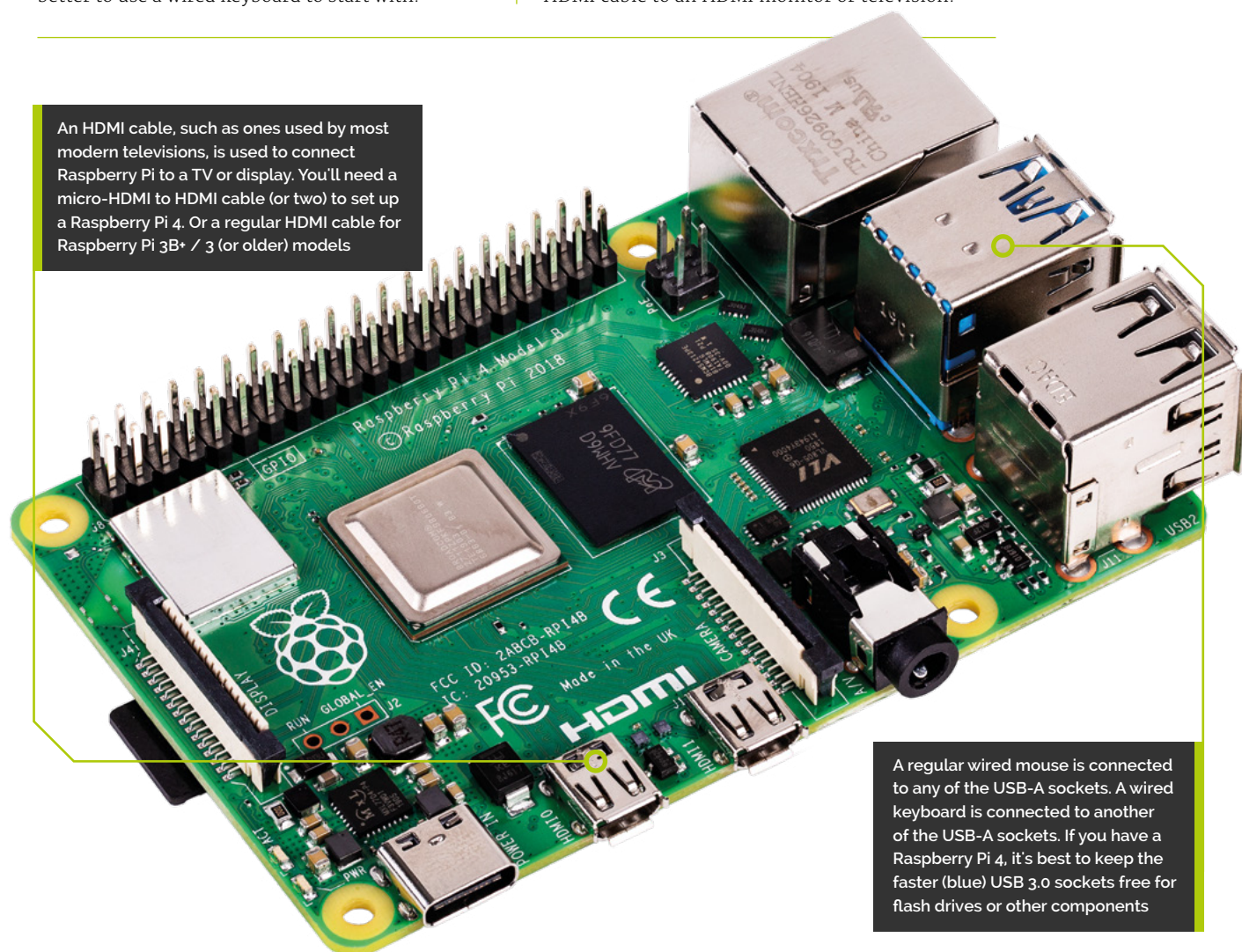
02 Connect a mouse

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

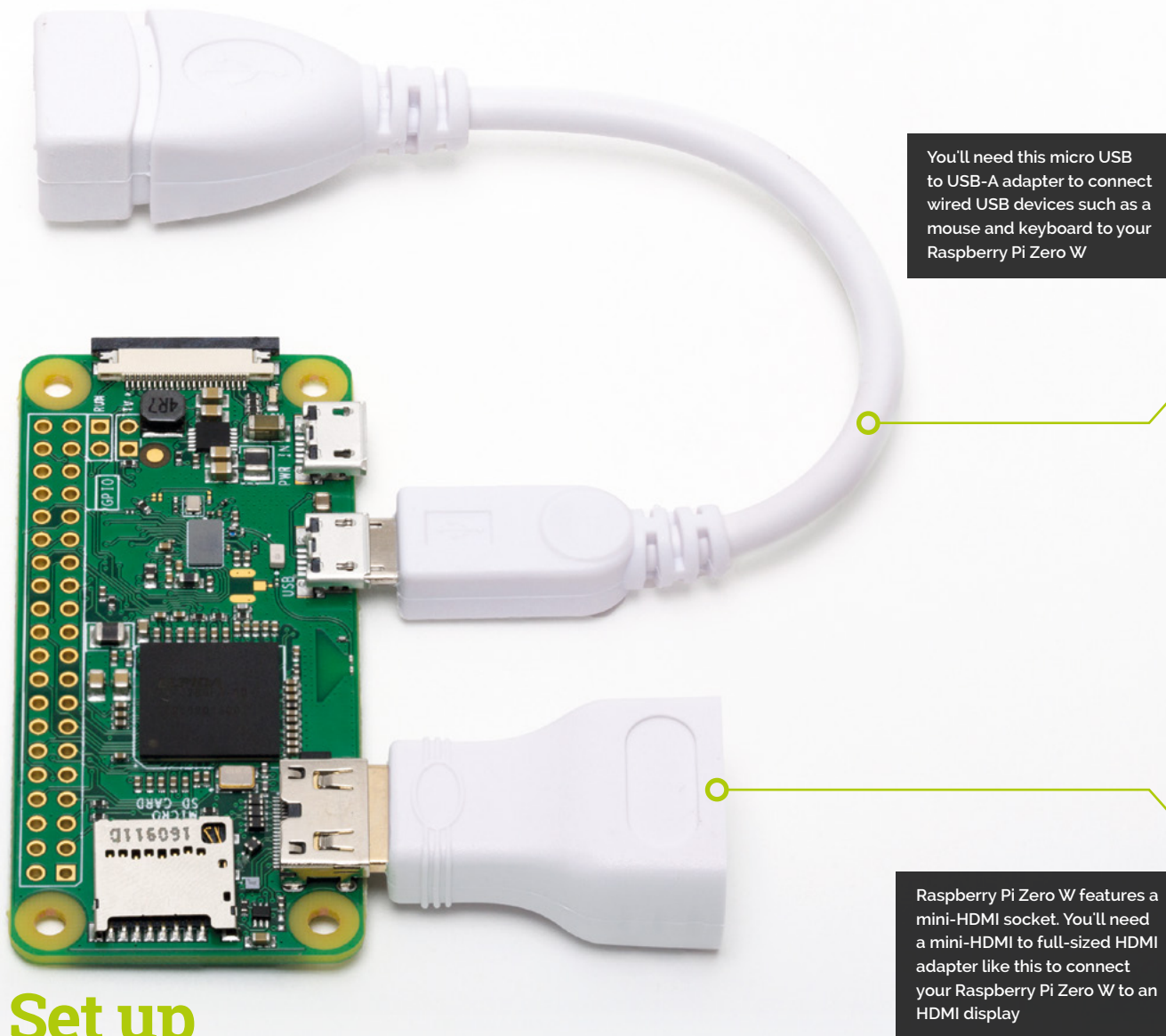
03 HDMI cable

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

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



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



You'll need this micro USB to USB-A adapter to connect wired USB devices such as a mouse and keyboard to your Raspberry Pi Zero W

Raspberry Pi Zero W features a mini-HDMI socket. You'll need a mini-HDMI to full-sized HDMI adapter like this to connect your Raspberry Pi Zero W to an HDMI display

Set up Raspberry Pi Zero

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

01 Get it connected

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

02 Mouse and keyboard

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

03 More connections

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

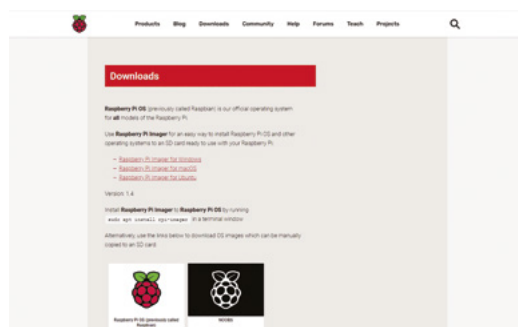
First, insert your microSD card into Raspberry Pi

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

Set up the software

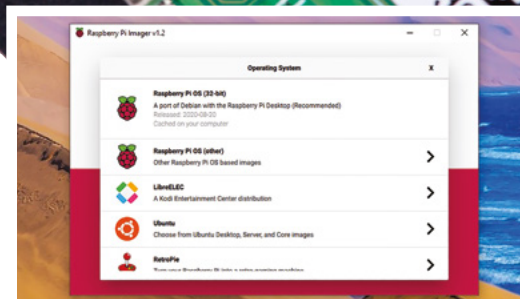
Use Imager to install Raspberry Pi OS on your microSD card and start your Raspberry Pi

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



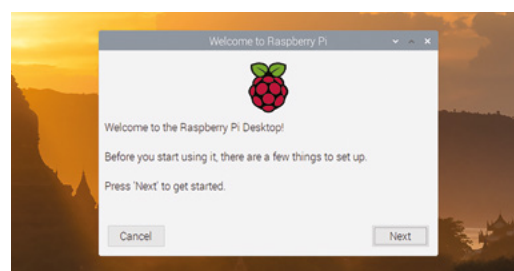
01 Download Imager

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



02 Choose OS

Click on 'Choose OS' in Raspberry Pi Imager and select Raspberry Pi OS (32-bit). Click 'Choose SD card' and select the microSD card you just inserted (it should say 8GB or the size of the card next to it). Click on 'Write'. Your computer will take a few minutes to download the Raspberry Pi OS files, copy them to the microSD card, and verify that the data has been copied correctly.



03 Set up Raspberry Pi

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

Top Tip

Is your card ready?

You don't need to do this if your Raspberry Pi came with a card pre-written with Raspberry Pi OS.

You'll Need

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

Use a retro DB9 joystick with Raspberry Pi 400



K.G. Orphanides

K.G. makes, writes about, and helps to preserve unusual gaming software and hardware.

@KGOOrphanides



Warning!
Copyright

Many (but not all) Spectrum games can be legally downloaded. See our Legal ROMs page for more information. magpi.cc/legalroms

You'll Need

- ▶ DB9 joystick
- ▶ DB9 breakout board magpi.cc/db9breakout
- ▶ 10–20 male-to-female jumper cables magpi.cc/mfjumper
- ▶ DB9 GPIO driver source magpi.cc/db9gpioit

Get the classic ZX Spectrum experience with Raspberry Pi 400 and a GPIO joystick

Raspberry Pi 400 is, with its integrated keyboard and tweaked performance, a modern home micro. This month, we pay tribute to one of the computers that helped inspire its look by emulating Sinclair's ZX Spectrum, complete with the latest games and retro joysticks connected via GPIO. These use the D-sub connector popularly called DB9, also known as DE-9.

01 Install the Free Unix Spectrum Emulator

Also available in the RetroPie emulation distro we've used in previous tutorials, the FUSE ZX Spectrum emulator can be found in Raspberry Pi OS's standard repositories, so installation is a bare minimum of fuss. Open a Terminal window and type:

```
sudo apt install fuse-emulator* spectrum-roms opense-basic libspectrum8
```

This will install FUSE, its GTK and SDL front ends, and both open-source system ROMs and the original Spectrum system ROMs. Permission has been granted for free modification and distribution of the latter (magpi.cc/SpecROMs).

While the open-source ROM can only handle a limited selection of files, that spectrum-roms package will allow you to play a wide array of games, including the latest generation of technically spectacular releases for the platform.

02 Test FUSE

Next, we'll make sure FUSE is working with the ZX Spectrum port of L'Abbaye Des Morts. In a Terminal, type:

```
wget https://spectrumcomputing.co.uk/zxdb/sinclair/entries/0030109/AbbayeDesMorts.tzx.zip
```

fuse-sdl

Press **F2** to open FUSE's file browser, navigate to **AbbayeDesMorts.tzx.zip**, and press **ENTER**. The game should load and run automatically. For full-screen mode, press **F1**, go to Options, and select 'Full screen'. Take note of the Filter option in the same menu, which lets you choose the emulator's upscaling method: 'TV 3x' gives you some pleasing scan lines and the correct aspect ratio.

“ Wiring up the DP9 port to Raspberry Pi's GPIO is a fairly simple process ”

03 Wire up your joystick port

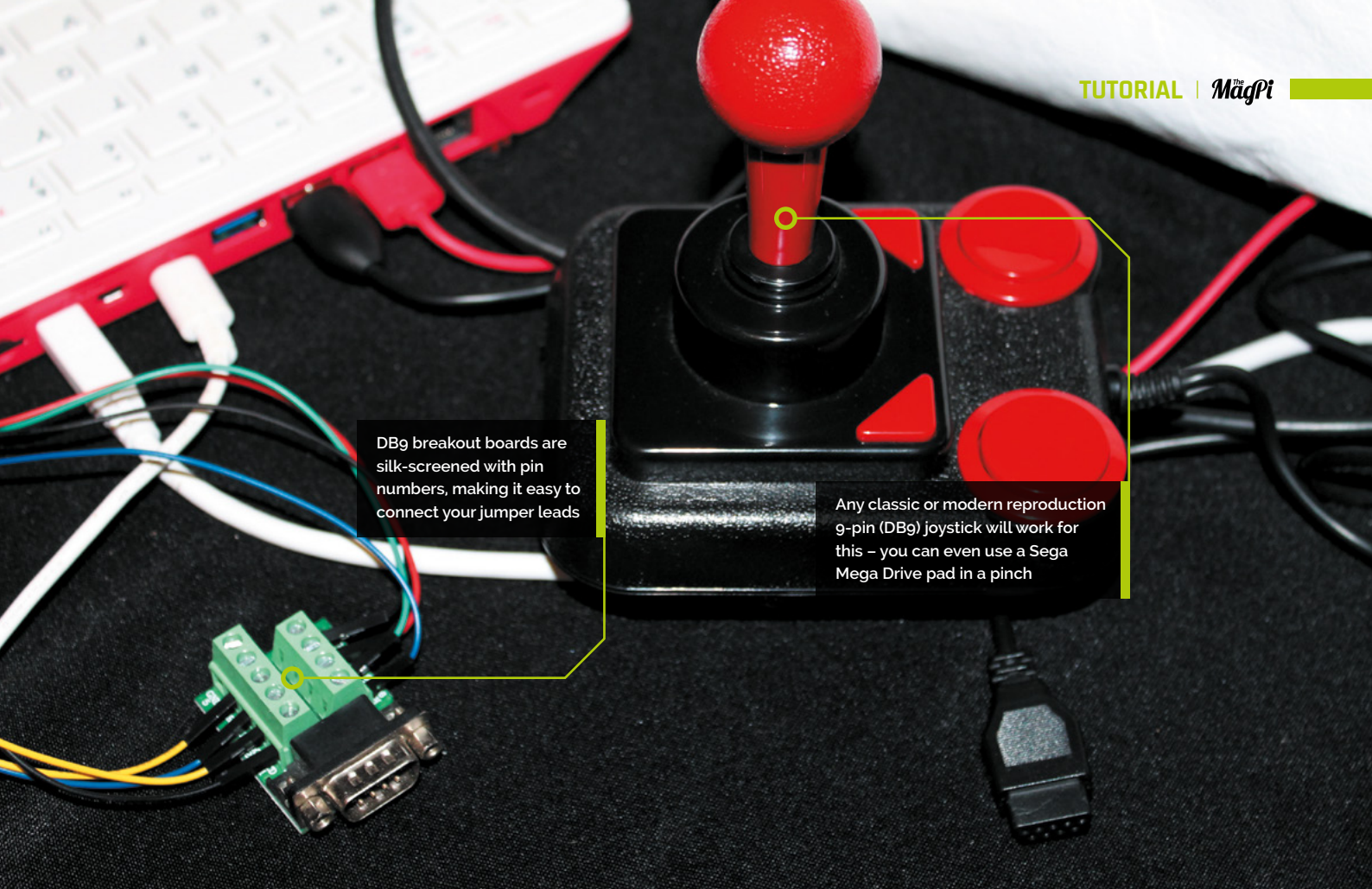
Standard DB9 connectors split the nine pins of your cable into nine screw-down terminals. We found it most convenient to use male-to-female jumper cables for this, clamping the male tips into our DB9 breakout connector.

For a classic single-button joystick like the Competition Pro Retro we used, pin 1 is up, pin 2 is down, pin 3 is left, pin 4 is right, and pin 6 is fire. Pin 8 connects to ground – we recommend using a green cable for it. Some joysticks may require you to connect port 7 to a 3.3V power connector on the GPIO, but the Competition Pro does not.

See the 'DB9 pins' box (overleaf) for an at-a-glance DB9 connection table.

04 Wire up Raspberry Pi

Wiring up the DB9 port to Raspberry Pi's GPIO is a fairly simple process, although you'll have to do some careful pin counting. On Raspberry Pi 400, pin 1 is at the top right of the horizontally



DB9 breakout boards are silk-screened with pin numbers, making it easy to connect your jumper leads

Any classic or modern reproduction 9-pin (DB9) joystick will work for this – you can even use a Sega Mega Drive pad in a pinch

oriented GPIO port and pin 40 is at the bottom left. Remember that GPIO numbers don't correspond with pin position numbers.

For a reminder of where everything is, open a Terminal and type: `pinout`.

Our diagram (**Figure 1**, overleaf) shows where the female jumpers connected to your DB9 port need to go on Raspberry Pi. For a single one-button joystick, up goes to GPIO 4, down to GPIO 7, left to GPIO 8, right to GPIO 9, and fire to GPIO 10.

05 Build the DB9 joystick driver

Let's build the driver. Enter this in a Terminal window:

```
sudo apt install dkms raspberrypi-kernel-headers
git clone https://github.com/marqs85/db9_gpio_rpi.git
cd db9_gpio_rpi
sudo cp -r db9_gpio_rpi-1.2 /usr/src/db9_gpio_rpi-1.2/
sudo dkms add db9_gpio_rpi/1.2
sudo dkms build db9_gpio_rpi/1.2
sudo dkms mkdeb db9_gpio_rpi/1.2 --source-only
sudo modprobe --first-time db9_gpio_rpi map=1,1
```

pullup.sh

► Language: **Bash**

DOWNLOAD THE FULL CODE:

 magpi.cc/pullupfix

```
001. #!/bin/bash
002. # fix for db9_gpio_rpi driver issue https://github.com/marqs85/db9_gpio_rpi/issues/8
003. # RPi 4 and 400 need this tweak to speak to db9_gpio_rpi gpio connected controllers as some inputs need explicit pullup
004. # ensure that you're applying the pullups to the correct pins - this is for a standard deployment of the driver
005. #
006. # Use:
007. # chmod pullup.sh +x
008. # add /path/to/pullup.sh to /etc/rc.local to load on boot
009.
010. # Joyport /dev/input/js0
011. raspi-gpio set 4 ip pu
012. raspi-gpio set 7 ip pu
013. raspi-gpio set 8 ip pu
014. raspi-gpio set 9 ip pu
015. raspi-gpio set 10 ip pu
016. raspi-gpio set 11 ip pu
017. raspi-gpio set 14 ip pu
018. # Joyport /dev/input/js1 - if we connect a second joystick
019. raspi-gpio set 15 ip pu
020. raspi-gpio set 17 ip pu
021. raspi-gpio set 18 ip pu
022. raspi-gpio set 22 ip pu
023. raspi-gpio set 23 ip pu
024. raspi-gpio set 24 ip pu
025. raspi-gpio set 25 ip pu
```

DB9 pins

For a one-button joystick – including multi-button sticks with only single-button functionality – connect these pins on your DB9 breakout board.

DB9 pin	Joystick function
1	UP
2	DOWN
3	LEFT
4	RIGHT
5	-
6	FIRE
7	-
8	GROUND
9	-

That `map` option defines what kind of joystick you're using, with each number classifying a different type of joystick. As we're using a one-button joystick, `map=1,0` would do it, but `1,1` means we can connect a second stick of the same type to a second port.

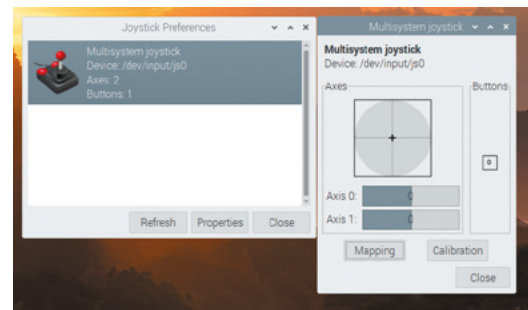
“ Although many Spectrum games support joysticks, you'll often have to enable support for these ”

06 Test your joystick

Building and loading the driver won't quite get us to a functional joystick, as the driver isn't fully compatible with Raspberry Pi OS's recent use of `raspi-gpio` instead of `gpio`. However, this is a great time to test your joystick to make sure that it's wired up correctly.

```
sudo apt install jstest-gtk
jstest-gtk
```

You should see your joystick in the peripherals list. When you click into it, if you're using a Competition Pro Retro or similar joystick, you're likely to find that the fire button is jammed on and that the horizontal x axis is stuck at the left.



▲ The `jstest-gtk` program allows you to test your joystick and also indicates whether it's working as it's supposed to

07 Pull-ups are good for you

This is because your GPIO needs to be set up to handle the joystick's pull-up switches. On a standard DB9 GPIO configuration, the script you'll find at magpi.cc/pullupfix will do this for you. Create it using your preferred text editor and save it somewhere handy. We've put ours in `/home/pi/pullup.sh`. Test it by running:

```
sh /home/pi/pullup.sh
jstest-gtk
```

If the joystick is now aligned properly and the button isn't stuck on, you're in business.

```
chmod +x /home/pi/pullup.sh
```

Finally, let's load those pull-up settings on boot.

```
sudo mousepad /etc/rc.local
```

Above the `exit` line, enter the following:

```
/home/pi/pullup.sh
```

You can also place the pull-up code directly in `rc.local` if you wish.

08 Load on boot

Once you're satisfied that your joysticks work, you'll want to load the driver module on boot.

```
sudo mousepad /etc/modules
```

...and add:

```
db9_gpio_rpi
```

After saving and exiting the file, enter:

```
sudo mousepad /etc/modprobe.d/db9.conf
```

This file should contain the following line:

Top Tip

GPIO reference

If you're flummoxed by GPIO pin numbering, see the official docs at magpi.cc/gpio.

```
options db9_gpio_rpi map=1,1
```

If you're using a different joystick and configuration, you'll need an appropriate map, and possibly some extra GPIO connections, which you can find at magpi.cc/db9gpio.

Reboot Raspberry Pi and use `jstest-gtk` to ensure that everything is working as it should. You can now use the driver as a generic controller input device.

09 FUSED joysticks

FUSE doesn't enable joystick support by default, so we'll have to set that up. Run `fuse-sdk`, then press **F1** for the menu. Go to Options > Peripherals > General. Press **SPACE** to enable Kempston joystick support, then press **ENTER**.

Press **F1**, then Navigate to Options > Peripherals > Joysticks and make sure both Joystick 1 and Joystick 2 are set to Kempston. If not, press **ENTER**, press **ENTER** again to open the Joystick type options, navigate to Kempston on the list, and press **ENTER** again.

Note that some games may default to using Joystick 2, so you'll want to configure both, even if you only have a single stick connected.

When you're happy with your settings, open the Options menu and select Save.

10 Game configuration

Although many Spectrum games support joysticks, you'll often have to enable support for these. *L'Abbaye des Morts* enables joystick support by default, but its menus provide a good example of what to look for.

Load the game and then press **C** on the keyboard to access the control configuration. Pressing **1** here enables and disables Kempston joystick support. In other titles, you may need to explicitly choose to use your joystick to control the game if you want it to work.

11 Get game

The Spectrum's been a long-time homebrew favourite, with software continuing to come out for years past its original availability. There's been a resurgence in popularity of the platform with the release of a number of successors, most recently the ZX Spectrum Next.

As ever, the indie-friendly itch.io digital distribution platform is one of the best places

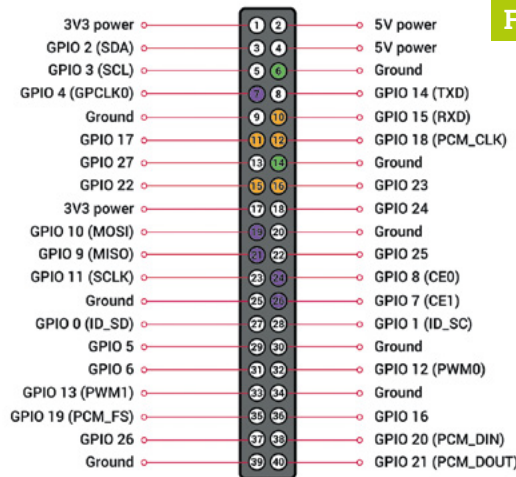


Figure 1

Figure 1 GPIO connection points for two single-button joysticks, corresponding to the 'GPIO connections' table (below). Joystick 1 is purple, joystick 2 is orange. Use your choice of ground pins for each controller: ground pins 6 and 14 are marked in green here

to find both free and commercial releases for the Spectrum, and we've put together a list at magpi.cc/zxspectrumgames.

12 Boot to black

Finally, let's start FUSE on boot for that authentic Spectrum ambience. In `/home/pi/.config/autostart` create a text file called `fuse.desktop`. If the directory doesn't exist, create it. Add the following lines to your new file:

```
[Desktop Entry]
Type=Application
Name=FUSE
Exec=/usr/bin/fuse-sdl --full-screen
```

You can exit FUSE at any point to return to Raspberry Pi OS's familiar desktop. **M**

Top Tip

Get in touch

Is retro gaming your hobby? Drop KG a message on Twitter @KGOphanides if you have any early-2000s physical Linux game releases.

GPIO connections

GPIO connection table for two one-button joysticks. The `db9_gpio_rpi` driver uses these pins by default for single-button joysticks. You will also need a ground connection for each.

BUTTON	Joystick 1 GPIO PIN	Joystick 2 GPIO PIN
UP	GPIO 4	GPIO 15
DOWN	GPIO 7	GPIO 17
LEFT	GPIO 8	GPIO 18
RIGHT	GPIO 9	GPIO 22
FIRE	GPIO 10	GPIO 23

Build a Home Assistant: home automation



PJ Evans

MAKER

PJ is a writer, software engineer and tinkerer. His coffee machine may have become sentient.

@mrpjevs

Now you have the basics down, it's time to up your game and create a truly automated home

In the previous two tutorials we've covered the basics of getting Home Assistant up and running. Hopefully, you can now command lights with a wave of a smartphone (well, maybe not a wave, let's be careful). It's all very cool, but really only the tip of the iceberg when it comes to true home automation. In this final part of the series, we aim to fire your imagination with the possibilities that your new setup offers and show you some of the amazing things you can do with Home Assistant. It's so much more than just switching lights on and off.

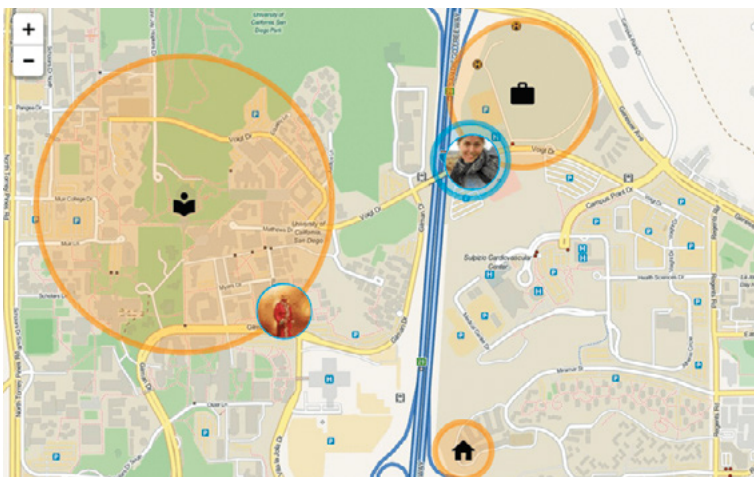
into its own when you start adding inputs into the mix. You can also add motion sensors, weather stations, smartphone location, and smart doorbells such as Ring. HA provides the tools to capture and manipulate the data. The community works very hard to add all kinds of devices and you can even create your own using simple, yet powerful, protocols such as MQTT. A useful approach to take is to capture as many inputs as you can without necessarily doing anything with the data. That way, when you have a brainwave, you just need to link inputs to outputs.

▼ When you combine Home Assistant with its iOS or Android apps, you can add location into your automations

01 Get some input So far we've been manually controlling lights and switches. Good, but hardly true automation. Home Assistant (HA) really comes

02 Automation magic Reacting to inputs with events is known in HA, funnily enough, as *automation*. In previous editions of *The MagPi* we created automations based on time and position of the sun, but you can react to any kind of input. Best of all, you have 100% control over what happens. HA's system for building an automation is simple and intuitive, but if you want something really special, you can even add custom code. So, if you want the kettle to start boiling when you're within a mile of the house, your partner is out, and it's a Thursday in winter, then you can.

03 Create a scene Home Assistant has a great feature called Scenes. Let's say you want to set things up 'just so' for a romantic dinner. You've got some cool backlighting, the main lights will need to be





Screen down, projector on, and play a movie all in one press? No problem for Home Assistant

Use Home Assistant's scenes to set colour and brightness of smart lights without fuss

dimmed, and your favourite metal playlist needs to be turned up to 11. Scenes will allow you to do all that with a single press of a button. You can set up a group of lights and switches easily in the user interface, but you can also get clever with a bit of code. By hooking up scenes with automations, you can 'set a scene' based on time or location. Clever stuff.

04 Stick to the script

If you fancy getting a bit more advanced with Home Assistant, the built-in scripting capability is definitely worth your attention. You can use scripts to trigger a sequence of events and you can even choose how they are executed: in parallel, in series, or even a combination. You can query sensors to make dynamic adjustments (say, lighting levels based on an outdoor light sensor) and you can even send notifications when things happen. Scripts are coded in YAML, a markup language that uses indentation similar to Python, so Raspberry Pi coders should feel right at home.

05 Helpers gonna help

So what if you need not just to switch different lights on or off, but at different levels of brightness, or even colour? It might be a bit fiddly to manually set a level on each group of lights, and then the colour. Your solution is to create a helper. Helpers are UI controls that can be set up to fire 'events' that you can define. For example, our problem here could be solved by creating a drop-down helper and defining each drop-down as the scene we need. We could have 'Evening', 'Cooking', or 'Disco Kitchen'. Each state can be linked to a scene to automatically set everything up.

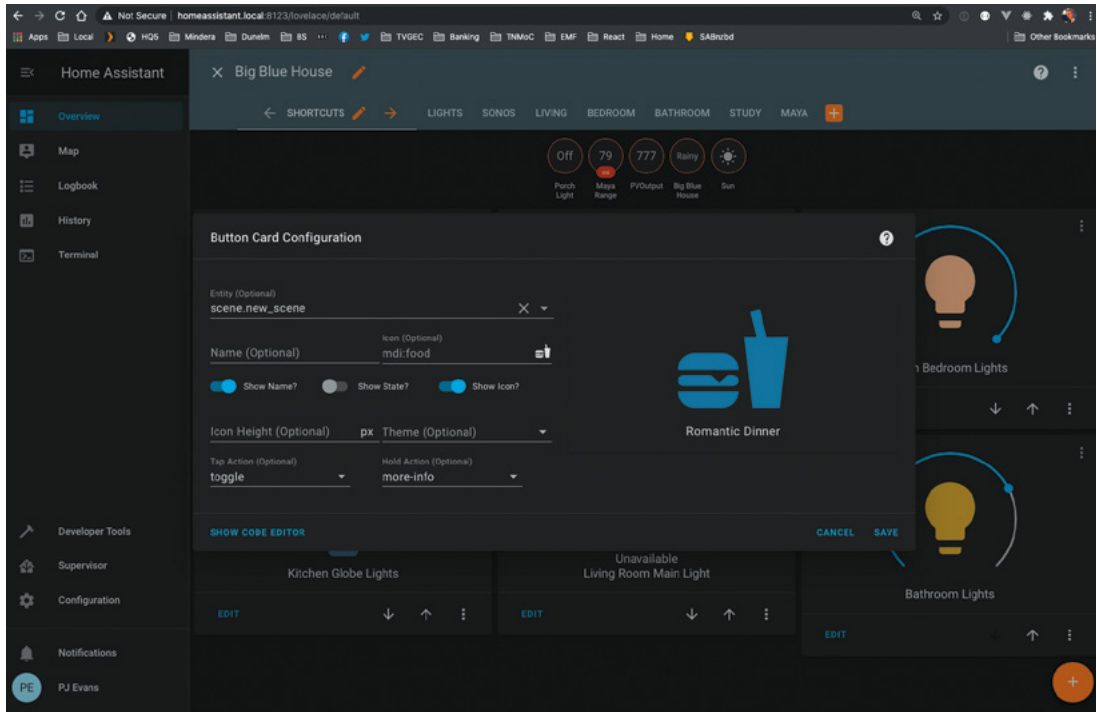
06 People are people (and HA entities)

Yes, there's no getting away from it, you're in the system too. Home Assistant's impressive iOS and Android apps enable you to become an input into the system. By allowing the app to monitor your location and report it back to your

Top Tip

Community care

A wonderful part of Home Assistant is its dedicated and enthusiastic community. If you need help, you will probably find answers at magpi.cc/hacom.



► Once you've created a scene, you can add it to the dashboard so your perfect environment is a single click away

setup, different automations can be added based on location. How about switching on the heating when you are within a couple of miles of home, or automating outside lighting so it comes on as you get close? You can also combine multiple 'persons of interest' so different things can happen based on who is where, like switching off lights only if all of you are out.

“ How about switching on the heating when you are within a couple of miles of home? ”

Top Tip

Will my smart toaster work?

Need to find out whether a particular device will work with Home Assistant? Check out the integrations page: magpi.cc/haintegrations. Don't despair if not: searching may find that an unofficial plug-in is available.

07 Switch your lights on from anywhere

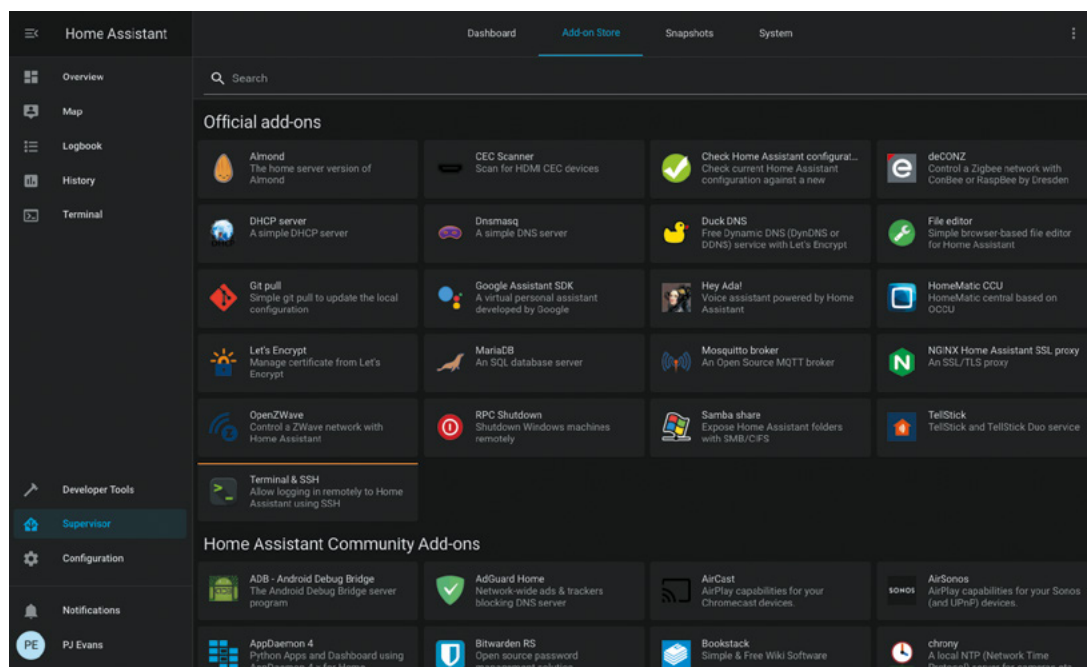
One of most fun things in home automation is the ability to control your home's electronics from anywhere you can get an internet connection. This can lead to advanced projects like a video doorbell or remote access control. There are some significant security concerns with this and there is a ton of advice from the authors of Home Assistant here: magpi.cc/homeasssitantremote. In short, the common approach is to use port forwarding so your home router allows traffic into your setup. A simpler solution is to use Home Assistant's cloud service, but this does come with a monthly fee.

08 Like and subscribe

If you're inspired to create your own sensors and gizmos around the house, such as temperature sensing or monitoring doors using reed switches, the easiest and simplest way to communicate with Home Assistant is the MQTT protocol. Commonly used by Internet of Things devices, an MQTT server (the 'broker') can receive data in any form from clients ('publishers') and relay that data to listening devices ('subscribers'). Home Assistant can act as a broker and/or subscriber and feed published events into the system so you can trigger any automation or scene from anything that can 'speak' MQTT. Learn more at mqtt.org.

09 Add on add-ons

Add-ons allow you to enhance the functionality of Home Assistant. Rather than integrations, which allow HA to talk to different devices, add-ons are improvements for the HA system itself. The range of freely available add-ons is franking mind-boggling. Under the 'Supervisor' menu item you'll find the Add-on Store. The core developers of HA offer 'official' add-ons that make it easy to implement things like SSH access, SSL certificates with Let's Encrypt, and so on. Then there are the community add-ons, which add all kinds of monitoring and management tools. You can even add additional multimedia capabilities like a Plex or AirPlay server.



◀ Home Assistant can be improved with a huge range of add-ons

10 Make your own

We've talked about the community offering integrations and add-ons, but if there is something you want to do or connect to and you can't find it, you can write your own. That may sound a bit intimidating, but Home Assistant is 100% Python. The Raspberry Pi Foundation's favourite programming language is right at the heart of this entire system. Better still, the Home Assistant online documentation has a full tutorial on how to set up your development environment and get started. There are no limitations on what you can do. Templates are provided for both integrations and add-ons. Get started here: magpi.cc/homeassistantdev.

11 All systems go

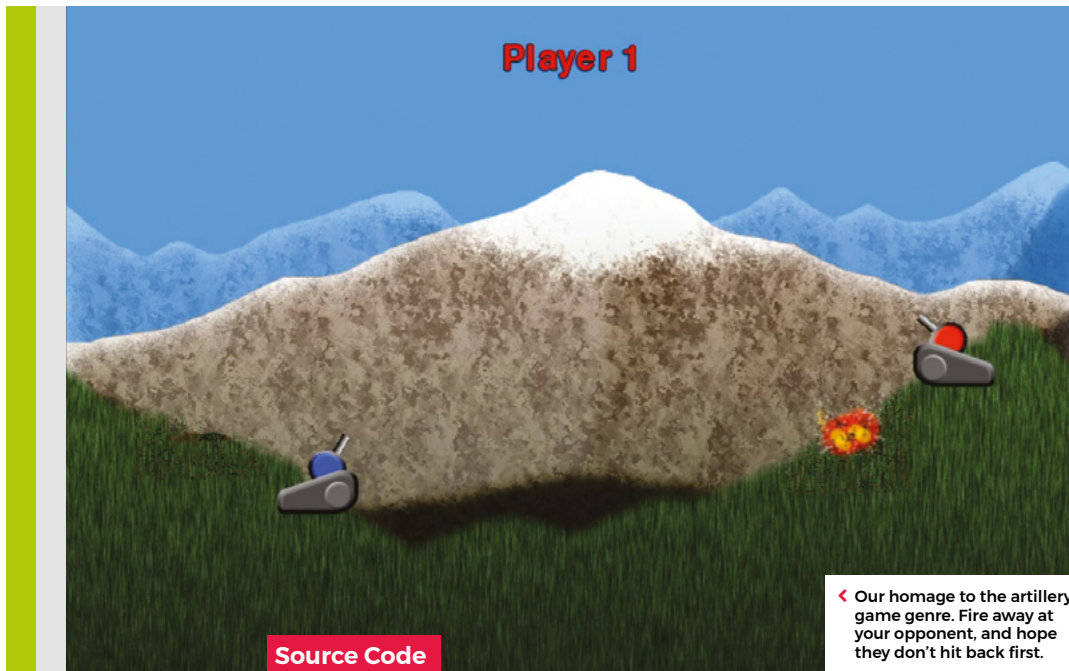
With great automation comes great complexity. Admittedly, it can take a long time to get everything set up just right. You may have complex scripts or elaborate scenes. It would be unthinkable to suddenly lose all your hard work. Regular backups are a must and Home Assistant has a cool 'Snapshot' feature that allows you to capture the entire configuration in a backup file and download it. Under the 'Supervisor' area you'll find a range of tools to manage your system and monitor memory, temperature, and CPU usage, along with a place to generate and download snapshots. You'll also be notified here of any updates available for your setup.

12 Going further

The great thing about home automation is that it is a never-ending hobby. You'll keep having ideas, being hit with inspiration, and will be forever tweaking the setup to get it just right. Then, the next shiny automatable device will appear and you'll be thinking, "Yes, I do need to automate the cat flap and receive notifications whenever Tiddles comes in." That said, if all you're after is being able to switch on the kitchen lights in Swindon from Las Vegas, Home Assistant is one of the most affordable and easiest ways to achieve this. It's free, open-source, and does nothing with your personal data without you knowing about it. Over to you. [M](#)



◀ Integrating the MQTT protocol means you can make your own automation devices like this door monitor. Use a Raspberry Pi Zero or ESP microcontroller



Wireframe

This tutorial first appeared in Wireframe, our sister magazine that lifts the lid on the world of video games. Every issue includes tutorials and in-depth interviews, along with news and reviews of the latest indie and triple-A games.

To find out more, visit their website at wfmag.cc.

Check out their subscription offers at wfmag.cc/subscribe.

Code your own Artillery-style tank game



AUTHOR
MARK VANSTONE

Fire artillery shells to blow up the enemy with our take on a classic two-player artillery game

To pick just one artillery game is difficult since it's a genre in its own right. Artillery simulations and games have been around for almost as long as computers, and most commonly see two players take turns to adjust the trajectory of their tank's turret and fire a projectile at their opponent. The earliest versions for microcomputers appeared in the mid-seventies, and the genre continued to develop; increasingly complex scenarios appeared involving historical settings or even mad ideas like battles between factions of worms.

To code the basics of an artillery game, we'll need two tanks with turrets, a landscape, and some code to work out who shot what, in which direction, and where said shot landed. Let's start with the landscape. If we create a landscape in two parts – a backdrop and foreground – we can make the foreground destructible so that when a missile explodes it damages part of the landscape. This is a common

effect used in artillery games, and sometimes makes the gameplay more complicated as the battle progresses. In our example, we have a grass foreground overlaid on a mountain scene. We then need a cannon for each player. In this case, we've used a two-part image, one for the base and one for the turret, which means the latter can be rotated using the up and down keys.

For this code example, we can use the Python dictionary to store several bits of data about the game objects, including the Actor objects. This makes the data handling tidy and is quite similar to the way that JSON is used in JavaScript. We can use this method for the two cannons, the projectile, and an explosion object. As this is a two-player game, we'll alternate between the two guns, allowing the arrow keys to change the angle of the cannon. When the **SPACE** bar is pressed, we call the firing sequence, which places the projectile at the same position as the gun firing it. We then move the missile through the air, reducing the

speed as it goes and allowing the effects of gravity to pull it towards the ground.

We can work out whether the bullet has hit anything with two checks. The first is to do a pixel check with the foreground. If this comes back as not transparent, then it has hit the ground, and we can start an explosion. To create a hole in the foreground, we can write transparent pixels randomly around the point of contact and then set off an explosion animation. If we test for a collision with a gun, we may find that the bullet has hit the other player and after blowing up the tank, the game ends. If the impact only hit the landscape, though, we can switch control over to the other player and let them have a go.

So that's your basic artillery game. But rest assured there are plenty of things to add – for example, wind direction, power of the shot, variable damage depending on proximity, or making the tanks fall into holes left by the explosions. You could even change the guns into little wiggly creatures and make your own homage to *Worms*. 🐛



Download
the code
from GitHub:
[wfmag.cc/
wfmag44](https://wfmag.cc/wfmag44)

Artillery-style tank game in Python

Here's Mark's code for an artillery-style tank game. To get it working on your system, you'll need to install Pygame Zero – full instructions are available at wfmag.cc/pgzero.

```
# Artillery
from random import randint
from pygame import Surface, image
from pygame.locals import *
import math

landSurface = Surface((800,600),SRCALPHA)
landSurface.blit(image.load('images/landscape.png'), (0,0))
gun1 = {"name": "Player 1", "actor": Actor('gunbody1', center=(700,
300)), "turret": Actor('gunbarrel1', center=(695, 280)), "angle": 30,
"multiplier": 1, "color": (255,0,0)}
gun2 = {"name": "Player 2", "actor": Actor('gunbody2', center=(200,
400)), "turret": Actor('gunbarrel2', center=(210, 380)), "angle": 30,
"multiplier": -1, "color": (0,0,255)}
bullet = {"active": False, "actor": Actor('bullet', center=(0, 0)),
"angle": 0, "speed": 0, "count":0}
bang = {"actor": Actor('expl1', center=(0, 0)), "frame": 0}
activePlayer = gun1
gameState = 0

def draw():
    screen.blit('background', (0,0))
    screen.blit(landSurface, (0, 0))
    if bullet["active"] == True: bullet["actor"].draw()
    if gameState != 1:
        gun1["turret"].draw()
        gun1["actor"].draw()
    if gameState != 2:
        gun2["turret"].draw()
        gun2["actor"].draw()
    if gameState == 0: drawText(activePlayer["name"],
activePlayer["color"])
    if gameState == 1: drawText("Player 2 Wins!", (0,255,0))
    if gameState == 2: drawText("Player 1 Wins!", (0,255,0))
    if bang["frame"] != 0: bang["actor"].draw()

def update():
    global activePlayer, gameState
    if gameState == 0:
        if keyboard.space and bullet["active"] == False: fireBullet()
        if keyboard.up: activePlayer["angle"] = limit(activePlayer["ang
le"]-1,5,90)
        if keyboard.down: activePlayer["angle"] = limit(activePlayer["ang
le"]+1,5,90)
        gun1["turret"].angle = gun1["angle"]
        gun2["turret"].angle = -gun2["angle"]
        if bullet["active"] == True:
            bullet["count"] += 1
            bullet["speed"] = bullet["speed"]*0.991
            bullet["actor"].pos = getNewPos(90-bullet["angle"])
            if checkBullet(bullet["actor"].pos) :
                explosion(bullet["actor"].pos)
                bullet["active"] = False
            if activePlayer == gun1: activePlayer = gun2
            else: activePlayer = gun1
        if bullet["actor"].y > 600: bullet["active"] = False
```

```
if bang["frame"] > 0:
    bang["actor"].image = "expl"+str(int(bang["frame"]))
    bang["frame"] += 0.2
    if bang["frame"] > 6: bang["frame"] = 0

def limit(n, minn, maxx):
    return max(min(maxn, n), minn)

def fireBullet():
    bullet["active"] = True
    bullet["actor"].pos = activePlayer["turret"].pos
    bullet["angle"] = activePlayer["angle"] * activePlayer["multiplier"]
    bullet["speed"] = 10
    bullet["count"] = 0
    sounds.canon.play()

def getNewPos(angle):
    newX = bullet["actor"].x - (bullet["speed"]*math.cos(math.
radians(angle)))
    newY = bullet["actor"].y - (bullet["speed"]*math.sin(math.
radians(angle)))
    newX += 10-bullet["speed"]
    if bullet["count"] == 60: sounds.whine.play()
    return newX, newY

def checkBullet(pos):
    global gameState
    if pos[0]>0 and pos[0]<800 and pos[1]>0 and pos[1]<600:
        pixel = landSurface.get_at((int(pos[0]),int(pos[1])))
        if pixel[3] > 0: return True
    if gun1["actor"].collidepoint(pos):
        gameState = 1
        explosion(gun1["actor"].pos)
    if gun2["actor"].collidepoint(pos):
        gameState = 2
        explosion(gun2["actor"].pos)
    return False

def explosion(pos):
    x = int(pos[0])
    y = int(pos[1])
    sounds.explosion.play()
    bullet["active"] = False
    bang["actor"].pos = pos
    bang["frame"] = 1
    for c in range(2000):
        landSurface.set_at((x+randint(0,100)-50,y+randint(0,100)-50),
(0,0,0,0))
        if c < 1500: landSurface.set_at((x+randint(0,50)-
25,y+randint(0,40)-20), (0,0,0,0))
        if c < 1000: landSurface.set_at((x+randint(0,20)-
10,y+randint(0,30)-15), (0,0,0,0))

def drawText(t,col):
    screen.draw.text(t, center = (400, 60), owidth=0.5, ocolor=(0,0,0),
color=col , fontsize=40)
```

Create GUIs with Python: Introducing guizero



Laura Sach

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Martin works in the learning team at the Raspberry Pi Foundation, where he creates online courses, projects, and learning resources.

@martinohanlon

► An alternative way to install guizero is to download the zip file from GitHub

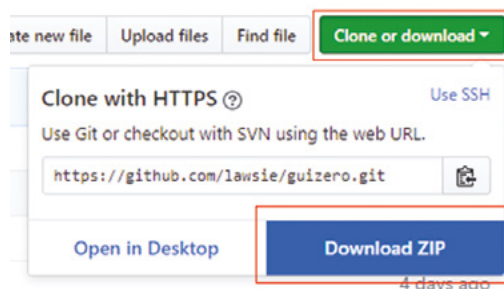
Install the guizero Python library and start creating your own GUIs

A graphical user interface (GUI, pronounced 'goeey') is a way of making your Python programs easier to use and more exciting. You can add different components called 'widgets' to your interface, allowing lots of different ways for information to be entered in to the program and displayed as output. You might want to allow people to push a button, to display a piece of text, or even let them choose an option from a menu. In this series we will use the guizero library, which has been developed with the aim of helping beginners to easily create GUIs.

Python's standard GUI package is called tkinter, and is already installed with Python on most platforms. The guizero library is a wrapper for tkinter – this means that it offers a much simpler way of using Python's standard GUI library.

01 Installing guizero

You will need to install the guizero Python library ([lawsie.github.io/guizero](https://github.com/lawsie/guizero)) to create the programs in this book. It is available as a Python package, which is reusable code you can download, install, and then use in your programs.



How you install guizero will depend on your operating system and the permissions you have to control your computer.

If you have access to the command line or terminal, you can use the following command:

```
pip3 install guizero
```

Comprehensive installation instructions for guizero are available at lawsie.github.io/guizero, including options for installing when you have no administration rights to your computer and downloadable installations for Windows.

02 Hello World

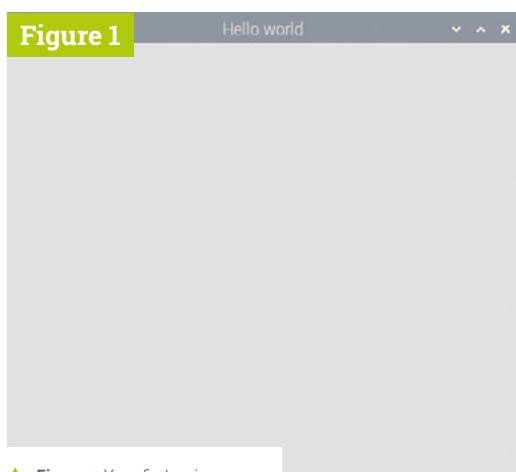
Now that you have guizero installed, let's check that it's working and write a small 'hello world' app which is traditional for programmers to write as their first program when using a new tool or language.

Open up the editor where you will write your Python code. At the start of every guizero program, you will choose the widgets you need from the guizero library and import them. You only need to import each widget once, and then you can use it in your program as many times as you like.

At the top of the page, add this code to import the App widget:

```
from guizero import App
```

All guizero projects begin with a main window which is a container widget called an App. At the end of every guizero program, you must tell the program to display the app you have just created.



▲ **Figure 1** Your first guizero app

Add these two lines of code underneath the line where you imported the App widget:

```
app = App(title="Hello world")
app.display()
```

Now save and run your code. You should see a GUI window with the title 'Hello world' (**Figure 1**). Congratulations, you've just created your first guizero app!

03 Adding widgets

Widgets are the things which appear on the GUI, such as text boxes, buttons, sliders, and even plain old pieces of text.

All widgets go between the line of code to create the App and the `app.display()` line. Here is the app you just made, but in this example we have added a Text widget:

```
from guizero import App, Text
app = App(title="Hello world")
message = Text(app, text="Welcome to the app")
app.display()
```

Did you notice that there are two changes (**Figure 2**)? There is now an extra line of code to add the Text widget, and we have also added Text to the list of widgets to import on the very first line.

Let's look at the Text widget code in a bit more detail:

```
message = Text(app, text="Welcome to the app")
```

Just like any variable in Python, a widget needs a name. This one is called 'message'. Then we specify that we would like this to be a 'Text' widget.

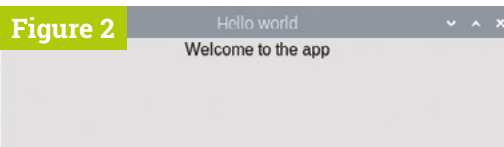
01-helloworld.py

► Language: Python 3

DOWNLOAD THE FULL CODE:

 magpi.cc/guizero-code

```
001. <from guizero import App, Text
002. app = App(title="Hello world")
003. message = Text(app, text="Welcome to the app")
004. app.display()
```



◀ **Figure 2** Add a text message

Inside the brackets are some parameters to tell the Text widget what it should look like. The first one, 'app', tells the Text where it will live. All widgets need to live inside a container widget. Most of the time your widgets will live directly inside an App, but you will discover later that there are also some other types of container widget you can put things in too. Finally, we tell the widget to contain the text "Welcome to the app".

Wanted poster

01 Make it more exciting

Now that you can create a basic GUI, let's make it look a bit more exciting. You can add text in different fonts, sizes and colours, change the background colour, and add pictures too. To practise all of this, let's create a 'Wanted' poster.

First of all, you need to start off by creating an app. In your editor, add this code to create the most basic app window:

```
from guizero import App

app = App("Wanted!")

app.display()
```

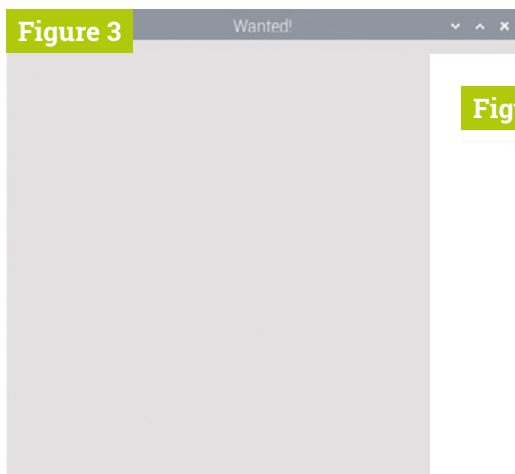
Save and run your code and you should see an app that looks like a plain grey square with the title 'Wanted!' at the top (**Figure 3**).

02 Background colours

Let's make the background of the app a bit different. Traditionally, wanted posters look like they are made of parchment, so let's add a pale yellow colour instead as the background.

You'll Need

- A computer (e.g. Raspberry Pi, Apple Mac, Windows, or Linux PC)
- Internet connection
- Python 3 (python.org)
- An IDE (code editor), e.g.: IDLE ([installed with Python 3](https://python.org)), Thonny (thonny.org), Mu (codewith.mu), PyCharm (jetbrains.com/pycharm)
- The guizero Python library (lawsie.github.io/guizero)



► Figure 3 The basic app

Find the line of code where you create the app. Immediately after this line of code, add one more line of code to modify the **bg** property of the window. In this case, **bg** is short for 'background' and will let us change the colour of the background. Now your code should look like this:

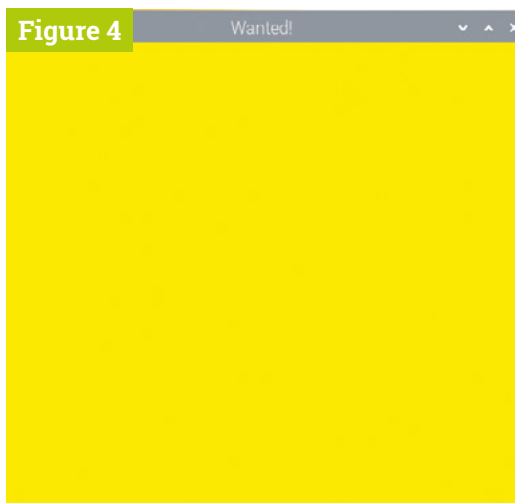
```
from guizero import App

app = App("Wanted!")
app.bg = "yellow"

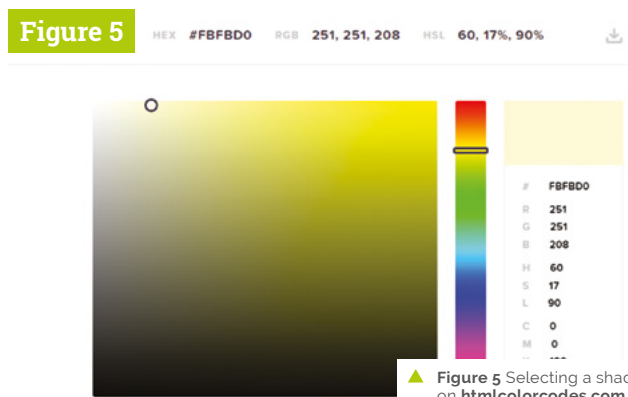
app.display()
```

This is called editing a property. In the code, you need to specify the widget you are talking about (**app**), the property you want to change (**bg**) and the value you want to change it to.

You might think this colour (**Figure 4**) is a bit too yellow, so let's look up the hex code of a different yellow colour. There are lots of websites where you can search for colours, for example you could try **htmlcolorcodes.com** (**Figure 5**).



► Figure 4 Change the background colour



▲ Figure 5 Selecting a shade on **htmlcolorcodes.com**

When you have selected the colour you want, you will see its code displayed on the site either as hexadecimal (in this case #FBFBDO) or as RGB (251, 251, 208). You can use both of these formats for setting colours in guizero; for example, you could delete the code for making your background yellow and then try one of these options in your program:

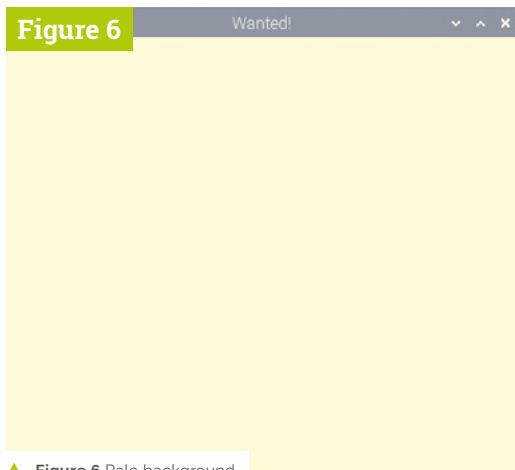
```
app.bg = "#FBFBDO"
app.bg = (251, 251, 208)
```

“ **bg** is short for 'background' and will let us change the colour of the background ”

Reading the docs

You might be wondering how to find out what properties a particular widget has that you can change. Even if you are a complete beginner programmer, it is worth learning how to read documentation because it will let you use the full power of guizero and any other libraries you come across.

The guizero documentation can be found at **lawsie.github.io/guizero**. Once you are there, click on the widget you would like to change, and scroll down until you reach the properties section. For example, if you select 'Text' under the heading of widgets, you will see all of the properties of a piece of Text that you can possibly change. Documentation also often contains helpful snippets of code which show you how to use a particular property or method, so don't be scared of having a look through – you never know what you might learn!



▲ Figure 6 Pale background

03 Add some text

Your app should look something like **Figure 6**. Now let's add some text to the GUI. We will begin by adding the text that all good wanted posters need – the word 'Wanted'!

First, look for the line of code you already have where you imported the App.

```
from guizero import App
```

You need to import Text to be able to create a piece of text, so add it to the end of the list. Now the line looks like this:

```
from guizero import App, Text
```

Every time you want to use a new type of widget, add its name to the end of the list. There is no need to keep adding whole new lines of code: just stick with one list so that your program doesn't get too confusing.

Now that you can use text, let's add a piece of text. Remember that all widgets on the GUI must be added between the line of code where you create the App and the line of code where you display it. Your code should now look like this:

```
from guizero import App, Text

app = App("Wanted!")
app.bg = "#FBFBF0"

wanted_text = Text(app, "WANTED")

app.display()
```

Let's take a closer look at that line of code you just added.

```
wanted_text = Text(app, "WANTED")
```

Here, `wanted_text` is the name of the piece of text. This is so that we can talk about it later on in the code – think of it like a person's name. (You could even call your piece of text Dave if you want – the computer won't care!)

Inside the brackets we have two things. The second one, `"WANTED"`, is straightforward as it is the text we would like to display on the screen. The first is the container which controls this piece of text, which is called its 'master'. In this case we are saying that this text should be controlled by the app. When you first start creating GUIs, most of your widgets will have the app as their master, but there are other containers that can store widgets that you will learn about later on.

04 Change text size and colour

Uh oh, this text is pretty small (**Figure 7**). Let's change the `text_size` property in exactly the same way as you did when we changed the background colour of the app. Remember that you needed to specify three things:

1. The name of the widget
2. Which property to change
3. The new value to change it to

So, in this case you are going to specify the widget (`wanted_text`), the property to change (`text_size`) and the new value (`50`). Add one new line of code immediately under the line where you created the text, to change the property.



Create Graphical User Interfaces with Python

For further tutorials on how to make your own GUIs with guizero, take a look at our new book, *Create Graphical User Interfaces with Python*. Its 156 pages are packed with essential info and a range of exciting projects. magpi.cc/pythongui

◀ Figure 7 The text is too small



► Figure 6 Larger text

```
wanted_text = Text(app, "WANTED")
wanted_text.text_size = 50
```

You now have larger text on your poster (Figure 8). See if you can now change the font of this text to something different. Which fonts are available depends on which operating system you are using, so here are some suggestions:

- Times New Roman
- Verdana
- Courier
- Impact

No 'wanted' poster would be complete without a picture, so let's add one. Our poster is going to be for the author's cat, because she is always scratching things she shouldn't be.

Save a copy of the image you would like to use in the same folder as your GUI program. You can use images in other folders, but if you do you will have to provide the path to the image, so it's a lot easier to just store them in the same folder when you are starting out.

Hopefully you're now getting used to adding widgets. Remember that they must always be imported at the top of the program, and then the

► Figure 7 The finished poster

widget created with a sensible name after the line of code where you create the App, but before the final `app.display()` line.

Add 'Picture' to the list of widgets to import at the start of the program.

```
from guizero import App, Text, Picture
```

Now create a Picture widget with two parameters: the app and the file name of the picture. This is the code we used because our picture was called `tabitha.png`.

```
cat = Picture(app, image="tabitha.png")
```

Run your code (which should resemble `02-wanted.py`) again and you should see the picture displaying below your text (Figure 9).

Now it's up to you to use your new GUI customisation skills to style your poster however you would like. [\[1\]](#)



02-wanted.py

► Language: Python 3

DOWNLOAD THE FULL CODE:

 magpi.cc/guizero/code

```
001. from guizero import App, Text, Picture
002.
003. app = App("Wanted!")
004. app.bg = "#FBFBF0"
005.
006. wanted_text = Text(app, "WANTED")
007. wanted_text.text_size = 50
008. wanted_text.font = "Times New Roman"
009.
009. cat = Picture(app, image="tabitha.png")
010.
011. app.display()
```

Image manipulation

Because guizero is a library for beginners and we wanted to make it as easy as possible to install, it does not come with the fancier image manipulation functions as these require an extra library called 'pillow'. You can always use non-animated GIF images on any platform, and PNG images on all platforms except Mac, so if you're not sure whether you have installed the extra image manipulation functions, stick to those image types.

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Santa's Run: Drop & Dash

Make an improved Christmas game and guide Santa on his Christmas Eve run, delivering The MagPi magazines



Mike Cook

Veteran magazine author from the old days, writer of the Body Build series, plus co-author of *Raspberry Pi for Dummies*, *Raspberry Pi Projects*, and *Raspberry Pi Projects for Dummies*.

magpi.cc/mikecook

MAKER

Last month we showed you *Santa's Run*, a game where you control Santa's sleigh to try to drop *The MagPi* magazines down chimneys. This month, we will see how to use two shaker controllers to play *Santa's Drop*, a game where Santa drops magazines and you have to manoeuvre the chimney to catch them. In addition, we also present *Santa's Dash*, a two-player race game.

01 What's new

Last month we were trying to drop copies of *The MagPi* magazine down the chimney. This month we reverse roles and try to catch magazines dropped by Santa in our large chimney as he hovers above the snowy rooftops. This time it is the chimney itself that we have to manoeuvre into place, by using our two shaker controllers. One controller moves the chimney to the left, and the other to the right. In terms of realism, remember we are talking about a hovering sleigh powered by two reindeer, so pinches of salt with regard to manoeuvring chimneys around are the order of the day.

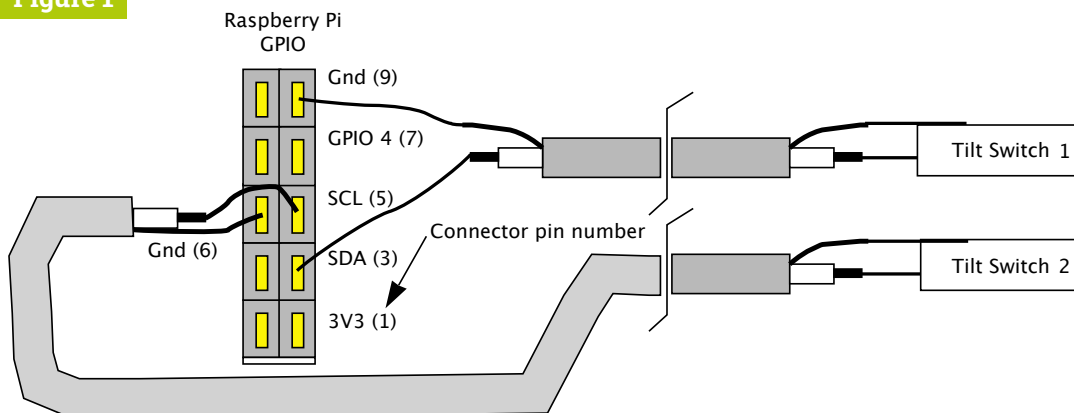
02 The game

Last month's game only allowed us to use small images of all the magazine covers, whereas this time we can use much larger cover artwork because the chimney is so big. However, a copy of *The MagPi* that is larger is much bigger than the Santa graphic, so it looks silly being launched that big. In order to maintain perspective, when the magazine first leaves the sleigh, we start off with a small image of *The MagPi* and increase its size as it descends. As well as vertical movement, we add horizontal movement, coupled with the effect of bouncing off the sides of the window.

03 The scoring

We did consider making the descent parameters random, which would have been easy enough to do. However, we wanted a more consistent game, so we used a random number generator but with a fixed seed, so we always get the same sequence of numbers. In that way someone couldn't complain that the game gave them harder magazine flight paths to catch; also, there would be a learning curve to the game. We

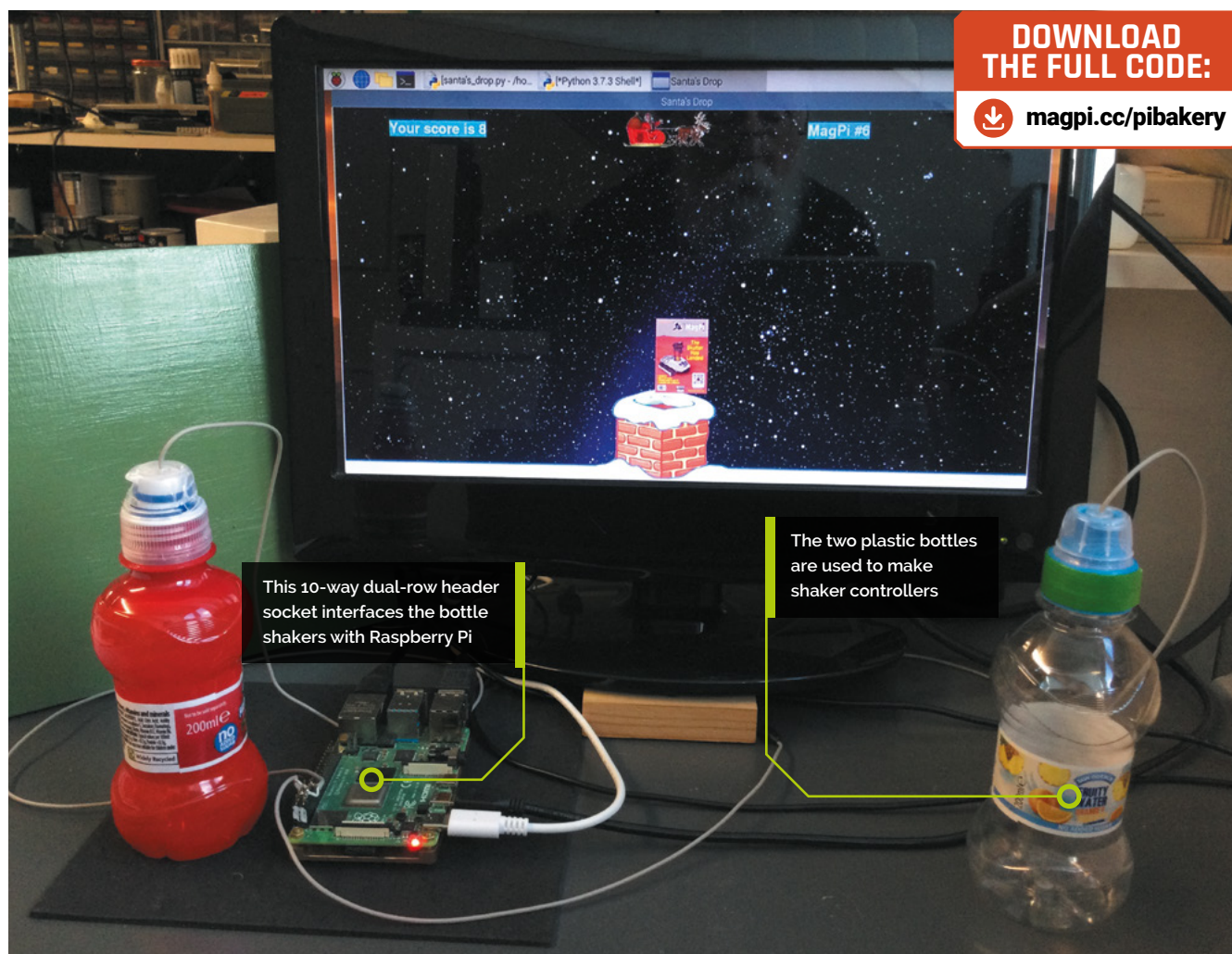
Figure 1



▲ Figure 1 Wiring up two shaker controllers

You'll Need

- Two shaker controllers, as featured in *The MagPi* #100 magpi.cc/100



thought the scoring should reflect this, so the score you get for catching a magazine is its issue number; this gives us a maximum possible score of the sum of 100 consecutive numbers, or 5050.

04 Make your shaker

Last month we showed you how to make a shaker controller. Repeat this to create a second shaker and add it to the other I2C pin. Because both I2C pins have 1K8 (1.8kΩ) pull-up resistors built into Raspberry Pi, this gives it good immunity from interference. **Figure 1** shows the physical layout diagram for connecting both shakers to a 10-way dual socket to slip over the GPIO pins, and a photograph of this wiring is shown in **Figure 2** (overleaf). We then ran a short test program, available on our GitHub page, to check they both work. We placed a green label round the neck of the bottle of this new shaker, or you could use a different-coloured bottle.

“ Catch magazines dropped by Santa in our large chimney as he hovers above ”

05 The drop

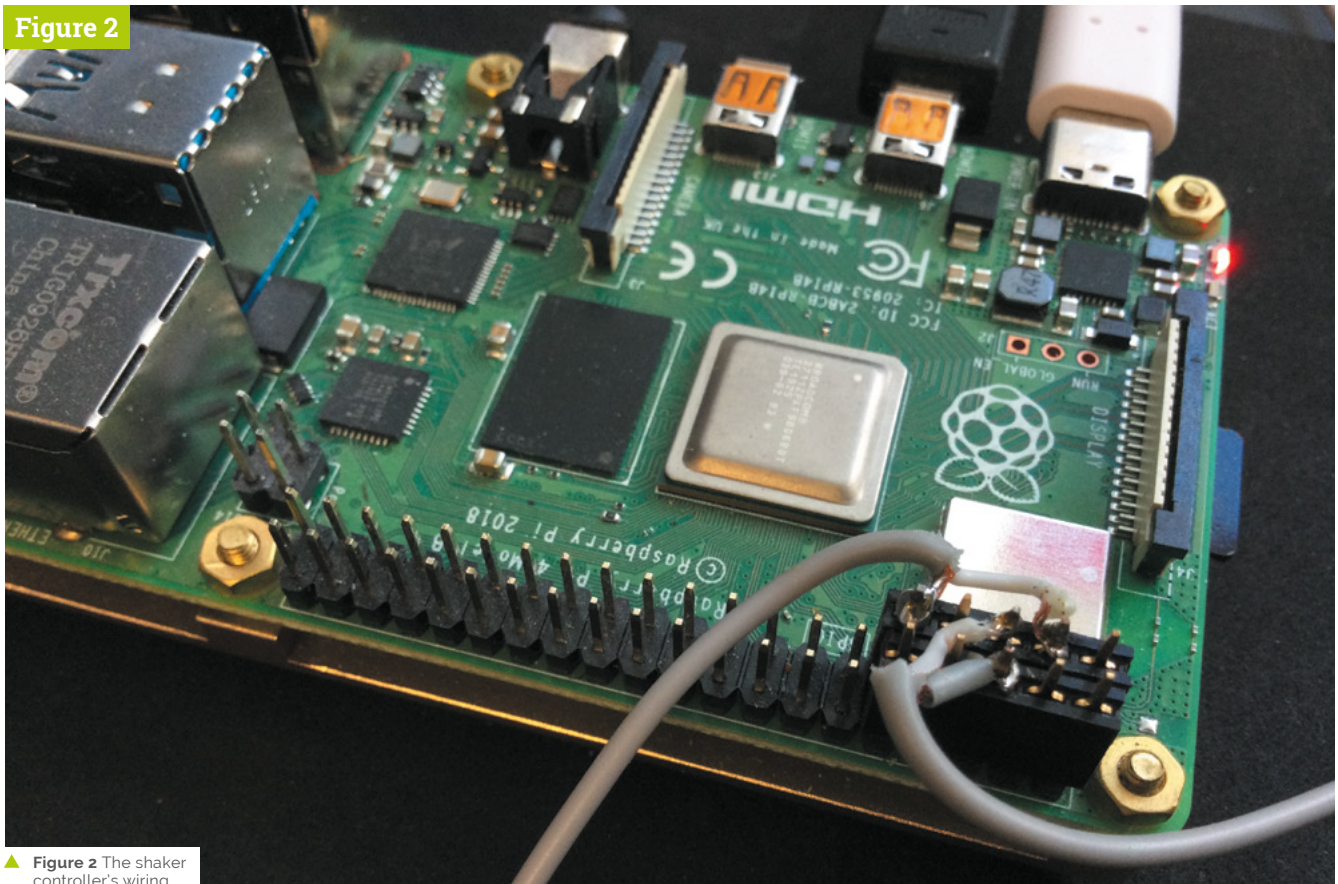
The first drop is simple: you don't have to move the chimney at all, it simply drops down. Note the satisfying way it drops down the chimney. This is done by having a second image of the chimney with the top part set to be transparent; this is drawn on the screen after the magazine is displayed. In this way, the lower part of the chimney obscures the lower part of the magazine, giving the effect of it actually going down the chimney. **Figure 3** shows Eben and Liz disappearing down the chimney, whereas **Figure 4** shows the normally invisible 'catching rectangle'. Both lower corners of the magazine need to be inside this rectangle for it to be captured.

Top Tip

Calculating the sum of n numbers

Take the first and last number, add them together, and divide by 2, then multiply this by the number of numbers you have.

Figure 2



▲ Figure 2 The shaker controller's wiring

06 Playing the game

The game lasts for 100 magazine drops, so is quite a marathon. If you want to shorten this then there is no need to start at the first magazine. By altering the initial value of the `throwCount` variable in the main function to another value, you can miss out earlier magazines. There is a comment next to the line you have to

change; it says '# Change for a shorter Game'. Note this variable runs from 0 to 99, representing magazine issues 1 to 100. The difficult part is learning to shake only one hand while keeping the other still, to get good control.

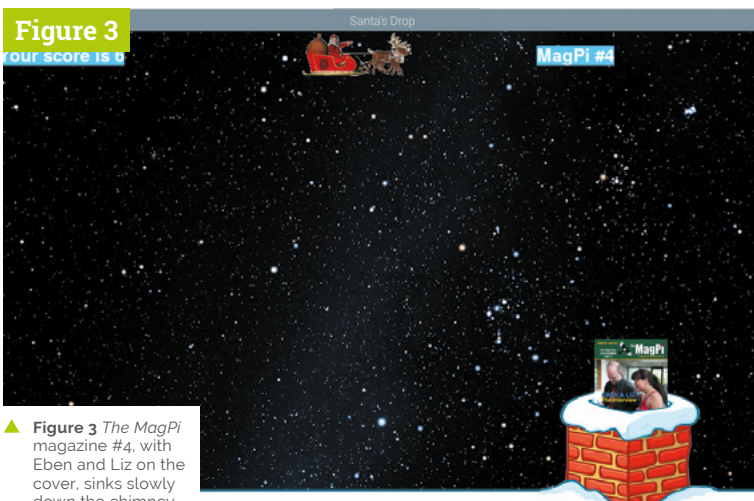
07 Customisation

If the game is too fast for you then you can change the range of speeds the magazines are thrown at. The penultimate line in the `init` function is:

```
speedDrop.append([random.randint(-10, 10),
([random.randint(2, 10)])]
```

This generates two random numbers that control the X movement and Y movement of the magazine as it drops. By changing the two numbers here, you alter the range of speeds at which the magazine can drop. Make these smaller for a slower game, and large for a faster game. Do not make the second number have a negative value, or else the magazine will fly off into space and the program will appear to hang while waiting for it to come down.

Figure 3



▲ Figure 3 The MagPi magazine #4, with Eben and Liz on the cover, sinks slowly down the chimney

08 Santa's Dash

This second game is a straight race between two Santas. As you know, there is only one real Santa – this second one is only an apprentice and he is marked out by having a green side to his sleigh. The faster you shake, the faster you go. However, there are obstacles in the way, in the form of chimneys that you have to get over. Santa is blocked until he has gained enough height to clear the chimneys. To do this, the shaking counts are transferred into vertical movement, but as the height is constantly decreasing due to gravity, you have to shake harder in order to get high enough to get over them.

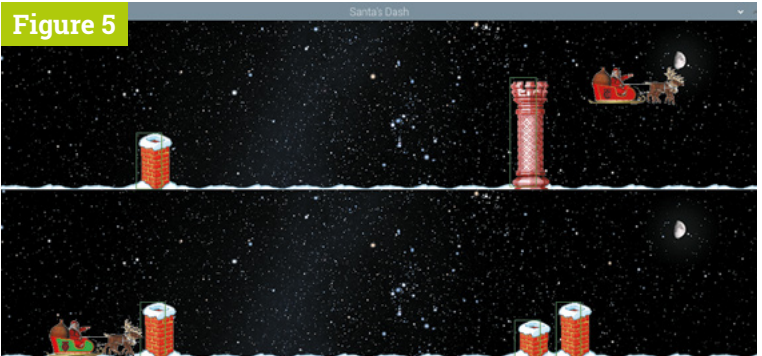
“ If you stop shaking, the reindeer's legs stop moving and the sleigh sinks down ”

09 Playing the game

If you stop shaking, the reindeer's legs stop moving and the sleigh sinks down. In front of each chimney is a normally invisible blocking rectangle. When the software detects that the start of the reindeer is inside this blocking rectangle, it switches the shakes to controlling upward motion. **Figure 5** shows the game with these blocking rectangles in a green outline. We used this feature to check that they were moving at the same rate as the chimneys. If you go fast enough after clearing one chimney then you can fly over some following ones. **Figure 6** shows part-way through a race, with the real Santa (in red) in the lead.

10 Customisation

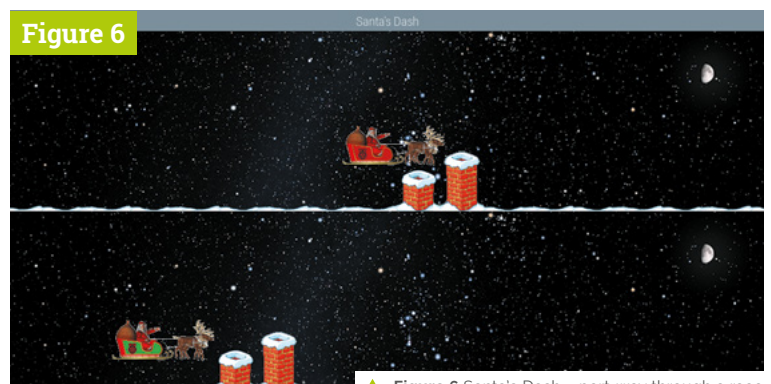
You can make any combination of chimneys appear in the foreground by defining where they are. The last lines of the `init` function control



this. First, a loop fills the whole ground line with lengths of snow; this is object number 3. Then the last three lines override the snow and put in a chimney of types 0, 1, or 2. The index of the `groundLine` variable defines how far along this track is the chimney, and the contents define the type – each of the types is higher than the other. We would recommend that using these sparingly gives you the best result, but it is up to you. ”

▲ **Figure 4** The *MagPi* magazine #3 with the normally invisible capture rectangle

▲ **Figure 5** Santa's Dash, showing all three chimney types with outlined blocking rectangles



▲ **Figure 6** Santa's Dash – part-way through a race

ARTS + CRAFTS

with Raspberry Pi

Combine creativity and artistry with these imaginative Raspberry Pi builds.

By **Rosie Hattersley**



Sticky tape



Jumper leads



Cardboard and card

One of the cleverest things about Raspberry Pi is its role as an enabler. Rather than dictating what you make or do with it, Raspberry Pi simply provides a means to achieve whatever you have in mind. This applies to practical, sensible aims, of course, but it's just as true for flights of fancy and imagination. A quite mind-boggling variety of creative, zany, and perplexing projects have come to fruition thanks to the 'jam' holding it all together: our beloved single-board computer.

Over the next few pages we present a range of crafty, artistic, and slightly off-the-wall projects that we hope spark your imagination and set you off on a creative endeavour or two of your own. Happy Raspberry Pi jamming!

“ One of the cleverest things about Raspberry Pi is its role as an enabler ”

Scissors and/or craft knife

BASIC CRAFTING PACK

Bulldog clips

Chances are you have most of what's needed to make up a basic arts and crafts kit for your creative projects. If supervising a youngster, keep an eye on them when using scissors, knives, or anything that could short-circuit.

Spare SD card

Glue

MAKERS GONNA MAKE

Things that pop, boxes that pop open, and bling to light up your clothes

PROJECT DIFFICULTY GUIDE

BEGINNER

Projects for everyone

ADVANCED

Projects that require some experience

EXPERT

Projects that require skill

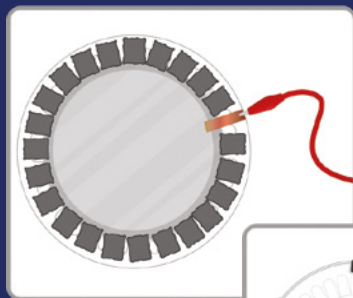
RASPBERRY PI WHOOP! CUSHION

BEGINNER

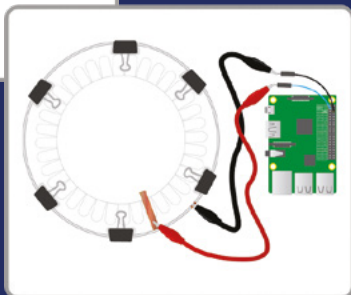
magpi.cc/whoopi

If something is fun, we tend to remember how to do it. Example A is this Whoopi Cushion project – an excellent way of showing off your Raspberry Pi's GPIO pin programming proficiency. Make a ring of slightly overlapping tinfoil squares around the inside of the paper plate, connect up to a speaker via Raspberry Pi, and use crocodile clips to complete the circuit. Hide your DIY whoopee cushion and await your unsuspecting victim...

TOOLS NEEDED - Paper plates, cardboard, aluminium foil, sponge, copper tape, speakers



▼ The joy of making in glorious Beano-esque form



▲ Aluminium foil, some crocodile clips and a paper plate – of course we're not up to anything...



▲ Light-up badge kits such as Space Kitty are ideal first craft projects

BADGES AND BAUBLES

BEGINNER - ADVANCED

magpi.cc/tindiewearables

Light-up badges are a great way to show off your techie makes, and Raspberry Pi Zero is tiny enough to keep discreetly hidden in a pocket. Tindie.com stocks a whole heap of wearables, particularly light-up badges and earrings you buy as kits.

For beginners, a good start is the Bearables Badge Kit, which includes a Bearables Python library (magpi.cc/bearables) with which you can program individual LEDs. More experienced users could create their own badge using 3D or laser cutting tools.

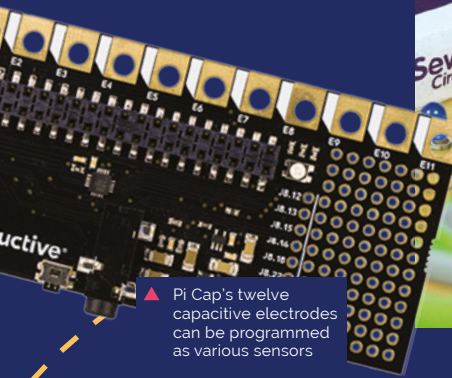
TOOLS NEEDED - Raspberry Pi Zero

▼ Bearables come with conductive thread and in two light-up badge designs



Craft Tip!

There's a fab tutorial on designing and 3D printing your own badges at magpi.cc/pendant



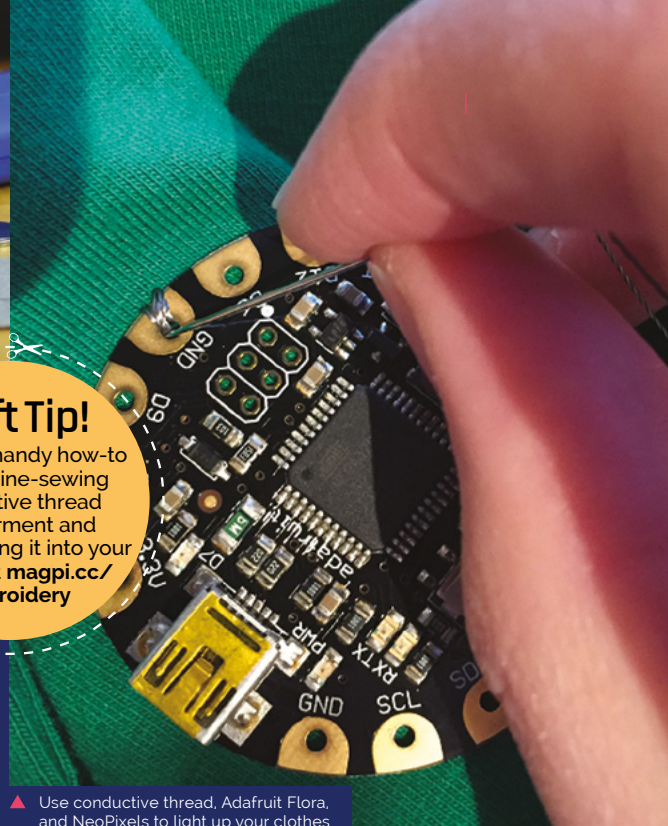
▲ Pi Cap's twelve capacitive electrodes can be programmed as various sensors



▲ Wearable tech kits, such as Sewing Circuits, provide everything you need to start tech crafting

Craft Tip!

There's a handy how-to on machine-sewing conductive thread to a garment and incorporating it into your design at magpi.cc/embroidery



▲ Use conductive thread, Adafruit Flora, and NeoPixels to light up your clothes

WEARABLE WONDERS ADVANCED

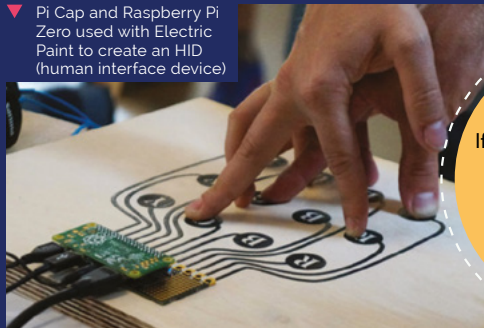
magpi.cc/picap

Team a Raspberry Pi Zero with a Bare Conductive Pi Cap and you can make your own interactive wearables. Sensors worn on the body trigger particular responses, which you program in advance. The Pi Cap's twelve capacitive electrodes work with Bluetooth and WiFi, and can be programmed as touch or proximity sensors that can be attached to textiles or any kind of surface. Electric Paint adds flexibility to your setup.

If you have a family pet, you could replicate the #PugProse project in which profound or amusing musings appear to be uttered by a bemused mutt: magpi.cc/pugprose.

TOOLS NEEDED - Raspberry Pi Zero, Pi Cap, Electric Paint (optional); textiles

▼ Pi Cap and Raspberry Pi Zero used with Electric Paint to create an HID (human interface device)



Craft Tip!

If you're after next level coding and geekery, consider something more like the Star Trek combadge: magpi.cc/pibadge

FASHION FLAIR WITH CONDUCTIVE THREAD BEGINNER - ADVANCED

magpi.cc/sewing

Sewing thread and knitting/crochet yarn are available in conductive versions from the likes of Pimoroni and The Pi Hut. Use it to stitch bracelets, earrings, and necklaces that light up. For more bling, add Adafruit NeoPixels. You could also stitch a light-up message onto clothing or an embroidery hoop. There's even more scope with wearables that can accommodate Raspberry Pi Zero - a jumper or skirt.

TOOLS NEEDED - Conductive thread, embroidery hoop or fabric, LEDs, Adafruit NeoPixels, Adafruit Flora

FACE-RECOGNITION TREASURE BOX ADVANCED

magpi.cc/treasurebox



▼ Face recognition and Raspberry Pi combine for a fun crafting feature

Sure to appeal to anyone with secrets to keep or precious items to hoard, the face-recognition treasure box first appeared on Adafruit's project pages several years ago but has undergone a recent update.

A discreet camera embedded in the top of the sturdy trinket box is programmed using OpenCV and checks the ID of anyone attempting to open it. You'll need to know how to run Raspberry Pi headless and to access it using SSH. Instructions for this and using servos are included.

TOOLS NEEDED - A Raspberry Pi, power supply, GPIO pins, WiFi network, a servo for a latch, lock solenoid for a door or sliding drawer

▲ If the face fits, it's open sesame, otherwise the box stays shut

ART ATTACK!

Unleash your inner artist with these visual projects

Can you create a function that draws a shape and calls your `randomcolour()` and / or `randomplace()` functions?

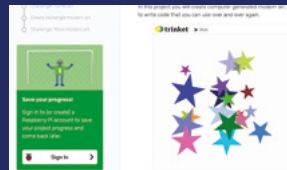
You can call your function from inside a `for` loop as you did in the rectangle art to generate modern art.

Ideas:

- Turtles have a function called `dot` that takes a radius (distance from the centre to the edge of the circle) as input. E.g. `turtle.dot(10)` You could create a `drawcircle()` function that draws a circle with a random radius.



▲ Using functions, you create random colours and random locations – voilà abstract art!

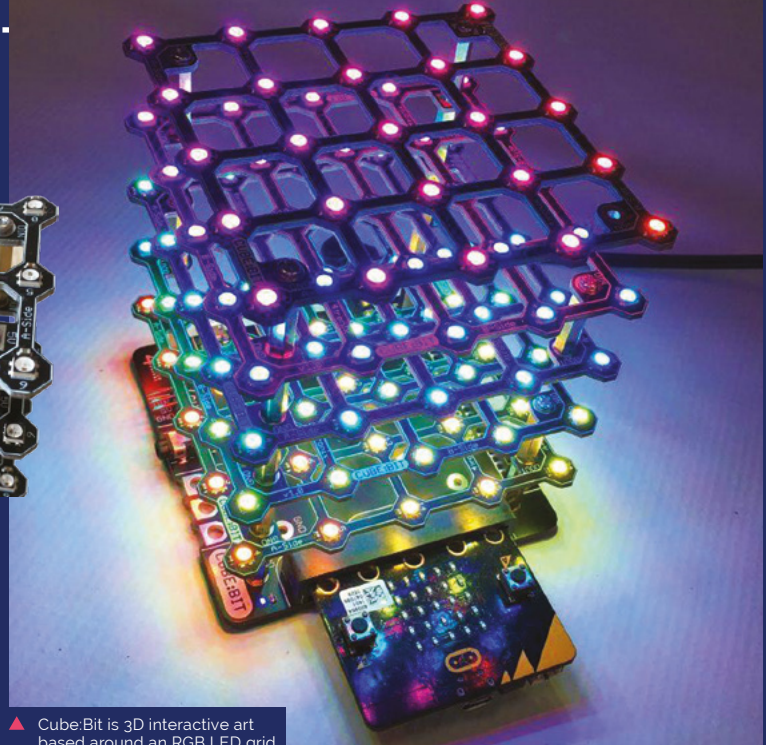
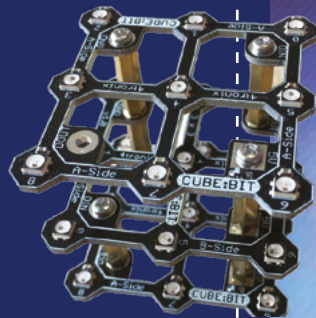


◀ Trinkets in Raspberry Pi tutorials offer a preview of what you'll make with code

MODERN ART BEGINNER magpi.cc/modernart

This introductory guide to electronic art is a great way to learn code that can be applied in all sorts of scenarios. The Scratch-based project sees users challenged to change the colours of their on-screen turtles and make them move randomly around the screen. You then have to apply what you've learned by creating and colouring different shapes to create random, abstract art.

TOOLS NEEDED: Raspberry Pi or a computer, online Trinket and resources zip file (both provided)



▲ Cube:Bit is 3D interactive art based around an RGB LED grid

CUBE:BIT ADVANCED TO EXPERT magpi.cc/cubebit

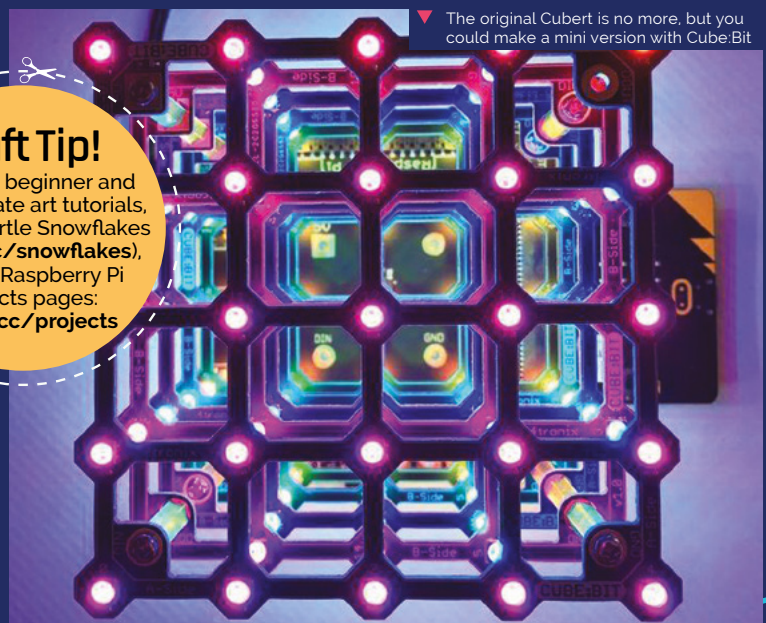
This art piece is inspired by the fantastic Cubert by Lorraine Underwood (magpi.cc/cubert), who made a 3D matrix from Raspberry Pi and a grid of ping-pong balls. Pimoroni now sells this amazing NeoPixel-encrusted Cube:Bit with which to make your own.

The Cube:Bit plugs into Raspberry Pi Zero and, once assembled, you can enjoy 3D NeoPixel art based on the 2D and 3D co-ordinates entered, have a 3D race or game, or hook it up to a sound source.

TOOLS NEEDED: Cube:Bit, Raspberry Pi Zero, speaker/sound source (optional)

Craft Tip!

For more beginner and intermediate art tutorials, such as Turtle Snowflakes (magpi.cc/snowflakes), see the Raspberry Pi Projects pages: magpi.cc/projects

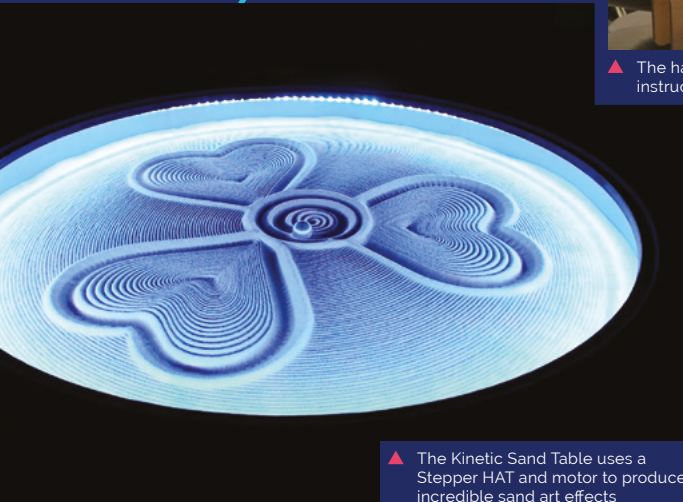


▼ The original Cubert is no more, but you could make a mini version with Cube:Bit

“ The Cube:Bit plugs into Raspberry Pi Zero ”



▲ The handcrafted table and control mechanism instructions are minutely detailed online



▲ The Kinetic Sand Table uses a Stepper HAT and motor to produce incredible sand art effects

KINETIC SAND TABLE

EXPERT magpi.cc/sandtable

The mesmeric Kinetic Sand Table project uses a ball bearing to cut swathes across a table of sand. The whole thing began as a high school project that maker Roberto Groza subsequently returned to. He crafted everything himself, from table design upwards. Detailed instructions for this amazing project are in his Instructable. A stepper motor and Raspberry Pi Stepper HAT keep things moving, while an LED strip around the edge gives it an eerie glow.

TOOLS NEEDED: Raspberry Pi with GPIO, 12V RGB strip, sand, magnetic ball bearing, circular wooden tray, flared table legs, stepper motor and shield, Raspberry Pi Stepper HAT

THE SLOW MOVIE PLAYER

EXPERT

magpi.cc/slowmovieplayer

Years ago, *The MagPi* looked at how to slow down or speed up camera footage for artistic effect (magpi.cc/30minprojects). The Slow Movie Player uses the same principle but, rather than dramatising crashing toy cars or bursting balloons, it ekes out famous film scenes over days to create a constantly changing photo on a moody Inky wHAT e-ink Raspberry Pi HAT.

You'll need SSH and a WiFi network for this project, and will be using Python code to extract the film frames for display. Maker Tom Whitwell provides GitHub details here: magpi.cc/slowmoviegithub

TOOLS NEEDED: Raspberry Pi, Inky wHAT or other display, microSD card, links to footage, internet connection

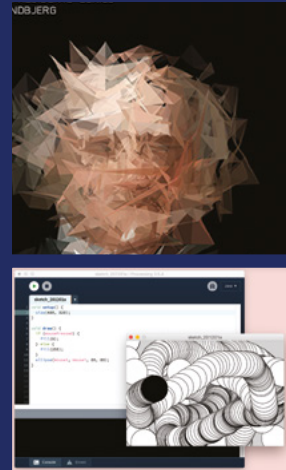


▲ Tense scenes from Hitchcock's *Psycho* make for an unsettling – and seemingly endless – photo stream

▼ Make your own disaster movie using props at home by setting the camera to 90 fps



▼ Mike Brondbjerg's *Dead Presidents* portrait was made using Processing.org code



◀ Easy-to-follow tutorials have you creating code-based visuals straight away

CREATE PORTRAIT ART WITH PROCESSING

BEGINNER TO EXPERT

magpi.cc/processing

If imitation is the sincerest form of flattery, why not combine your appreciation with some impressive code? Mike Brondbjerg's unusual portrait art makes use of Java-based Processing code (processing.org). The programming language can be used to generate still graphics, animations, and interactive applications such as games. Each line of code creates an artistic stroke, be they loops, lines, or variables. The Processing Foundation maintains a code library to help newcomers produce visualisations with relative ease.

TOOLS NEEDED: Raspberry Pi; free Processing.org account

FHD Touch Display & Bluetooth Keyboard

SPECS

DISPLAY:

11.6-inch
1920×180
(190 ppi) IPS,
ten-point
capacitive
touchscreen

PORTS:

USB-C 5V/3A
input, HDMI 1.4
Type-A input,
USB-A 2.0,
5V/3A output

BATTERY:

3.7V, 740 mWh
(200 mAh)
keyboard
battery

▼ The pi-top [4] DIY Edition clips to the kickstand for a neat all-in-one solution

▶ pi-top ▶ magpi.cc/pitop4diy ▶ £180 / \$190 (FHD Touch Display), £42 / \$45 (Bluetooth Keyboard)

This keyboard and touchscreen display provide Raspberry Pi with a first-class portable computing experience. By **Lucy Hattersley**

Recently we reviewed pi-top [4] DIY Edition, an enclosure for Raspberry Pi 4 with a battery and an interesting 128×64 OLED display (magpi.cc/pitop4review).

We were mighty impressed by the build quality, and noted that the pi-top [4] DIY Edition case would complement the FHD Touch Display & Bluetooth Keyboard.

The two parts are sold separately, but designed to work together. The result resembles a Raspberry Pi-based Microsoft Surface laptop. To the rear is an adjustable kickstand, which the pi-top [4] case clicks onto. An 80 cm display cable connects



▲ A stand-out for us was the touchpad which was snappy and responsive, and deflected accidental touches. A first for a Raspberry Pi laptop

the two elements. The length ensures you can disconnect the pi-top [4] and have it sitting to one side.

Weighing it up

Altogether, the keyboard, screen, pi-top [4] DIY Edition, and display cable weigh in at 1620 g. Not exactly low for a tablet computer, but light enough for us to throw in a backpack and take to the coffee shop. It was stylish enough to use without raising any eyebrows.

There's an elephant in the room that we should address. Together, the FHD Touch Screen and Bluetooth Keyboard will set you back £222. This is on top of £95 for the pi-top [4] DIY Edition case. And you will need to supply your own Raspberry Pi 4 (from £35, or £54 for the 4GB model tested here). So you are looking at around £350–£370 for this setup.





With that elephant firmly kicked out of the room (for now) we are pleased to report that everything we tested was fantastic.

FHD Touch Display

First up is the 11.6-inch touchscreen display with a resolution of 1920×1080 at 190 ppi (pixels per inch). It's a great display, although the chunky bezels are a tad retro.

It is a ten-point capacitive touchscreen and we found it highly responsive. While there is no multi-touch interface support in either pi-top OS or Raspberry Pi OS, it's very useful to tap buttons and interface elements.

Bluetooth Keyboard

The Bluetooth Keyboard clips to the base of the screen (again, magnetically) via a connector. There is no need to pair the keyboard. However, set up Bluetooth and you can disconnect the keyboard and use it to one side. We found it an absolute joy to type this review out on it.

Along the function keys sit a selection of shortcuts, including a dedicated Terminal key that we quickly fell in love with.

Below the keys is a multi-touch trackpad and, by Jove, they have cracked it. There is no accidental thumb touching, no awkward cursor jumping, and you can left- and right-click with ease. This is the only time we have encountered a Raspberry Pi laptop with a fully decent touchpad.

“ Hands-down the best way to use Raspberry Pi on-the-go ”

pi-top OS

We spent a couple of hours in Costa writing this review. With pi-top [4], Raspberry Pi comes together into one neat package that's a delight to work on. All that really leaves is the price, and once again the elephant shows its snout.

It is a big step up from using a Raspberry Pi with a repurposed keyboard, mouse, and monitor. On the other hand, it is considerably cheaper than a Microsoft Surface. And Raspberry Pi is a much more fun and useful computer. **M**

▲ The green display cable enables the pi-top [4] case to be used at the side of the keyboard. It's handy for using with electronic additions, like the Foundation kit

Verdict

This setup is packed with clever ideas and we love the keyboard, touchpad, and Raspberry Pi integration. Hands-down the best way to use Raspberry Pi on-the-go.

9/10

Pirate Audio: Dual Mic

SPECS

MICROPHONES:

2 × SPH0645 LM4H-B microphones, 65 dB SNR, ADC, I2S output

DISPLAY:

240×240 IPS colour LCD

CONTROLS:

4 × tactile buttons

► Pimoroni ► magpi.cc/dualmic ► £24 / \$27

Capture sound clips with this new audio board. By **Phil King**

The Pirate Audio: Dual Mic is a bit different from Pimoroni’s other Pirate Audio boards.

While the rest of the range are all about sound output, the latest addition concerns the capture of audio using two built-in microphones – since it lacks its own audio output, you have to rely on Raspberry Pi for that.

This mini HAT looks very similar to other Pirate Audio products, with an integrated 1.3-inch colour LCD screen surrounded by four push-buttons. Located on either side of the board are two tiny digital microphones. These feature a SiSonic acoustic sensor, a serial ADC (analogue-to-digital converter), and an interface to convert the signal into the industry-standard 24-bit I2S format. In our tests, we found that they record sound with crystal-clear quality, although the mics aren’t that far apart so the stereo effect is limited.

To make use of the Pirate Audio: Dual Mic, you’ll need to download the software; this involves entering three commands in a Terminal window to make all the necessary configuration changes behind the scenes.

“ The dual mics record sound with crystal-clear quality ”

Portable clip recorder

One of two Python code examples is an FFT (Fast Fourier transform) program that shows the levels of various sound frequencies on a graph. The other is a simple audio clip recorder which uses the tactile buttons to record, play, skip, and delete clips. Playback (using PulseAudio’s ‘upmix’ feature to avoid resampling) is via HDMI by default and we couldn’t get it to output through Raspberry Pi’s AV jack unless we played the clips separately with OMXPlayer. Portable playback is problematic on a Raspberry Pi Zero (which lacks AV output), too, so you’ll need to use Bluetooth or also attach an audio board using something like the HAT Hacker HAT. **M**

Verdict

High-quality audio capture in a small package that might be useful for a portable recorder or voice assistant project. It lacks its own audio output, though.

8/10



▲ With no chunky components on the underside, it’s a very flat, compact board

► Recording an audio clip, with the volume levels shown on the LCD



Embedded Learner Board

► Moonshot ► magpi.cc/learnerboard ► £19 / \$26

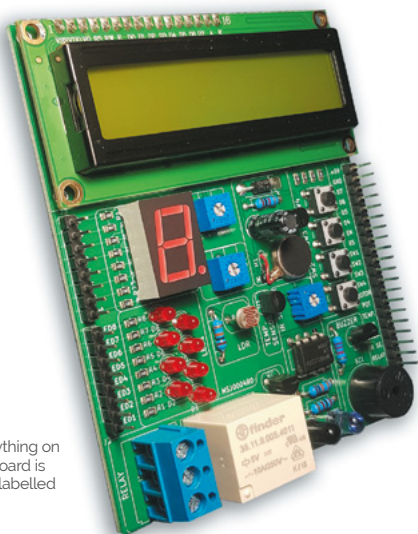
Can you ditch a breadboard for this all-in-one electronics board?
Rob Zwetsloot has a play to find out

We've seen a few HATs over the years that try something similar to the Embedded Learner Board – a number of electronic components attached to a board that you can control with Raspberry Pi. They're neat ways to help with someone's first steps in digital making.

The Embedded Learner Board takes it a step further, though. Also, it's not a HAT, which allows it to be a bit platform agnostic – it works with Arduino boards as well. The board itself contains a ton of different components: a 16×2 LCD display, a 7-segment display, buttons, LEDs, thermistor, IR sensor, a buzzer, even a light sensor. It packs a lot of functionality and because of that, it's also larger than a Raspberry Pi.

Learn to connect

As it's not a HAT, you'll need to manually connect wires to specific GPIO pins for what you'd like to



► Everything on the board is well-labelled



◀ The board box comes with the board itself, as well as some starter code to experiment with

SPECS

DISPLAYS:

16 × 2 alphanumeric, 7-segment

SENSORS:

IR, temperature

OTHER

COMPONENTS:

Vibration motor, buzzer, potentiometer, 4 × push-buttons, 8 × LEDs

use/control. Each element on the board is labelled and each corresponding pin is equally well-labelled so it's not a big issue – especially with the code examples that teach you how each part works. You can then start using bits in conjunction with each other.

“ It packs a lot of functionality and because of that, it's also larger than a Raspberry Pi ”

The examples are great and the board is pretty cool, although some of the parts are a bit more advanced for beginners than we'd prefer. Experienced parental supervision is required in our opinion, although it will be a fun shared activity. **M**

Verdict

It offers a lot of functionality for quite a low price, although it may be a little fiddly for younger kids.

9/10

10 Amazing: Raspberry Pi laptops

Take a Raspberry Pi wherever you go with these amazing kits and projects

While Raspberry Pi is optimised to be kept in a standard case, it's very easy to build a laptop around it – whether with a specialised kit for Raspberry Pi, or an excellent DIY project. Here are some kits and inspirational projects that should spark your interest. [M](#)



▲ Piper Computer Kit

Toy chest computer

A very unique laptop, Piper is a wooden box that you build with a Raspberry Pi, screen, and loads of other electronics bits. It even has bespoke software that teaches you about digital making.

£225 / \$299 | playpiper.com



▲ pi-top [4] FHD Screen & Keyboard

Green and lean

One of the most popular ways to turn a Raspberry Pi into a laptop, pi-top has been through many iterations. It's latest is a cracker. For Raspberry Pi 4, check our review of the pi-top FHD Touch Screen and Bluetooth Keyboard (page 78).

£222 / \$235 | pi-top.com



◀ NightPi

Pentesting briefcase

While the design may evoke images of a spy in a mid-to-late noughties movie, this pentesting build is very useful for security researchers. It runs Kali Linux and has a ton of extra useful tools as well.

magpi.cc/nightpi

▶ Steampunk Raspberry Pi Laptop

Covert present organiser

Is this laptop practical? Possibly not. Does it marvellously stick to its aesthetic while still working as a laptop? Absolutely. The woodwork is honestly top-notch here.

magpi.cc/steamlaptop



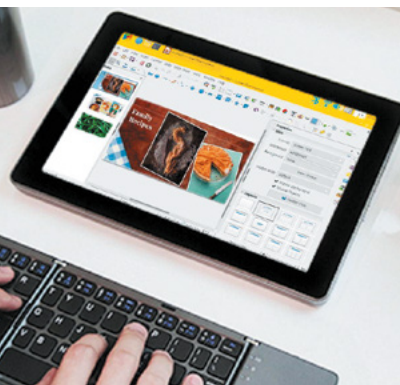


▲ Raspberry Pi Recovery Kit

Post-apocalyptic computer

A modern build with retro aesthetics, this cyberdeck is designed to help you through the apocalypse. It's even contained within a waterproof and EMP shielded box.

magpi.cc/recoverykit



◀ RasPad 3

Tablet computer

A tablet rather than a full laptop but you can easily connect a wireless keyboard to get the same functionality if you so desire. This version uses a Raspberry Pi 4.

£179 / \$239 | magpi.cc/raspad3

▼ CrowPi2

Hidden compartment laptop

A little similar to Piper, CrowPi2 is very cool in that it works like a normal laptop but the keyboard is removable. Underneath the wireless keyboard is a whole host of components to play around with.

£202 / \$269 | magpi.cc/crowpi2



▲ Raspberry Pi and Arduino Laptop

Raspberry Pi powered

While this is titled Raspberry Pi and Arduino laptop, the Arduino parts are accessories for the build, including a separate screen for battery charge, which is pretty neat.

magpi.cc/lappi



◀ LapPi

DIY laptop kit

A more traditional laptop-style build, LapPi is no less able to be used for digital making and is able to be customised a fair bit with HATs and other add-ons.

£147 / \$196 | magpi.cc/lappi



▲ Build a laptop project

Make your own

In issue 74 of *The MagPi*, we showed you how to build your own pocket laptop from scratch. It uses 3D-printed parts and a little TFT screen to display everything. It's pretty cute!

magpi.cc/74

Learn LibreOffice with Raspberry Pi

The best resources to use with this free and open-source office suite. By **Phil King**

LibreOffice Getting Started Guide

CREATOR

The Document Foundation

Price:
\$11

magpi.cc/librebooks

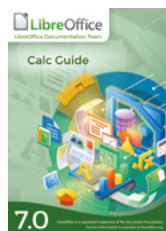
You don't need to pay big bucks or for a regular subscription to access high-quality office software. Available on all major platforms, LibreOffice is a fully-fledged office suite that includes apps for word processing (Writer), spreadsheets (Calc), presentations (Impress), vector graphics editing (Draw), mathematical formulae (Math), and databases (Base). The whole suite is included in the full version of Raspberry Pi OS, so you can get straight to work on your new Raspberry Pi 400 (or any other model). Although the main office programs will feel

fairly familiar to many users, this official guidebook (also available as a free PDF download) from the makers explores the suite in detail to help you get the most out of it. A setup chapter goes through various general settings, before the book shows how to create and apply styles and templates (a key feature of LibreOffice) to help speed up document formatting. Subsequent chapters take you through each individual office app, followed by guides to printing, images, HTML files, macros, and customisation.



Books to read

Essential reading for learning more about LibreOffice



CALC GUIDE

Discover all the features of the suite's spreadsheet app, Calc. Every detail is covered by this hefty 544-page guide, also available as a free PDF.

magpi.cc/librebooks

MATH GUIDE

A far slimmer tome, this shows you how to create and edit mathematical formulas with LibreOffice Math and then use them in the other apps.

magpi.cc/librebooks

WRITER GUIDE

While this 452-page book hasn't yet been updated to LibreOffice 7.0, it provides essential info, plus tips and tricks, for the popular Writer word processor.

magpi.cc/librebooks

LibreOffice Help

CREATOR

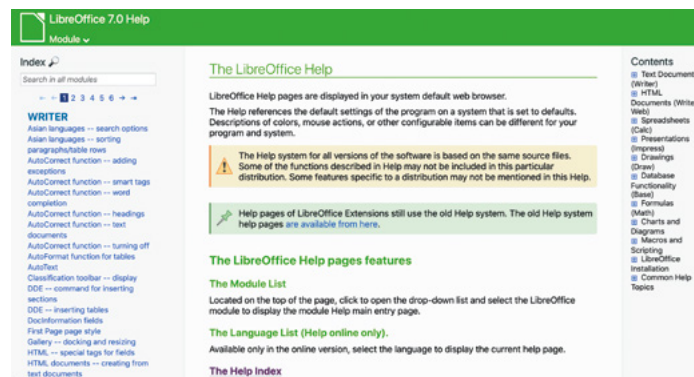
The Document Foundation

Price:
Free

magpi.cc/librehelp

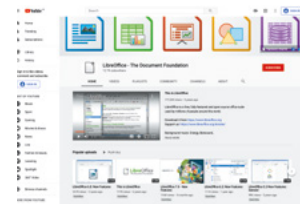
Clicking the Help option within LibreOffice takes you to this comprehensive online resource that should help you solve most issues. Every aspect of the suite is covered in detail and it's easy enough to navigate. As well as a drop-down list of modules (apps) and a search facility, there's an index list of keywords for all LibreOffice modules: click on a keyword to open the linked Help page.

In addition, there's a handy section for Common Help Topics, such as configuration, version tracking, printing, charts/diagrams, working with PDFs, and automatic functions. A particularly useful topic in this section covers compatibility with documents in Microsoft Office formats – they can all be imported without issue, although some special features may not work in exactly the same way.



Web resources

Get up to speed with this online information



LIBREOFFICE YOUTUBE

This official YouTube channel is a good place to catch up on new features in the latest version of LibreOffice. Some videos are in other languages. magpi.cc/libreyoutube

ASK.LIBREOFFICE

If you have a question not covered in the documentation, this is the place to come to ask away and get help from community members. magpi.cc/libreask

BUGZILLA

Spotted a bug or issue with the software? You can report it here. LibreOffice is a community-driven project, so you could also offer your help and/or donate. magpi.cc/bugzilla

Udemy LibreOffice courses

CREATOR


Udemy

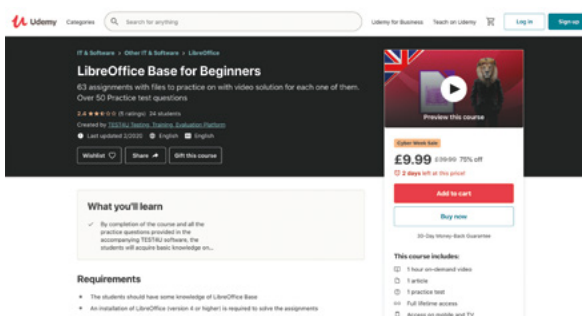
Price:
From £19.99

magpi.cc/libreudemy

There's no end of online courses available to learn LibreOffice, at a wide range of prices – you can pay hundreds for some. Udemy's courses

start at a reasonable £19.99 – at the time of writing, many were on sale at £9.99, so it's worth looking out for special offers.

Most of the courses cover a single app and all comprise a series of short video lectures, so it's bite-size learning that you can dip in and out of easily when you have time. There are also assignments or exercises to complete and example files on which to practise your new-found skills. Complete the course and you'll receive a certificate, although it can't be used for formal accreditation. 





Novaspirit Tech, aka Donald Hui

Meet the free spirit behind some ground-breaking Raspberry Pi projects

- ▶ Name **Donald Hui** | ▶ Occupation **YouTuber**
- ▶ Community role **Maker** | ▶ Website **magpi.cc/novaspirit**

Whatever your feelings are about Flash, it's impossible to overstate how important it was to a burgeoning generation of creative online teens in the noughties. Reminiscing about Homestar Runner will have to wait for another time, but it's a perfect way to introduce Donald Hui, aka Novaspirit Tech, who started his online adventure with Flash.

"Novaspirit Tech started back in 2003 as a placeholder for my Macromedia Flash web designs

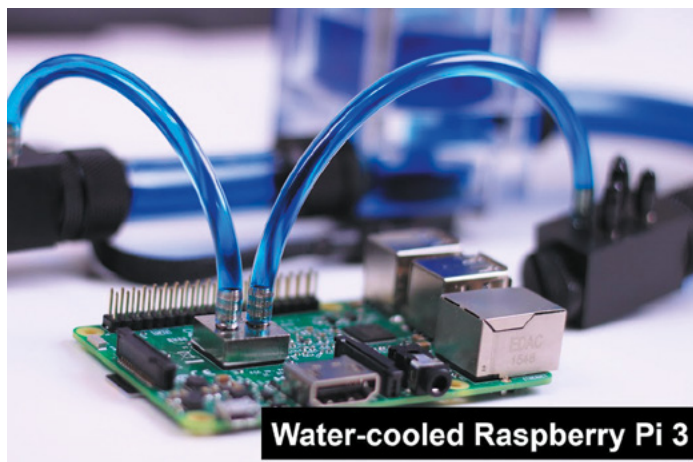
on GeoCities," he recalls. "Then I relaunched the website at its own domain in 2010 to host my tutorials and projects, such as installing GPU on laptops to installing kernels on Android phones. In 2013 my website crashed and lost the data, so I looked towards YouTube to host my tutorials, and at the same time I discovered Raspberry Pi. That's when it started to really define the tech in Novaspirit, putting together hundreds of projects for myself, friends, and families."

What is your history with making?

I've been a tinkerer since I was a kid. I would love to take things apart and try to rebuild or improve on them. That's where my quote 'Hack till it hertz' originated from, which means hack it till it works. Making devices do what they were not first intended to do was my specialty and also my flaw, because I tend to break more things than I fix.

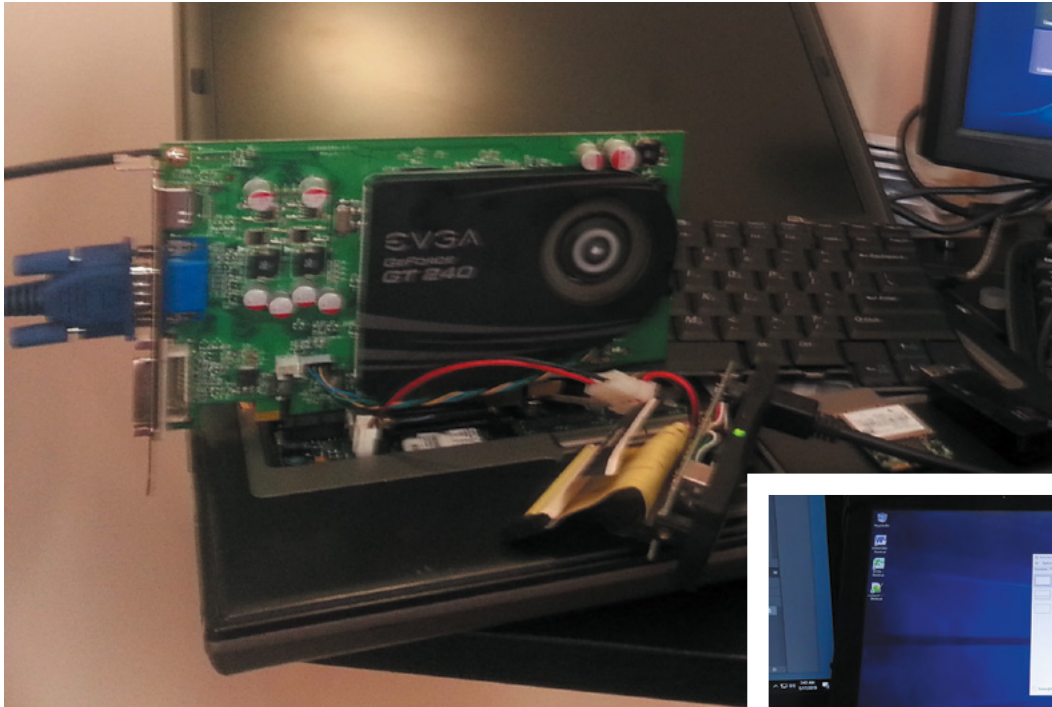
How has Raspberry Pi helped some of your builds?

Raspberry Pi has been a very critical part of my creations because I use it for what it's intended for, a dev board. Most of my projects will start with a Raspberry Pi, whether building a small web server or running a garage door opener with GPIO. Every step of the way you will always need an environment that is reliable and doesn't change too dramatically. From building the base code to GUI and interacting with GPIO, it's always nice to start with a board like Raspberry Pi.



Water-cooled Raspberry Pi 3

- ▶ Water-cooling a Raspberry Pi is unnecessary, but very fun to see



- ◀ Donald used to do a lot of hacks like this, installing GPUs into laptops
- ▼ Hacky makes with Raspberry Pi is Donald's specialty



What has the response been to your videos?

Most of the projects I've done with Raspberry Pi have gotten a lot of good feedback, mostly impressed at how I managed to get things to work on Raspberry Pi. I believe I was the first to install Amazon Echo on Raspberry Pi. I've even water-cooled a Raspberry Pi. I do have many firsts and the responses I get are great, although the water cooling one was just for jokes.

What are some of your favourite Raspberry Pi builds?

My favourite Raspberry Pi builds are the ones I use every day. The quad SATA Raspberry Pi NAS, USB over network with Raspberry Pi, and my most recent Raspberry Pi KVM over IP. *M*

“ My favourite Raspberry Pi builds are the ones I use every day ”



▲ The quad SATA is something Don says he likes to use every day

This Month in Raspberry Pi

MagPi Monday

Amazing projects direct from our Twitter!

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

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

01. When we first saw these pics, we didn't realise these keyboards were just graphics
02. Another cool robot build – we do like tracks
03. One step towards a DeLorean dashboard?
04. The number of stack light projects we see makes us think we need one
05. Android on Raspberry Pi 4 is something we always love to see
06. Recycled Raspberry Pi boards never looked so good
07. A very neat idea that we have been thinking about as well
08. At the time of writing, it is early December and people are gearing up with Christmas projects
09. We love this robot. It looks like it could cross any terrain

JP Atkinson
@JP_Atkinson

01

Replying to @TheMagPi

This week I have mainly messing with old school synthesizer emulators using 'bristol' & 'synthv1' applications. Used ALSA & JACK to connect Midi keyboard.

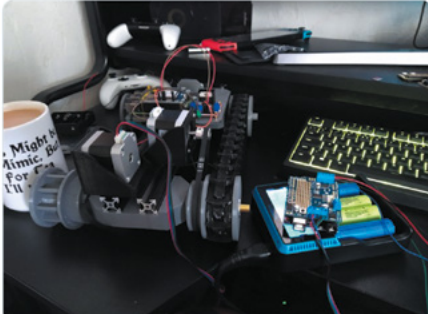


TheShaneOBrien
@TheShaneOBrien

02

Replying to @TheMagPi

Blissfully stumbling through this



03

Jon Rusho
@jon_rusho

Replying to @TheMagPi

Weekend project: @Raspberry_Pi GPS-sync'd NTP server with @adafruit displays for time/date.

04

Graham Allan
@GrahamAllan

Replying to @TheMagPi

A Stack Light using MQTT and @NodeRed for monitoring IoT devices.

05

JP Atkinson
@JP_Atkinson

Replying to @TheMagPi

Fun weekend with Android TV on RPi4. Hoping to add a Voice remote.

06

alesio minotti
@alemino13

Replying to @TheMagPi

#MagPiMonday just getting second hand Pi and putting them in a box, give them some cooling fan, power supply and they work tirelessly for @WCGrid right now: 1 1B, 2 2B, 1 3B, 1 3B+ and 2 4B.. more to come

07

PJ Evans
@MPEvans

Replying to @TheMagPi

Prototyped a @windowswap viewer for our kitchen nook zoom station. A different world view every 10 minutes.

08

Tech Dave M
@TechDaveM

Replying to @TheMagPi

Its CHRISTMASSSSSS!!! (NEARLY)

09

Ernam
@esesticorreo

Replying to @TheMagPi

Roverpi 2020

Translate Tweet

Best of the rest!

A bumper-sized best of the rest section to fit in everything from this month

LITTLE BACKUP BOX



We got an email from Dmitri, aka dmpop, about a fun project he's been maintaining called the Little Backup Box.

"It is a software that transforms Raspberry Pi into a simple yet versatile backup device," Dmitri says in his email. "Designed with photographers in mind, Little Backup Box provides a fully automated way to back up data from storage cards and directly from cameras. Little Backup Box has been featured on several hacker and photography websites, and it's used by many professional photographers and amateurs alike."

Installation and setup is very streamline, with a great little web UI. We all need a backup now and then, so see if it will fill your needs.

► magpi.cc/littlebackupbox

THE CHILDREN MACHINE LEARNING PORTAL



Dr Wednaud Ronelus, whom we interviewed back in *The MagPi* #92 (magpi.cc/92), is still doing a lot of work with Google AIY and machine learning in education. He's been pushing for AI tech to be used in education for ages now, and has had many successful workshops with kids in the New York area who have made use of Google AIY kits to play around with the voice services they provide, allowing them to understand more how the systems at home work. He's currently working on the Children Machine Learning Portal related to it.

He recently gave a presentation at the Brooklyn North National STEM/STEAM Day to show off how the kits could be used. You can watch the video of it at the following link.

► magpi.cc/cmlp

RETROPIE GAMECUBE



The GameCube has an iconic design, and a lot of space inside it once you gut it. A full RetroPie build has been installed into this one.

► magpi.cc/retrocube

INTERNET CONTROLLED PUZZLE ROBOT



The video of this robot solving a 3D puzzle is quite charming, and is similar to watching Twitch Plays Pokémon all those years ago – complete with upsets.

► magpi.cc/puzzlebot

Crowdfund **this!** Raspberry Pi projects you can crowdfund this month



Pi-oT 2

This new version of Pi-oT adds a UPS to the standard IoT features such as serial ports, analogue inputs, digital inputs, and digital outputs. "The addition of four digital inputs brings the precision series up to true industrial standards with IEC-61131-2 compliant inputs," says the page.

► kck.st/3fj1UYO



PiFinger

Biometrics have been a big part of smartphones for a while now, and while some of that stuff can be recreated using computer vision training, the humble fingerprint sensor is not something you've been able to fully do. Until now. The PiFinger is a fingerprint HAT, and we're very intrigued to know how it turns out.

► kck.st/3mcV5uk

CROWDFUNDING A PROJECT?

If you've launched a Raspberry Pi-related project, let us know!

magpi@raspberrypi.com

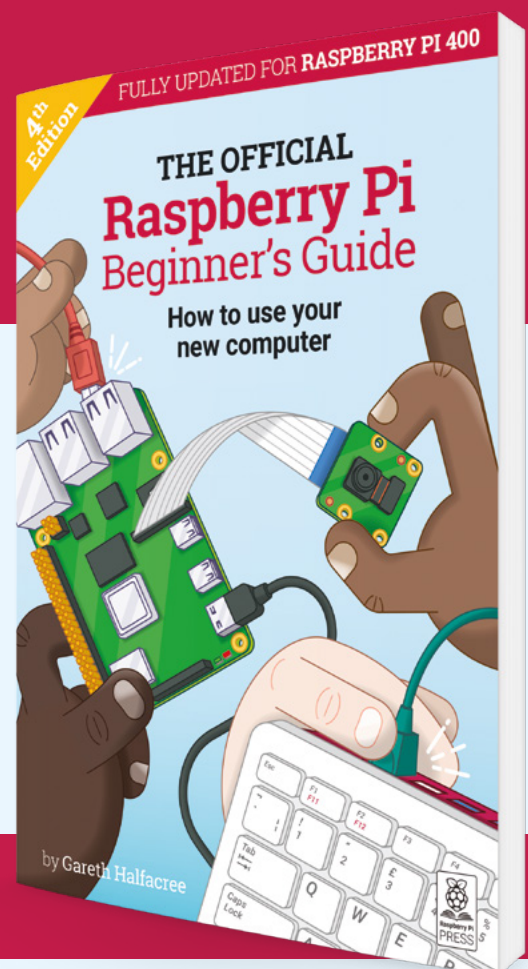
THE OFFICIAL Raspberry Pi Beginner's Guide

The only guide you need to get started with Raspberry Pi

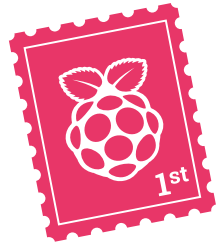
- Learn how to set up your Raspberry Pi, install an operating system, and start using it
- Follow step-by-step guides to code your own animations and games, using both the Scratch 3 and Python languages
- Create amazing projects by connecting electronic components to Raspberry Pi's GPIO pins

Plus much, much more!

Buy online: magpi.cc/bgbook4



Your Letters



Camera conundrum

I have a simple web-based webcam that looks at my front door and I can see if I have any post. This is OK for the basics.

It may seem a bit silly as my house is not large, but this is in another country and it is a very small holiday home. Post is not a good reason for me to fly right now, even if the flights were not cancelled.

The webcam has proved useful this year, as I was able to get a friend in to collect some important-looking post and send it on. I could just make out one of the pieces of mail was a card from the post office saying 'I was not in'!

I have looked around and I can find some expensive cameras but have no idea if they are fit to work with Raspberry Pi. A lot of money to waste if I get it wrong.

I am confused as to where to look and what to look for. This will connect to a Raspberry Pi and needs to pan, tilt, and zoom with focus (small shopping list there).

Has anyone out there put together such a device? I'm looking to see what they used and maybe where they got it from. I love to tinker, hack, or whatever the latest term is, but this seems an expensive project to fail and I have looked around.

Please, I am looking for the pointers to the sort of kit I may need. I can take it from there.

Peter via email



▶ The HQ Camera does have lens support, but it lacks the functionality to control motors

Pan and tilt with a Raspberry Pi camera is fairly simple – it can be accomplished with something like the Pan-Tilt HAT: magpi.cc/pantilthat.

As for motorised zoom and focus, that's where it starts to get trickier. We've not tested anything out, but there are some products you can find that have a motorised focus function installed into a Raspberry Pi Camera Module.

They don't have zoom functionality, though. Unfortunately, the new HQ Camera doesn't have a way to control attached lenses, so there's no way to attach a zoom/focus lens on one of those either. So you'd be looking at something a bit hackier. At the very least, you can set it up so you get a better picture of the mailbox and make use of the higher resolution to zoom digitally.

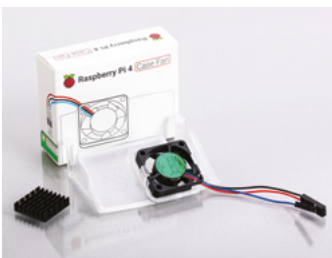
Fan functionality

I picked up the Official Raspberry Pi Case Fan after it was released as I was happy to see a more active cooling solution for use in the official case, of which I have a couple. I was thinking of modifying my case to add extra ventilation – any clues on where the holes should go?

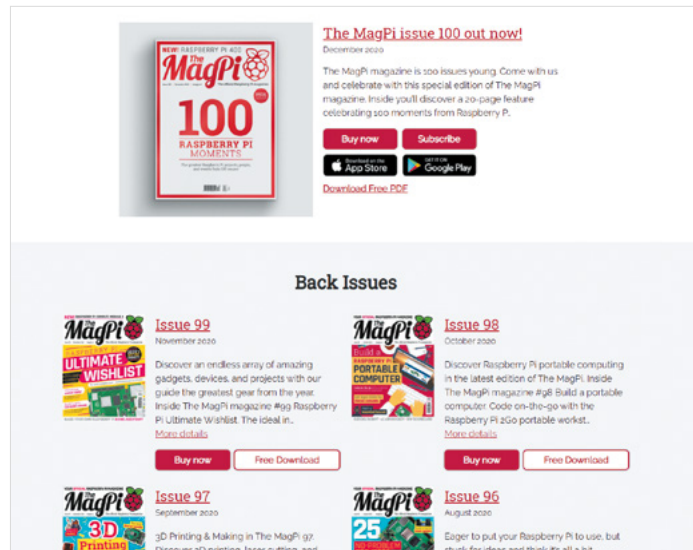
Leah via Facebook

The designer of the Case Fan, Gordon Hollingworth from Raspberry Pi Trading, has mentioned that it doesn't actually improve airflow by adding ventilation. You can read more on the design and flow of the Case Fan in our news piece starting on page 10.

As the air exits through the microSD card slot of the case, however, you could possibly add some holes to that side of the case, as well as above the USB and Ethernet ports. Be careful using a drill, though!



▼ The new Case Fan is able to keep your Raspberry Pi much cooler – perfect for high load scenarios



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The MagPi magazine is 100 issues young. Come with us and celebrate with this special edition of The MagPi magazine. Inside you'll discover a 20-page feature celebrating 100 moments from Raspberry Pi.

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Eager to put your Raspberry Pi to use, but stuck for ideas and think it's all a bit...

▲ Your regular reminder that every issue of *The MagPi* is available to download as a PDF from the website: magpi.cc/issues.

Digital contribution

I regularly download *The MagPi* and although most of it is not relevant to my interests, it's good to know about the work going on. Not interested enough to pay a regular subscription, I'm afraid, but would be happy to make an occasional donation so was happy to see your new front-end asking for such prior to downloading.

Derek via email

For folks who don't usually grab the PDF, you may not have noticed that we've rolled out a contribution page before accessing it. You can still download it for free, but we regularly get asked about whether or not we accept contributions, so decided to add this option.

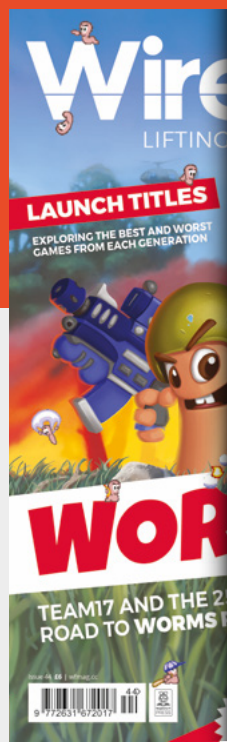
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A brand new year

Rob Zwetsloot looks ahead to next year, and how to keep things attainable

As I write this, it's about a month until January. While there are a couple of... small events between now and the new year that are taking up most of my concentration, I've still had the few thoughts about what to do when 2021 rolls around.

A new year usually means resolutions (please, no display jokes – that joke is older than I am, probably), something folks usually take to heart for upwards of two weeks and then slowly forget. Especially when it's the classic 'exercise more' – it's always a bit harder to keep up than you suspect!

“ There's a whole host of new Raspberry Pi stuff that wasn't there before ”

I'm sure many of you have resolutions based around making. Or at least, I hope you do so that I can construct this narrative. Is this year

the year you finally make that robot? Maybe you have your eyes on some home automation projects? Whatever it is, obviously we at *The MagPi* will be there to help you along the way, but I want to reiterate the theme of my previous column by saying: build up to it.

New toys for a new year

Unlike last year, there's a whole host of new Raspberry Pi stuff that wasn't there before. The HQ Camera with swappable lenses was launched earlier in 2020, while Raspberry Pi 400 and Compute Module 4 were released in the last few months. Plenty of cool tech to play around with, however you decide to make in 2021.

For me, the big release was Raspberry Pi 400. Although it's on the other side of the size scale, it does remind me of when Raspberry Pi Zero first launched five years ago. Back then I was imagining amazing things I could do with my Raspberry Pi Zero, and now I'm thinking about ways to tinker with Raspberry Pi 400. Could it be made into a synth? Very likely. Can I make it into an all-in-one synth with speakers and battery and

such? Now I'm thinking with portals. Unfortunately, I can't play music. I'll cross that bridge when I get to it.

Centenary

We also released our 100th issue in 2020, of which I've worked on 70. It's been an enormous privilege to work on *The MagPi* for nearly six years now, and I feel very lucky every day that I get to interact with the community and the teams at Raspberry Pi to make sure as much as possible gets into the magazine. Spoiler: it's usually me asking you what you've built on a Monday.

We're not planning to slow down any time soon either. We have eleven more fantastic issues to make for you this year, and I can't wait to see what you all do over 2021 that we can shout out in them. Have a happy new year, and remember: forgiveness is divine, but never pay full price for late pizza. 🍕

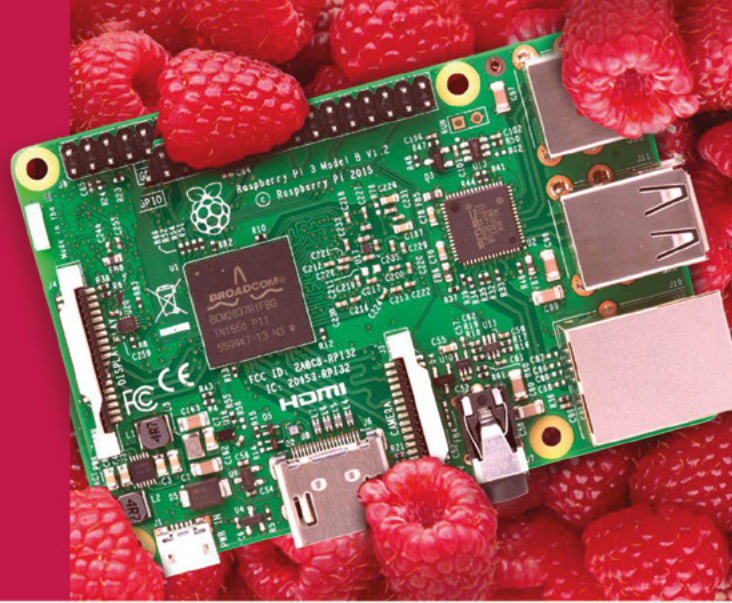
Rob Zwetsloot

AUTHOR

Rob is amazing. He's also the Features Editor of *The MagPi*, a hobbyist maker, cosplayer, comic book writer, and extremely modest.

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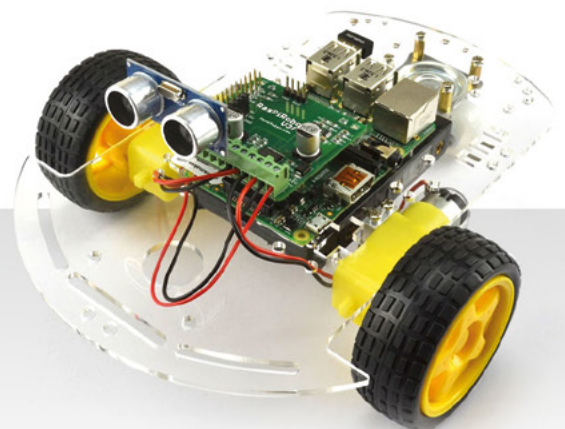
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