MAKE | BUILD | HACK | CREATE

HackSpace

TECHNOLOGY IN YOUR HANDS

hsmag.CC | May 2021 | Issue #42

THE REPAIR REVOLUTION

BUDGET CNC
Automate your carving

HOW I MADE
A guitar pedal tester

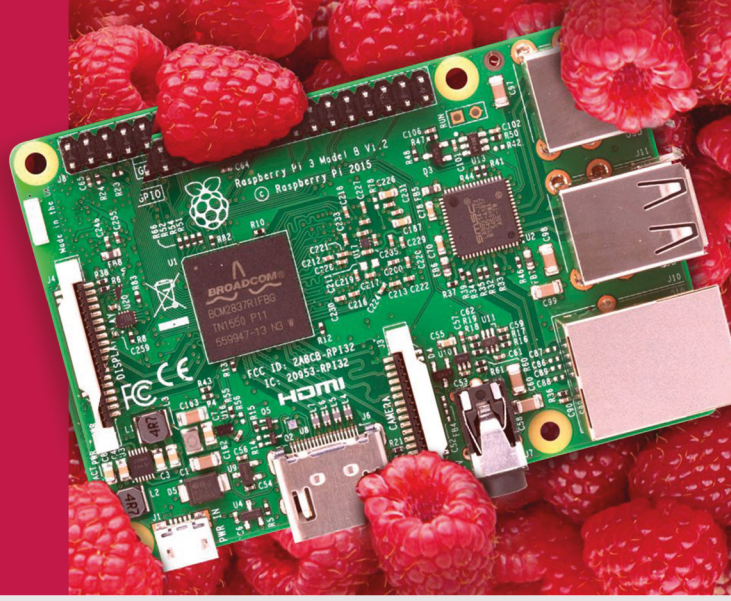
DIY GAMES
Make a Raspberry Pi Pico USB controller

Raspberry Pi PRESS
May 2021
Issue #42 £6
9 772515 514006 42

SAVE YOUR MONEY | SAVE YOUR TOOLS | SAVE YOUR PLANET

INSIDE: ESTEFANNIE EXPLAINS IT ALL

American **Raspberry Pi** Shop

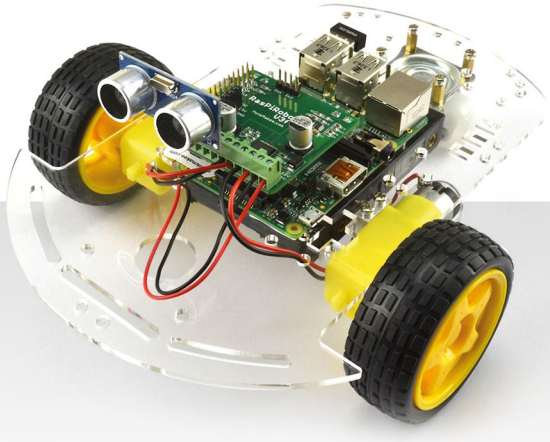


- Displays
- HATs
- Sensors
- Cases
- Arcade
- Swag
- Project Kits
- Cameras
- Power Options
- Add-on Boards
- Cables and Connectors
- GPIO and Prototyping

Partner and official reseller for top Pi brands:

adafruit · sparkfun ELECTRONICS · PIMORONI · HiFiBerry · and many others!

Price, service, design, and logistics support for **VOLUME PROJECTS**



USA PiShop.us

Canada BuyaPi.ca

Raspberry Pi APPROVED RESELLER

Welcome to HackSpace magazine

"If ifs and ands were pots and pans, there'd be no work for tinkers", my Gran used to like to say. Of course, I had no idea what a tinker was (it's a travelling pan repairer if you're also unfamiliar with the word). The simple act of repairing a pan was unimaginable to me, and probably to most people of my generation. Pans last a while, then you get rid of them, and get some new ones. Buy why? Why don't we fix our pots and pans? Why does it make sense to dig in the ground to extract some ore, go through the energy-intensive process of extracting the metal from that ore, then heat the metal up until it's white-hot, and form it into a pan shape? Surely it's easier to repair something that's already 99% of a working pan than start with some bits of rock that contain the basic pan-making ingredients?

Repair is starting to become fashionable again. It's cheaper, better for the planet, and gives us more sense of ownership of our things. Let's stop throwing broken things away, and start fixing them again. Maybe there is still work for tinkers.

BEN EVERARD

Editor ben.everard@raspberrypi.com

Got a comment, question, or thought about HackSpace magazine?

get in touch at **hsmag.cc/hello**

GET IN TOUCH

hackspace@raspberrypi.com

hackspacemag

hackspacemag

ONLINE

hsmag.cc

Available on the App Store

GET IT ON Google Play

EDITORIAL

Editor
Ben Everard
ben.everard@raspberrypi.com

Features Editor
Andrew Gregory
andrew.gregory@raspberrypi.com

Sub-Editors
David Higgs, Nicola King

DESIGN

Critical Media
criticalmedia.co.uk

Head of Design
Lee Allen

Designers
Sam Ribbits, James Legg, Ty Logan

Photography
Brian O'Halloran

CONTRIBUTORS

Rosie Hattersley, Jo Hinchliffe, Mayank Sharma, Marc de Vinck, Andrew Lewis, Alex Bate

PUBLISHING

Publishing Director
Russell Barnes
russell@raspberrypi.com

Advertising
Charlie Milligan
charlotte.milligan@raspberrypi.com

DISTRIBUTION

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

SUBSCRIPTIONS

Unit 6, The Enterprise Centre,
Kelvin Lane, Manor Royal,
Crawley, West Sussex, RH10 9PE

To subscribe
01293 312189
hsmag.cc/subscribe

Subscription queries
hackspace@subscriptionhelpline.co.uk

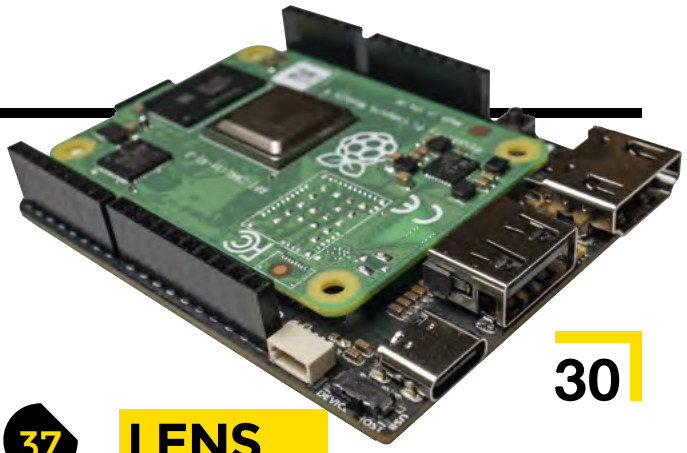
recycle

CC BY NC SA

This magazine is printed on paper sourced from sustainable forests. The printer operates an environmental management system which has been assessed as conforming to ISO 14001.

HackSpace magazine is published by Raspberry Pi (Trading) Ltd., Maurice Wilkes Building, St. John's Innovation Park, Cowley Road, Cambridge, CB4 0DS The publisher, editor, and contributors accept no responsibility in respect of any omissions or errors relating to goods, products or services referred to or advertised. Except where otherwise noted, content in this magazine is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0). ISSN: 2515-5148.

Contents



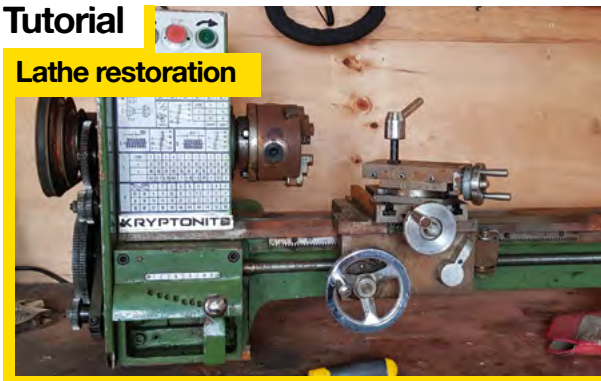
30

06 SPARK

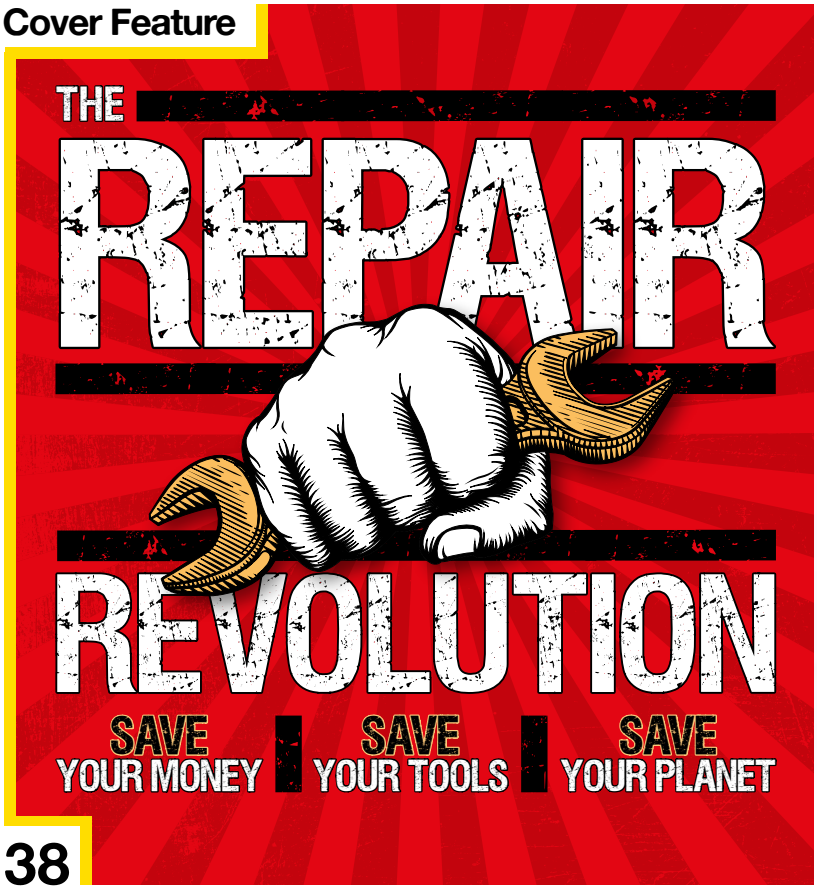
37 LENS

Tutorial

Lathe restoration



Cover Feature



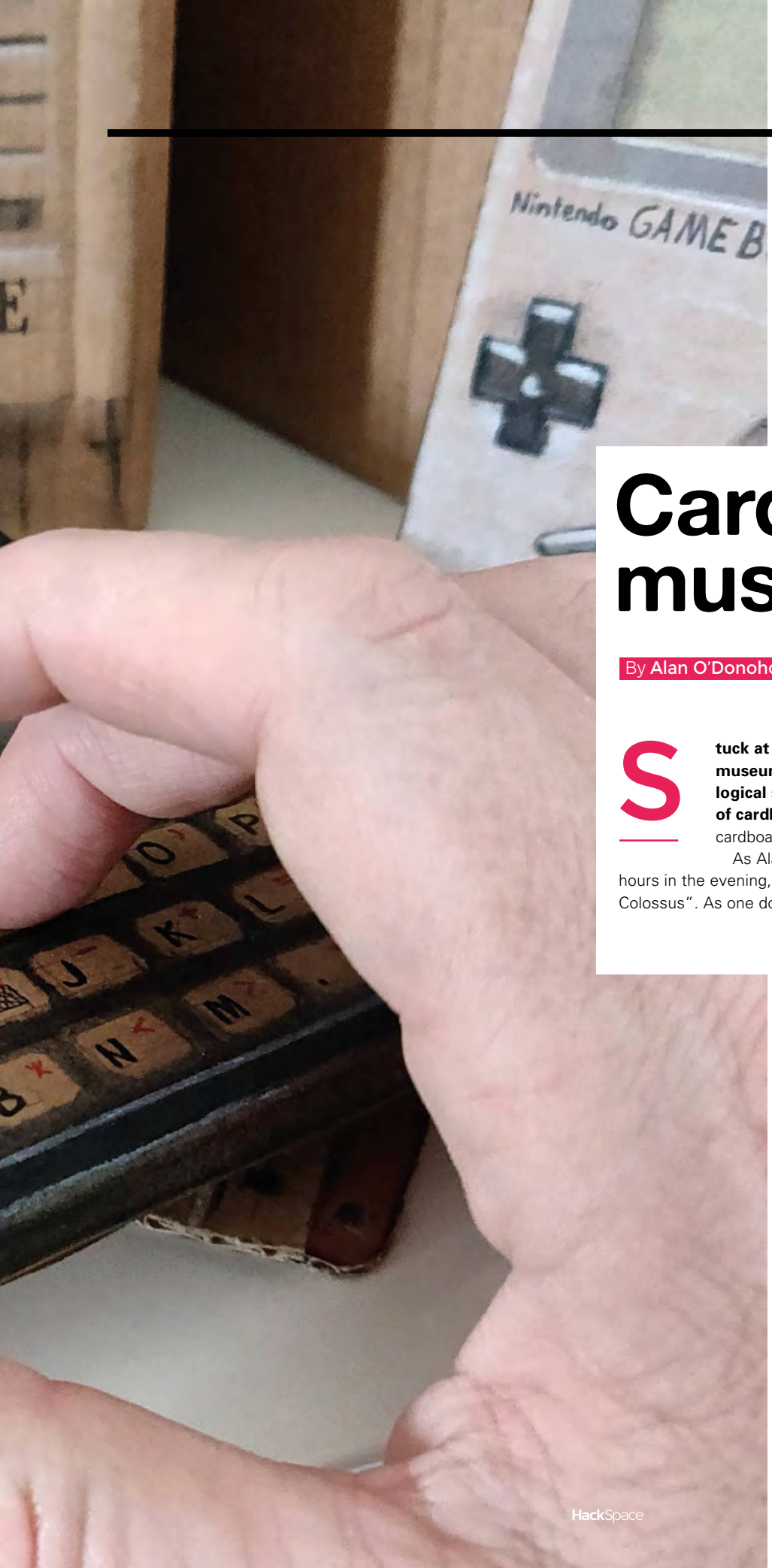
Best of Breed

VFD kits

Interview

Estefannie

REGULAR



Cardboard museum

By Alan O'Donohoe

hsmag.cc/CBMuseum

Stuck at home and unable to go to his favourite museum, Alan O'Donohoe came up with the most logical solution: he'd build his own museum out of cardboard. Builds include a BBC Micro, ZX81, a cardboard Colossus, and the Mac Classic.

As Alan puts it, "I was without my phone for a few hours in the evening, so I decided to try building a replica of part of Colossus". As one does!

Left
Alan's a former teacher, who left in order to spend more time inspiring kids to learn about STEM, especially computing: check out exa.foundation to see more

REGULAR

Disco Geiger counter

By **Hamilton Karl** hsmag.cc/DiscoGeiger

During the Cold War, in order to distract us from the thought of total nuclear destruction, the US government distributed Geiger counters, apparently for civil authorities to check that it was safe to come out of the bomb shelters in the event of a nuclear attack. Of course, we now know (and they knew then) that any military nuclear attack would devastate the world. Civil defence Geiger counters were a piece of security theatre, to kid the public that there would ever be a 'normal' life again.

Still, they make excellent starting points for whimsical electronics projects, as this Disco Containment Unit shows. Hamilton has kept controls to a minimum, with power, motor control, lights on/off, and a light mode switch. A motor turns the disco ball, lit with four NeoPixels, and there's an Arduino Nano clone powering the whole thing.

Right
When the machine boots, it plays *Stayin' Alive* by the Bee Gees on a piezo buzzer

Puri Nixie clock

By Dalibor Farny

hsmag.cc/PuriClock

We've seen the beautiful work of Dalibor Farny before in HackSpace magazine, and it's always a treat when he comes out with something new. This is the latest product from his medieval castle workshop: a six-digit, 3.2 kg, brand-new Nixie clock.

Unlike the old-stock Nixies that you may find on auction sites acquired from former Soviet warehouses, these Nixies come with a ten-year warranty. Also, unlike anything else we've seen using this technology, the clock comes with a phone app that enables you to set the time zone, time format, specify whether you want daylight-saving time, and more. And of course, it looks so, so nice.

Right
Dalibor has had a four-digit version of this clock for a while; it's taken some time to get round to adding the seconds


6432
PORTS

REGULAR


IP: 192.168.20.18
CPU Load: 0.67 31.0°c
Mem: 66/1933mB 1.40%
Disk: 6/12mB 55%

Desktop Raspberry Pi case

By Michael Klements

hsmag.cc/DesktopCase

PC aficionados love two things above all else: overclocking and cooling. We looked into cooling a Raspberry Pi with liquid nitrogen way back in the early days of HackSpace magazine, but this solution by Michael Klements is just a smidge more user-friendly.

He's used an ICE Tower cooling system for Raspberry Pi, an I2C OLED display, various cables and screws, clear laser-cut 2 mm acrylic for the sides, and black PLA filament for the body. Michael designed the case in Tinkercad – he's also made the design files available so that you can build this case yourself.

Left
The OLED screen displays system data such as CPU load, and how much RAM is in use

REGULAR

Terrahawks!

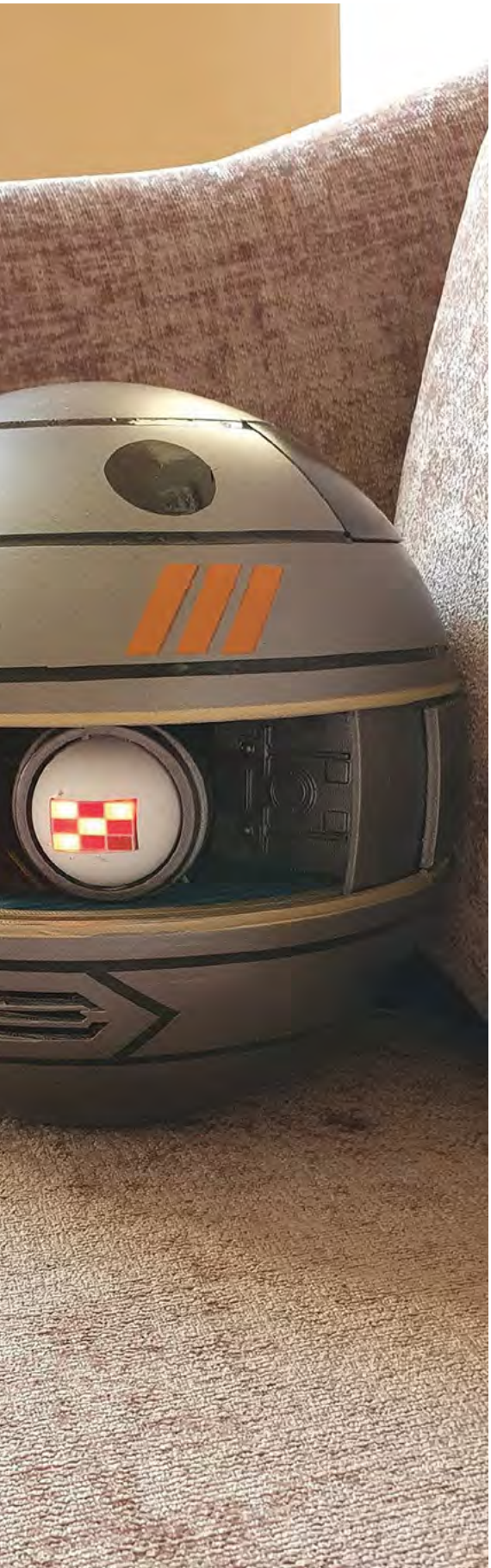
By Dave Stapley

hsmag.cc/Terrahawks

***Terrahawks* was a children's TV show produced by Gerry Anderson (he of *Captain Scarlet, Stingray,* and *Thunderbirds* fame).** As such, it relied on Supermarionation: Anderson's technique using puppets that included electric moving parts. Forty-one short years after it was first screened, *Terrahawks* is now perfect inspiration for Dave Stapley, who has made his own 3D-printed Major Zeroid from the show.

We don't have many details to share; frankly, we don't need any. Dave says he's going to share the 3D print files soon. The LEDs in the eyes and mouth are animated, and the character's eyes open and close. Hopefully he'll include the voice of the original character (provided by Windsor Davies!) Until that time, we'll just have to imagine it.

Right
Terrahawks was set in (what was then) a distant and desolate future: the year 2020



Pocket Arduino weather station

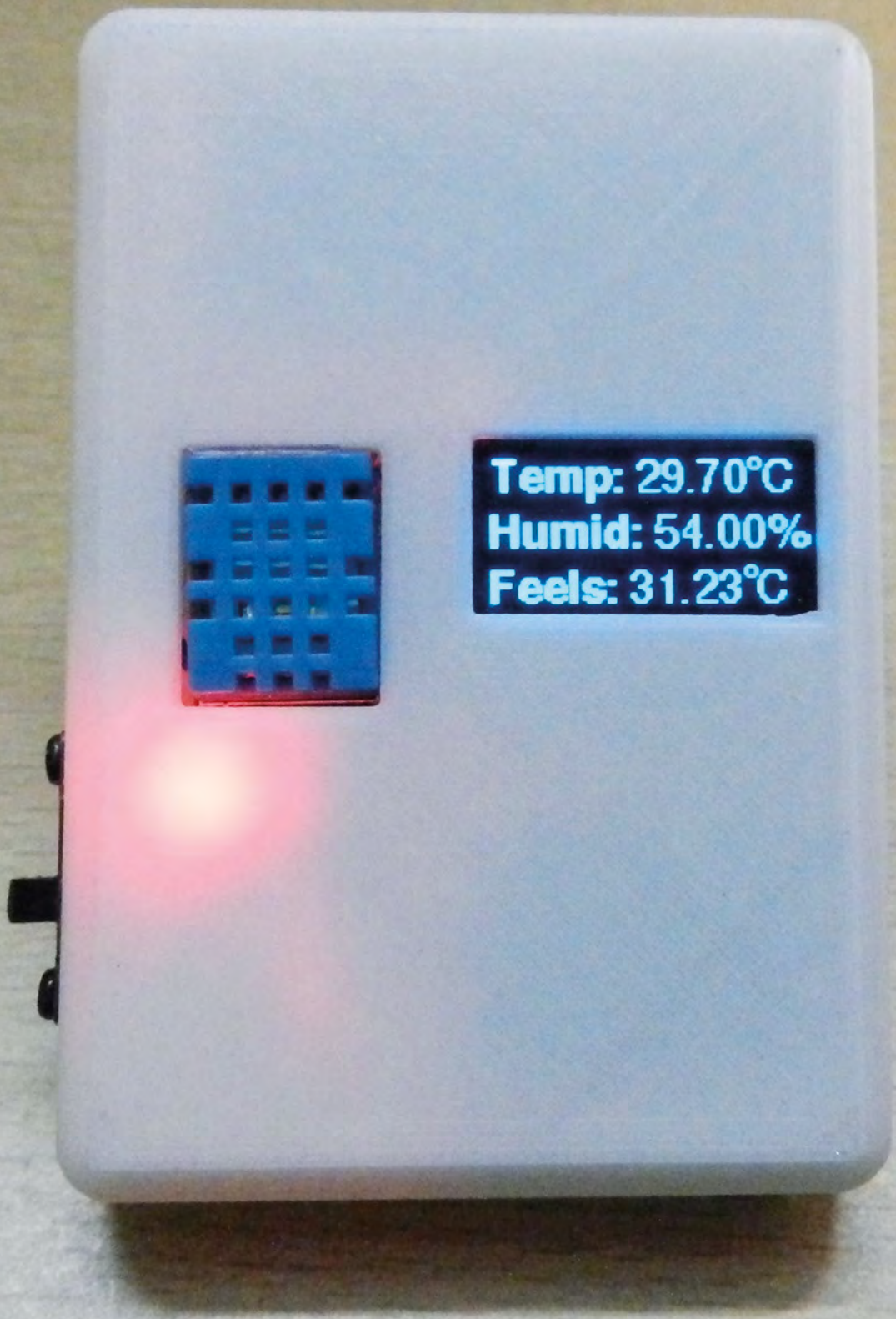
By Aarav Garg

hsmag.cc/PocketWS

On the day of writing this, England has had snow, hail, clear blue skies, sunshine, and freezing cold, all in the space of about four hours in early April. What we need is a pocket weather station, like this one, designed and built by Aarav Garg.

Aarav got into technology about four years ago; he's since delivered lectures in universities, and taught robotics in high schools in India. He's also only 15 years old! Aarav's device uses a DHT11 temperature sensor, an Arduino Nano, an OLED display, a 160mAh battery plus charging module, and a circuit he designed in Fritzing. It's a perfect example of a device that does one thing and one thing well; it's finished, therefore it's perfect.

Right
There's more detail on Aarav's builds, including this project, on his Instructables page: hsmag.cc/Aarav


Temp: 29.70°C
Humid: 54.00%
Feels: 31.23°C

Objet 3d'art

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

This beautiful object is a MIDI Fighter, designed by Liz Clark and Noe Ruiz. It has 16 buttons inspired by the more-is-more aesthetic of the Street Fighter II arcade game, with each button linked to a sound file triggered by MIDI. Oh, and it's controlled by a Raspberry Pi Pico and programmed in CircuitPython. We could go on, but we'll leave that for the next issue where Liz will tell us all about it. Until then, feast your eyes: layer lines are usually something that we like to minimise, but here they're part of the aesthetic. This object would look wrong if it were anything other than 3D-printed. ◻

hsmag.cc/MIDIFighter

Meet The Maker: Steph Piper – Elkei Education

Making a unique product comes with unique challenges

As our regular columnist Drew Fustini will tell anyone who wants to listen, PCBs have got a lot more interesting over the last couple of years. They're not just green anymore: you can get different coloured solder masks, weird component orientations, different thicknesses and, thanks to free software, it's not beyond the realm of the possible to lay out your own custom design. PCBs are art, and art is human and good.

> So I pitched the idea of electronics for girls, **without having much idea about circuit boards or anything like that**

Even so, we were amazed by the designs produced by Australian companey Elkei Education, so we had to speak to Elkei's CTO, Steph Piper.

"Elkei began as an idea for a startup competition weekend. The idea of these is that makerspaces let people go and do entrepreneurship activities; you can hire a desk and work on your own business ideas. They often host competitions where you can go and pitch the bare wisp of an idea. You say to everyone. You form teams all around the idea, and work on it over the weekend until you pitch the idea to a panel of judges.

"So I pitched the idea of electronics for girls, without having much idea about circuit boards or anything like that. That's where I met my business partner Andrea [Madden]; she's fantastic. She's the marketing and social media expert, which is great because I'm not very good at that stuff. We ended up winning that weekend and we got to go to the international finals, which were in Bali, Indonesia. We got to go and pitch again against a bunch of other teams from Malaysia, Japan, Brunei, all kinds of places. And we ended up winning that as well. So we thought, wow – maybe this idea has got legs.

"We started off with a bunch of different ideas, and at that point I hadn't actually designed a circuit board before. We footered around with a bunch of different stuff, until I sat down and did like a marathon of YouTube tutorials and figured out circuit board design.

"We pivoted quite a few times before we landed on starting more organically, and starting small with the soldering kits. And in August 2019, we ended →

Right
"If anyone wants to get started in PCB design, I'd recommend starting by watching Shawn Hymel's YouTube series on KiCad; he's fantastic. He explains things beautifully, steps through it, and someone who doesn't have an electronics engineering background can follow along and understand what's happening really quickly."

REGULAR

> Lucky for me, learning KiCad, the PCB software, **was the last missing piece I had to learn**

up travelling to China. We found a factory that would do the two colours on the board for us, which is pretty wild to think about now – we were originally planning to go over there for the Maker Faire in November, which would have been impossible when Covid came along, because that's when it all started to happen.

"We ended up travelling to a circuit board exhibition in China as part of our trip. We went through there and spoke to everyone, and none of them were interested in doing two colours. "[Go away] with your weird, beautiful circuit board ideas. Circuit boards are meant to be functional!" We were very lucky to find a place that would do it for us, because it's a little bit of extra work on their end, as you can imagine.

"I was inspired by the #badgelife hashtag, because there are so many solder mask colours that people use around that. The big pinky-white one that they did for the Mr. Robot badge. Those are just fantastic, oh my gosh.

"My expertise is in 3D printing. I did some time doing research on 3D-printed body parts; that's my main research area. I started getting more and more into electronics, Arduino, and designing my own circuit board – that's the next thing that you want to be doing. You always want to challenge yourself, and that was the next thing that I wanted to challenge myself to do. It was always on my list of things to try.

"There was way too much trial and error along the way to getting these designs. The most recent design, the cat, took nine iterations to get to this point. The software, in particular, is a lot of work by the time you want to do the art stuff. Lucky for me, learning KiCad, the PCB software, was the last missing piece I had to learn. You have to start off in 3D modelling software to work out how the pieces snap out and fit together in a three-dimensional shape. Then you put all that down and make your edge cuts, then export that from your 3D modelling software into Adobe Illustrator, and work with your artists to make the artwork. You fix that up to make sure it's circuit board-friendly, then you put that into Inkscape, fiddle around with it even more, then you put it into KiCad. This is the stage where you realise you've overlapped your art design with your schematic design. It's very easy to have to start from scratch in that process all over again, because you realise that things don't match up. Using the actual circuit board lines as the art lines is something that I can see why nobody else is really doing it, because it's a huge pain in the arse. →

Above
"Elkei is a bit of side hustle for me. I have a day job working at the local university; I run the makerspace there."

REGULAR

"We've had a fantastic response whenever I've posted something new on Twitter. I think people really like them because they're a good example of what STEAM should look like. We see a lot of STEM stuff, the science, technology, engineering, and maths, but we don't see a lot of STEAM [the A is for Art] stuff being done all that well. I feel like this is one of the few things that hopefully will start to get the message across as to why it's important to incorporate all those things.

"In terms of the business model itself, not everyone in the mainstream is going to have a soldering iron at home. In terms of scaling up so that you buy kits like this in a shopping centre, we're certainly not there yet.

"The aim of Elkei Education is to make electronics as least a frustrating process as possible. I get pretty frustrated with some of the stuff that I try and teach and do. Especially with wearable tech – normally, you'd be getting your classic LilyPad stuff, getting your conductive thread out, and hand-stitching it. And by the time you get around to teaching a class full of kids, you soon realise how frustrating hand-sewing is, especially for someone who has not done it before. Especially kids – it is so frustrating trying to get them to put the thread through the needle and then move the needle through the fabric to create the stitch.

"So, sort of trying to figure out ways to make that process easier and more fun for people is something that we've tried to do with one of our current projects. Rather than using conductive thread to do a running stitch, we're using conductive tape instead: you make a couple of rails with the tape, and then you can just stitch the pieces down without having to stitch in-between them, which makes it a little bit easier, and makes the project easier to scale as well.

> People see a 3D printer and are like **'oh gosh, I could never do anything like that'**

"I'm working on a new type of machine-sewable wearable tech board. It has auto-cycling LEDs – they flash through a rainbow sequence without inputting any code. The idea is that you can put down a couple of rails of conductive tape on either side, and once you've tested that the circuit works, you can run it straight through a sewing-machine, which you can't do with any other board at the moment – it's all hand stitching stuff. I want to get making things real easy to do, and real easy to work with if you're a wearable tech professional of some kind.

"I absolutely adore all the stuff at the moment that's coming out from the likes of Lumen Couture. They have pretty much plug-and-play methods of

If you're lucky enough to live in the UK, you can get hold of Elkei's soldering kits at Pimoroni.com

installing heated pads into clothing, soft-touch buttons, lights – it's so cool; I love it!

"I've also got a new type of little coin cell battery holder. It's got conductive tape-compatible ends, and it also has a little hole for a screw underneath – the idea behind that is that it will comply with Australian product safety guidelines around kids swallowing coin cell batteries. You've got to make sure that you can only take out the battery with a tool of some kind, so the child doesn't have access to it. That's important if you want to get stuff into schools. You just don't want to have any of that kind of risk.

"One of our goals is to get 500,000 girls in Australia into STEAM. It's a lofty goal that we can continue to work towards. I'm not sure if we'll get there, but we're sure hoping to. It feels like a slow crawl at times, but we're getting there.

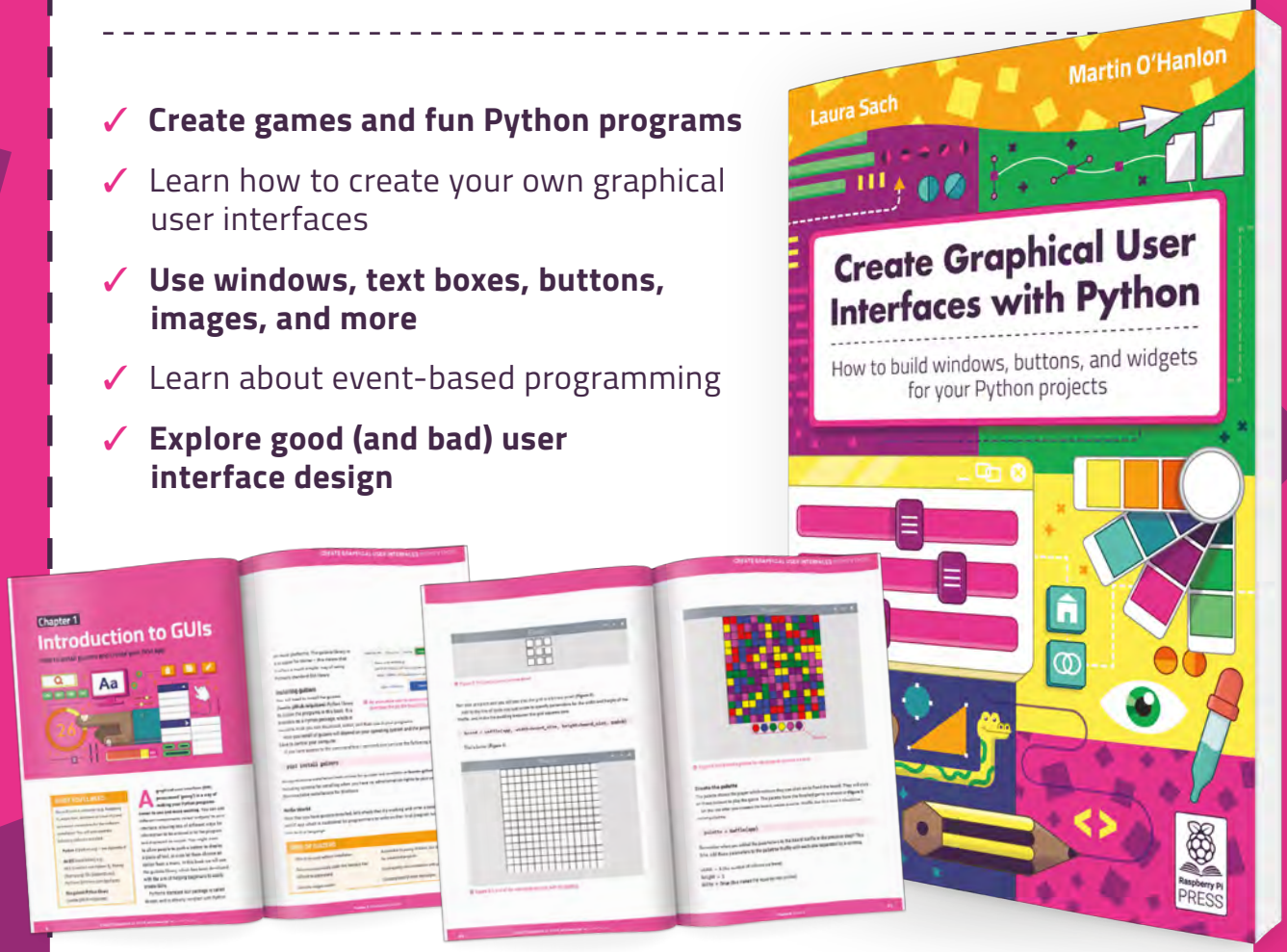
"I don't get to see much of what goes on in schools; the age group that we work with is university level. I still see so much fear of technology sometimes. People see a 3D printer and are like 'oh gosh, I could never do anything like that. Put that in the hard basket. Terrifying!' Where in reality, it takes 15 minutes to put on a print of Baby Yoda, and off you go.

"There's still so much left to do in this space. It's so fresh, because there's this gap of skills. People who are sewing experts aren't going to be experts at electronics too. It seems really surprising to me that the first person to design a machine-sewable electronics thing is me: it feels weird. Why am I the first person to do this?

"We're still so early. That's one of the things I'm really excited about, to keep creating and inspiring others to look at this stuff. I want to make sure that everything I'm doing is as accessible and open as I can make it, because the more people who get involved, the more we'll be able to do, and the more cool things will happen." ◻

Create Graphical User Interfaces with Python

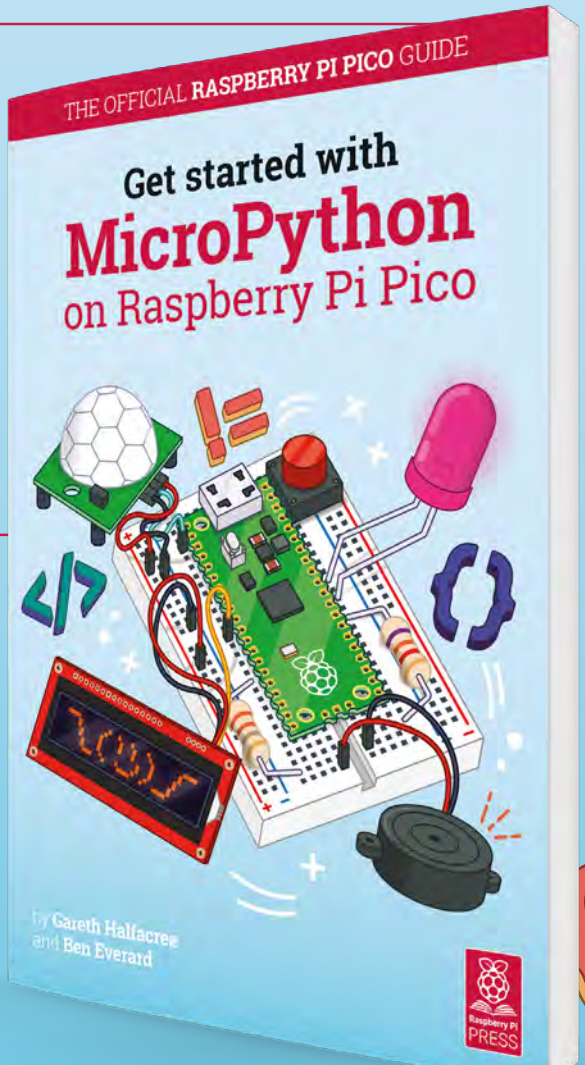
- ✓ **Create games and fun Python programs**
- ✓ Learn how to create your own graphical user interfaces
- ✓ **Use windows, text boxes, buttons, images, and more**
- ✓ Learn about event-based programming
- ✓ **Explore good (and bad) user interface design**



Buy online: magpi.cc/pythongui

Get started with MicroPython on Raspberry Pi Pico

Learn how to use your new Raspberry Pi Pico microcontroller board and program it using MicroPython. Connect hardware to make your Pico interact with the world around it. Create your own electro-mechanical projects, whether for fun or to make your life easier.



- **Set up your Raspberry Pi Pico and start using it**
- **Start writing programs using MicroPython**
- **Control and sense electronic components**
- **Discover how to use Pico's unique Programmable IO**

Available now: magpi.cc/picobook

Letters

ATTENTION ALL MAKERS!

If you have something you'd like to get off your chest (or even throw a word of praise in our direction), let us know at **hsmag.cc/hello**

OUR CORRESPONDENT

Something Lucy Rogers said in one of your early issues resonated with me: if you're good at exams at school, you get pushed away from working with your hands. Now I earn decent money at a fairly boring job after a fairly boring degree, and I spend my weekends doing what I'm really interested in: making stuff. Anything – shelves, a pizza oven, a ridiculous dog bed that pings my phone when the dog gets in. I really do hope that kids at school today aren't taught that making things isn't for those who are good at school – I hate to think how many brilliant engineers never even got the chance to try metalwork, but the flip side to that is a kid who has access to an Arduino or a Raspberry Pi, or similar. We could be on the edge of a wave of brilliant young people who are going to fix the mess we've made of the world.

Pete Fitzwilliam
County Wexford

Ben says: **There's an old joke about a nuclear physicist who retrains as a plumber because the money's better. It's not a great joke, but I think you get the gist. Anyway, I think you're right: the more kids who try their hand at making things (even daft things like your dog bed), the better off we'll all be when the makers are ruling the world in twenty years time.**

BARGAIN PRINTING

I've just been reading your article in issue 41 on 3D printers under £100. It's good to see how the cost for entry in to this hobby is coming down, and how machines are improving. I think 3D printers still have a long way to go before they are in every home, like an inkjet printer.

Adding to your article, the second-hand market in printers is a great place to grab a bargain. For a little more than your budget, there are some fantastic printers available. Also, many not-so-good printers as well, so it pays to do your homework.

If you are willing to put the work in, then the 'for parts not working' listing is another place to grab a bargain, but beware that you could be buying a dangerous machine with damaged wires to the heaters.

That said, some time ago I adapted one of these damaged machines to make it into a small CNC router. More recently, I have been using a printer that cost me around £40 because it was in bits.

I thought I might set you a challenge. What is the best 3D printer you can build from scratch for less than £100?

Will White

Ben says: If you've got the skills, the tools, and the time, then buying second hand, or for parts, is a great way to get yourself a cheap printer for less money than it's worth. What it's not, however, is a way into 3D printing as a new hobby: for that, you need the confidence that everything is working as it should, and a set of decent instructions that you can follow. That's why we didn't even review one of the printers that we got hold of: it could have been the greatest machine in the world, but as it came with no instructions, we had no way of knowing.

CONNECTED LITTLE BOXES

I'm sure by now we've all read Rob Miles' tutorial in issue 41 on passive computing – but have you watched the lecture? It's mainly in rhyme, there are 1000 cheese-based puns and, apart from that, it really emphasises how simple it is to get devices talking to one another using something called naked JSON. Oh, and it's for charity – Rob's raised £430 so far for Comic Relief, and you can still watch the talk (it was delivered on 19 March) on **hsmag.cc/RobMilesComRelief**.

Andrew Price
Warrington

Ben says: Good work! I'm pretty good at getting in information via written words, but in lockdown, I've been learning to love video recordings. Somehow the information just seems to work its way into my brain, probably through osmosis. I need to watch some biology lectures and find out.

CROWDFUNDING NOW

Piunora

Raspberry Pi meets Arduino

From $30 | **crowdsupply.com** | **Delivery: June 2021**

When you first see the Piunora carrier board for the Raspberry Pi Compute Module 4, you might think it's just a Raspberry Pi in an Arduino form factor.

This might seem mildly amusing, but entirely pointless. If that were all it was, then it would be, but we'd encourage you to look past the form factor. The useful things going on here have almost nothing to do with the shape of it. It's a Raspberry Pi Compute Module designed for embedded development.

There are 14 GPIOs exposed which, while not as many as on a full Raspberry Pi header, is plenty for most projects. True to its form factor, Piunora also has six analogue inputs. There's also a STEMMA QT / Qwiic connector for adding I2C devices. There's a full-sized HDMI if you want graphics, and a camera connector for getting images into your projects.

The Piunora has a great range of storage options – there's an SD card slot, some versions of the Compute Module have flash memory, and there's an M.2 slot for expansions (which can include adding an SSD). This PCIe slot gives the option to add a huge range of hardware, but be careful because not all PCIe slots accept all PCIe cards. The one on Piunora is B-Key and supports 2230, 2242, 3042, and 3030 (and there's an optional expander for 2280 and 2260 devices).

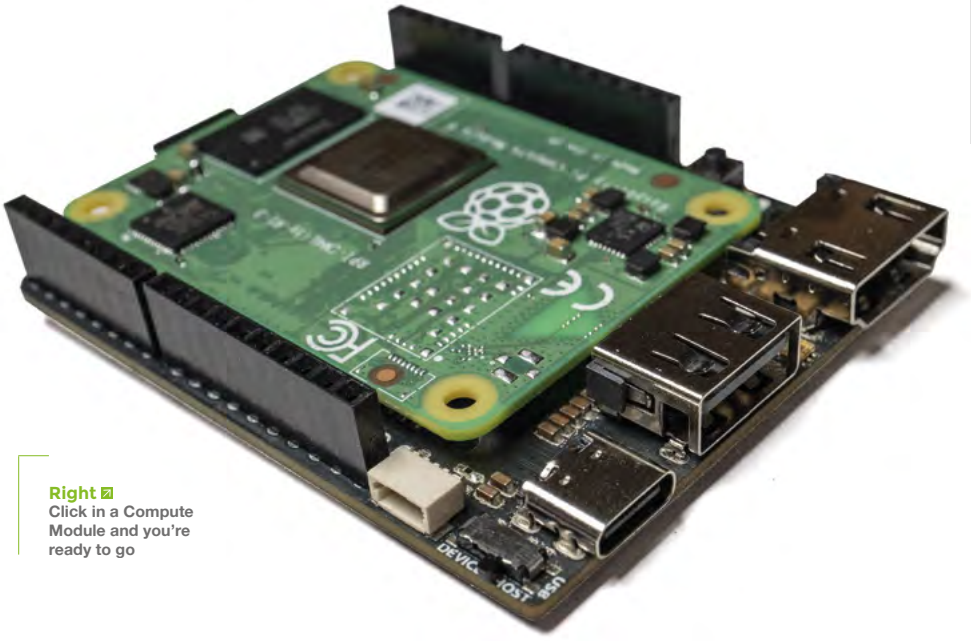
The USB setup is a little different than on many Raspberry Pi boards. This is because on Raspberry Pi 4s, the PCIe bus is used to provide USB 3.0 ports. On Piunora, the PCIe bus is exposed, and isn't used to provide additional USB. There's a single USB available. This can be routed to the USB-C port, and there it acts as a USB device. For example, you can connect it to your computer and communicate with it over USB Ethernet, USB serial, or USB mass storage. You can even use Piunora like a super-powered CircuitPython device using the Adafruit Blinka library.

Alternatively, you can flip the switch, which means that the USB on the Compute Module will be in host mode, so the connection is routed to the USB 2.0 socket and you can plug other devices in.

Raspberry Pi computers are masters of general purpose. They can be embedded, or they can be desktops. They can even be both at the same time. Piunora takes the heart of a Raspberry Pi 4 and turns it into a specialist hacking/embedding board that will, no doubt, be useful for a lot of people.

BUYER BEWARE

When backing a crowdfunding campaign, you are not purchasing a finished product but supporting a project working on something new. There is a very real chance that the product will never ship and you'll lose your money. It's a great way to support projects you like and get some cheap hardware in the process, but if you use it purely as a chance to snag cheap stuff, you may find that you get burned.



Right
Click in a Compute Module and you're ready to go

Above
The M.2 slot on the back offers a lot of expansion options

Space of the month: East Essex Hackspace

East Essex Hackspace

eehack.space

eastessexhackspace

eehspace

East Essex Hackspace is a community-based workshop located in Hawkwell, Essex, a few miles north of Southend. They have metal and woodworking facilities, an intriguingly named wet lab (which turns out to be used mainly for brewing beer), computers, an electronics workbench, 3D printers, and a dedicated room for a Mantech 9060 laser cutter. There's also a social space, which in some ways is the most important room of the lot, as founding director Tim Neobard told us:

"We're a community space, so we want the building to be used as much as possible. We let other groups use the space, such as the local scouts and the University of the Third Age, partly because it's nice to be nice, and partly because the gear's safer when there's someone else in the building. We've made it clear to the local police that if they want a place to stop and have a cup of tea while they're out and about, they can come here any time – you can't buy security like that!"

"We got the building on a seven-year lease from the council, and they've done all the exterior work that needed doing – painting, repairing the roof, etc., they've been slow, but they've been helpful."

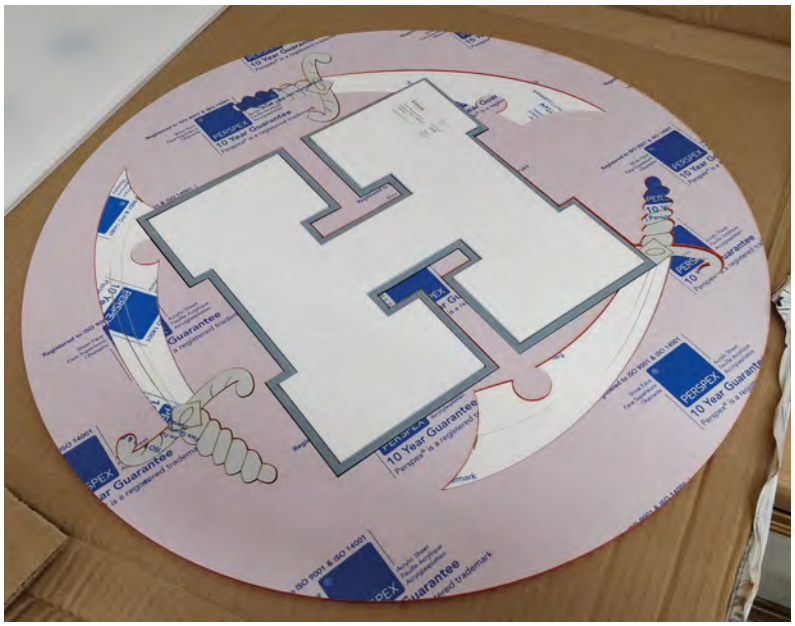
While the pandemic has been an obstacle for many makerspaces, for East Essex Hackspace, it's proved quite the opposite: the effort its members put into making PPE not only brought them together with members of the community and, crucially, the council, but it also helped raise awareness locally of what a hackspace is, and what you can achieve when you have the right tools, the right talent, and the right attitude.

Right
You wouldn't know it now, but the building was a shell – the directors (Alex Chiolo, Gary Ott, Tim Neobard, Stephen Ford, Steven Tong, and Scott Window) have done a cracking job in renovating it

> **We're a community space, so we want the** building to be used as much as possible

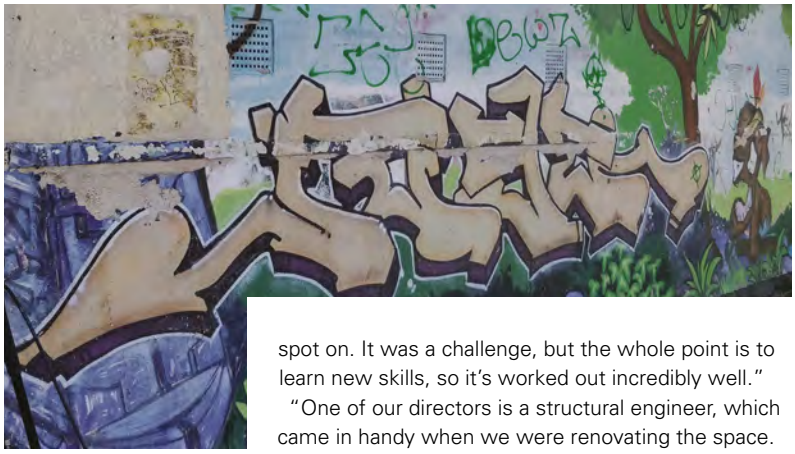
For one, lockdown gave the members much more time on their hands to get the space ship-shape. When the group took over the space, it was a pretty sad, run-down looking former sports pavilion.

"There was a lot to do. Electrics, painting, installing ramps, fire doors, cleaning the place up – and the plastering. That's one skill that I was pleased to get the chance to learn. When it's your own house, you pay somebody else to do it, but with the hackspace, we needed to save money to spend on more important things. If you look at it from the right angle, you can see that the plaster on one wall in the hallway isn't quite right, but the rest of the work is →



Above
The device on the far wall is a Maslow CNC machine – a router suspended on two lengths of wire that can more around a large surface

Right
Each room has its own independent air-conditioning, so when the space is allowed to open back up, it'll be pretty much the most Covid-safe place you can be



spot on. It was a challenge, but the whole point is to learn new skills, so it's worked out incredibly well."

"One of our directors is a structural engineer, which came in handy when we were renovating the space. We realised that one of the rooms was almost the perfect size to house the laser cutter. For most people, almost perfect is a synonym for 'wrong', but being a structural engineer, he just moved the interior wall 30 cm in one direction, and now there's room in there for the laser cutter and the person who's using it. Perfect!"

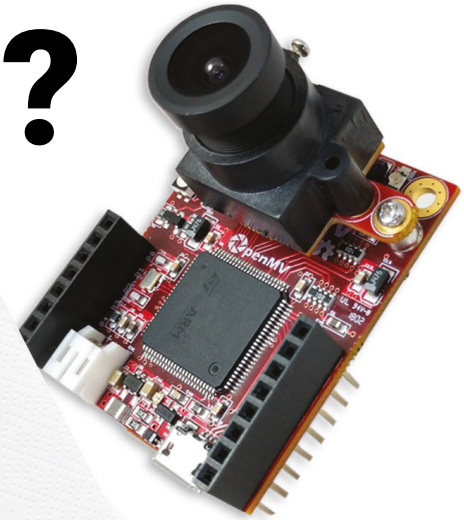
As well as the time to get the building up and running, the pandemic provided something else: a purpose. As makers with skills in laser cutting and 3D printing, East Essex Hackspace members set about making PPE around March/April 2020, eventually supplying protective equipment to the local doctors and three local hospitals. And that's not all: the group have been renovating laptops for local school children so nobody fell behind during the long, long months of home-schooling that parents in the UK have had to endure.

If you're passing through, East Essex Hackspace would love you to drop by and say hello. After all the work they've put in, it would be rude not to. □

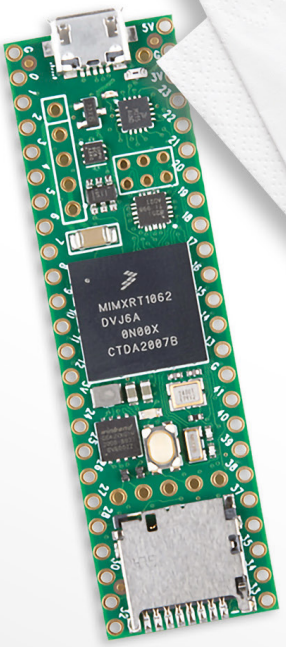
CONTACT US

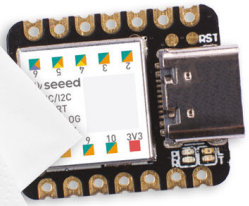
We'd love you to get in touch to showcase your makerspace and the things you're making. Drop us a line on Twitter **@HackSpaceMag,** or email us at **hackspace@raspberrypi.org** with an outline of what makes your hackspace special, and we'll take it from there.

Board?

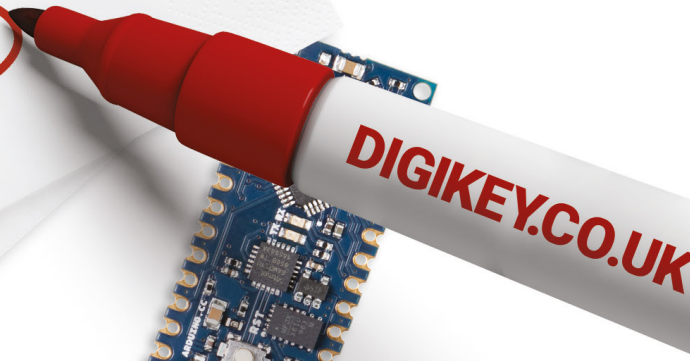


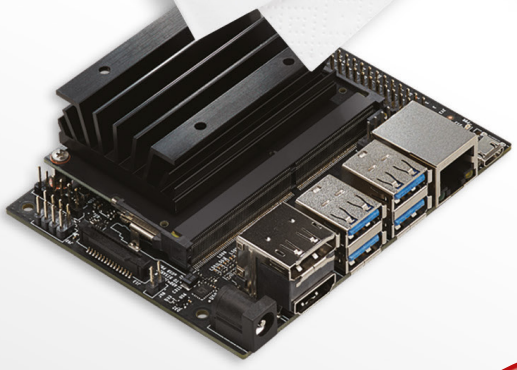
Let's make something!





Digi-Key ELECTRONICS





FREE SHIPPING
ON ORDERS OVER £33 OR $50 USD*

DIGIKEY.CO.UK

0800 587 0991

DIGIKEY.CO.UK

Digi-Key® ELECTRONICS

10 MILLION+ PRODUCTS ONLINE | 1,300+ INDUSTRY-LEADING SUPPLIERS | 100% FRANCHISED DISTRIBUTOR

*A shipping charge of £12.00 will be billed on all orders of less than £33.00. A shipping charge of $18.00 USD will be billed on all orders of less than $50.00 USD. All orders are shipped via UPS, Federal Express, or DHL for delivery within 1-3 days (dependent on final destination). No handling fees. All prices are in British pound sterling or United States dollar. Digi-Key is a franchised distributor for all supplier partners. New products added daily. Digi-Key and Digi-Key Electronics are registered trademarks of Digi-Key Electronics in the U.S. and other countries.

ECIA MEMBER
Supporting The Authorized Channel

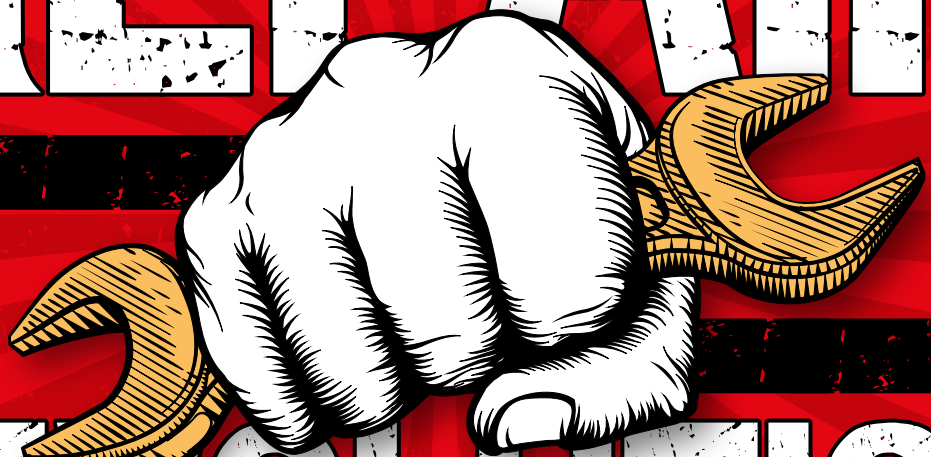
HackSpace
TECHNOLOGY IN YOUR HANDS

LENS

HACK | MAKE | BUILD | CREATE

Uncover the technology that's powering the future

THE REPAIR REVOLUTION



REFURBISHING A WORN-OUT ITEM CAN BE A REWARDING LABOUR OF LOVE

ROSIE HATTERSLEY DETAILS TEN PROJECTS THAT CHERISH AND RENEW VINTAGE OBJECTS

Just because something is old, it doesn't mean it's automatically destined to be replaced. Often, an older item has both sentimental value and plenty of wear left in it. It just needs a sympathetic repairer to recognise what can be achieved by stripping off the layers of use, resetting joints, and replacing a worn-out finish.

TV programmes such as *The Repair Shop*, as well as plenty of online tutorials and video diaries, demonstrate the possibilities of overhauling items that have lain overlooked for years.

In some cases, the restoration will involve stripping back the evidence of years of use and replacing worn-out parts. Other projects result in finding a new use for the item, or giving its functional parts an update so the object can be used with more modern technology. Whether the goal is 'good as new' or a new lease of life with a sympathetic update, restoring and repairing is a valuable craft. →

ANTIQUES

WWI MONOCULAR

hsmag.cc/Monocular

This fantastic restoration sees a World War I monocular from the world-famous Carl Zeiss workshop in Jena, Germany, given a complete overhaul.

Above
The splendid restoration is complete, with its model and make far easier to read, and ready for stargazing or wildlife watching

Men in the trenches would often use a monocular to detect and decode Morse code signals sent at night over distances of up to eight miles. However, the lens on this one needed to be reground and polished, while its focusing ring would no longer turn smoothly. Dirt inside the lens needed to be removed too, so restorer Odd Tinkering carefully took the monocular apart. This also gave access to the monocular's two prisms.

Everything was dirty, silted up, and needed cleaning, so he unscrewed the outer casing to reveal the frame but left the brass ring which wraps around the lens, since this would be difficult to take apart.

Having laid out all the pieces, he set about cleaning and polishing each one. Paint stripper was applied to the metal pieces using a paintbrush, and a steel brush used to remove residual adhesive, although it didn't prove as effective as he'd hoped. Still, some of the black grot from the original sealant was softened, making it easier to scrape off with the end of a flat screwdriver.

Left
Worn leather and dirt inside meant a full disassembly and clean-up treatment was needed

Larger surface areas were cleaned using steel wool pads on a rotary tool. Areas that still had unwanted material clinging to them were given an hour-long soak in ketchup. They were then washed and brushed again with a stiff brush.

Acetone stripped gunk from the lens, while a buffer polished the monocular's brass ring. Car polish compound helped rid the bakelite exterior of its many noticeable scratches, making the monocular look far more presentable. A belt sander was used on the rear of a new piece of leather. As well as making it look better, this stretched the leather, making it easier to mould into shape to cover the monocular's case. To do this, he soaked the leather in water to soften it, applied glue, wrapped the leather tightly around the monocular, and then secured it in place while it dried in shape.

Next came the prisms, which needed thoroughly cleaning before replacing in the case. Silicone was applied to the inner bevels of the monocular's case so the metal nameplate would adhere securely, and the focusing ring and brass covering screwed in place. A final polish, and a check of how much clearer things were when viewed through the lens, confirmed another excellent restoration on Odd Tinkerer's part.

ANTIQUES

MECHANICAL COIN BANK

hsmag.cc/CoinBank

Above
The 1930s money bank was rusty, and its moving parts didn't operate correctly. Awesome Restoration gave it a complete overhaul

YouTube features many excellent videos of items being repaired. Popular channel Awesome Restorations produces fabulously shot and edited restoration videos, and recently tackled the repair of a characterful 1932 coin bank that had seen far better days. The whole thing was covered in rust and the spring mechanism, that responded to a coin being dropped in the money bank, was stiff and would barely move. The first task was to take everything apart, with a liberal application of WD40 on some of the more stubborn screws. Several vintage coins that had turned green with age dropped out. These were placed in a jar of spicy chilli oil for several days to reverse the surface discolouration.

After this, the toy car and mechanic atop the coin bank were taken apart. While many 1930s die-cast toys were zinc or aluminium, this one was made from solid metal. An grinding disc was needed to free the rusted up wheels of the car, before all the components could be sandblasted to clean them up and reveal their details, such as the lettering proclaiming the Full Service garage. Smaller parts were treated to the sand scouring treatment by being placed in a jar and rotated in a mini tumbler for two hours, after which they were plunged into a bath of alkaline to degrease them. All the parts, except the screws, were powder-coated with metal primer and baked for ten minutes.

Above
The fully restored money bank is now ready to accept customers willing to deposit coins

Meanwhile, the screws were heated with an acetylene burner and coated in oil to give them a lovely black finish. Midnight blue and red Humbrol paints were then carefully applied to the sign, coin box, and car.

Next, it was time to check how well the chilli oil had stripped back the discolouration from the old coins. The spicy solution had worked well and the coins glistened beautifully, with one revealing its 1834 Swedish origins.

With every aspect of the coin bank cleaned up and looking pristine, Awesome Restorations reassembled everything, dropped a coin onto the tray, and the money was deposited into the bank for safekeeping for another few decades. →

Right
The wheels of the toy car were so rusted up that the screws on the axles had to be ground to release them for restoration

ANTIQUES

1891 RATCHET SCREWDRIVER

hsmag.cc/RatchetSD

Above
Most pieces were given a precision makeover at the expert hands of 'my mechanics'

The finder of this 19th-century screwdriver mentioned it to famed restorer 'my mechanics', who soon realised its design was rather unusual. Research revealed that it's a levered or ratcheted version from the 1890s – not that this was obvious from the tool itself since all its movable parts were completely stuck. Having been found among detritus from a steel works, the heavily rusted screwdriver took three days to yield to its restorer's attempts to prise it into its constituent parts for cleaning and repair.

The restoration process began with scraping off the heavily soiled top layer of worn wood and rust to get at anything that could be unscrewed. Once clamped in a vice, the metal bar surrounding the handle could be prised loose. A metal stopper at the grip end of the handle was removed, revealing a rusty spring. Dusting down with a stiff brush helped to remove more of the handle's surface detritus. With its head largely missing, there was no way a screw embedded far beneath the wooden handle's surface could be persuaded to loosen. Heat was applied in order to force the remains of the screw to expand and widen its screw hole so it could be pulled out.

Now the handle needed to be parted from the metal parts of the screwdriver, before a day-long rust removal bath. After its soak, the screwdriver began to reveal its original gun-metal grey colours, and a screw inserted in it could be turned with ease. The ratchet mechanism could now be disassembled and cleaned using a sanding belt. However, a pin stubbornly remained in the screwdriver's head and had to be drilled out.

Once everything had finally been taken apart, it was clear that rust had badly damaged the head and a couple of other components. These were spot-welded and the very slightly tapered shaft ground down. Next, he set about milling each damaged item until they were smooth and fitted together perfectly. A new 0.5mm steel spring wire was wound around the shaft, ready to be fitted inside the screwdriver head. The screwdriver shaft was very bent but was deemed salvageable. Clamped in a vice, the curved part was heated up and pulled back into alignment, before being welded and milled smooth. Finally, its angled edges met a thick sharpening steel.

Unfortunately, the handle had several cracks, "was beaten up", and was stained with rust, so he set about turning and shaping a brand-new one to fit the vintage tool. He also made a new replacement screw from scratch. In addition, he wasn't happy with the ball bearing that fits in the top of the handle and decided to make a new one. He did, however, keep the two intact screws, cleaning them up before reusing them. By the end of the project, the ratchet screwdriver looked almost brand-new. As one of the video commenters noted, "130 years old, and that's a better ratchet screwdriver than you can buy today."

Right
The finished ratchet screwdriver – better than as good as new

TECHNOLOGY RESTORATION

TURNTABLE RESTORATION

hsmag.cc/Turntable

HackSpace magazine readers who are handy with wood and a chisel, and are looking for a centrepiece for a handmade cupboard, could do a lot worse than a record player. After all, there's something evocative about playing an album on vinyl that digital playback seems to miss. If you happen to have some old LPs stashed somewhere, bringing them out of retirement and giving them a spin is almost certain to trigger nostalgia.

Djpolymath acquired a supposedly working turntable from a jumble-sale, only to find it didn't work at all. He got to work identifying loose connections and checking it could be salvaged, before giving it a complete clean-up, and returning it to its original, pristine state.

Since he eventually intended to fit the restored record player in a housing, he disassembled it at the outset. This involved removing the turntable platter, internal cover, and bottom protective case.

An initial check of the player established it was the on/off switch mechanism at fault, which djpolymath easily bypassed with a piece of wire. Although he didn't find a problem with the power, once he'd given it the once-over, the player powered up each time, suggesting a loose connection.

Below
The first step was to disassemble the record player to get to the bottom of its power issues

Above
With a new stylus, correctly weighted tone-arm, and new capacitors, the record player is ready for use

He decided to replace all the electrolytic capacitors, since these commonly corrode with age. Each one was numbered on the record player's internal circuit board, so he was able to make a note of their voltage and capacity in order to choose their correct replacements. Soldering the new capacitors in place was a delicate, but not onerous, task as djpolymath had first practised this process on an old alarm clock.

Next, he turned to the tone-arm, checked its weight, and compared this to the manufacturer's guide. "Adjust the counterweight until you achieve the correct tracking weight," he advises. In the case of this turntable, it seemed to have a replacement tone-arm rather than the manufacturer's original.

Above
Electrolytic capacitors have positive and negative ends, so you need to check their orientation before soldering each one in place

To ensure the stylus didn't skate across the surface of the record, he turned the dial on the record player to match that of the tracking weight.

Having used an old stylus as a guide while working on his record player refurbishment, djpolymath switched it for a new one before playing his first record. He also swapped the old RCA interconnects for new ones, to ensure better connections with the all-important speakers.

TECHNOLOGY RESTORATION

WORLD'S FIRST LAPTOP

hsmag.cc/FirstLaptop

Upgrading and making use of an old laptop can be really worthwhile, especially if it's only a few years old and has network and/or internet capabilities. The stripped-back feature set can be quite refreshing. Element14 offers a great insight into the possibilities of what can be done if you've a mind to restore some form of electronics. Clem, from the site, stumbled across the world's first laptop, a self-assembly Epson HX-20 BASIC model. It came with a manual and promotional material, which are the sorts of things that help if you're about to embark on a renovation project, particularly when, like this one, said item doesn't actually work.

With a built-in printer and tiny LCD, the Microsoft BASIC machine would certainly have needed to have been hooked up to an external display. The fact there's provision for an external screen makes this project potentially quite useful. If the printer can be made to work, it could still be used since the paper cartridge is a standard size. A different operating system could also be installed using a separate hard disk drive.

Above
Carefully cleaning the inside of the case, and checking each connection, resulted in a largely operational 40-year-old laptop

Below
Taking apart the display and cleaning up its connections made all the difference

To make the laptop work again required welding the 1.2V NiMH C-cell battery pack (8V was needed to power it). As well as these, it has an internal battery, also ripe for replacement. To rebuild the battery pack, Clem welded it rather than soldering.

Clem also inspected the circuitry and replaced any old screw caps on the circuit board. Specific caps are important here so close to the main computer components. The two 301 processors run at 630kHz, with one for the main computing tasks and the other for I/O. These were checked over, including whether the keyboard is able to send and receive information to the I/O processor.

Missing keyboard letters – here it's a stubborn R button – and a build-up of dirt are familiar problems to anyone who's tried to trouble-shoot an ageing computer. The same is true with this 1980s Epson model. A blast of compressed air does wonders.

Once cleaned up, the electronics were tested for life using a voltmeter and the laptop was powered on – or at least it beeped to indicate it had booted correctly. The motherboard and keyboard were also communicating with each other. A glimmer of activity on the LCD suggested the display was also receiving instructions. A further clean-up of contacts and connections resulted in the display coming on and, after a reset, Clem even got a program to load. A pretty rewarding result from a supposedly dead 40-year-old computer.

TECHNOLOGY RESTORATION

RETRO-FUTURE TV PROJECT

hsmag.cc/RetroTV

Above
The flat screen is ideal for wall-mounting, making for a space-saving hybrid retro gaming display and TV

Upcycling, rather than restoration, can be a really good option if you want to bring an old and otherwise unused object back to life. Martin Mander has turned all manner of unlikely objects, often picked up at car boot sales, into Raspberry Pi-enabled devices, with attention to detail being a point of pride. The same careful principle applies to his repurposing and restoration of two old TVs into a marginally more modern one.

The frame from the early portable colour TV has been retained, its enormous cathode-ray tube removed, and the front fascia, complete with manual tuning knobs, fitted over the front of an early flat-screen TV. The end result is a piece of vintage 1980s charm combined with the space-saving convenience of a flat, wall-hung screen for a smart update that salvages elements of both original TVs. "I've also added an adjustable webcam to give it more functions and a futuristic look," Martin says.

Spotting the Sanyo TV at a boot sale for £4, Martin was initially deterred by its bulk and size. However, "I noticed that the case had a join about 5cm from the front, so I was taken by the idea of using just the front section and making a slim, wall-mounted flat screen conversion," he says. Better yet, he would be able to combine it with a flat screen he had at home that had lost its remote control and had no HDMI port, making it rather obsolete. Two restorations could be effected in one!

Martin discarded the flat screen's case and broken integrated DVD player, leaving just the circuitry. When he came to fit the flat screen into the CRT TV's frame, he was amazed to find it "a perfect fit for the hole left by the old CRT, which made this build a lot easier."

There was the small matter of the curved frame and much more angular flat-screen corners, however. Martin chopped out some of the corner mounts, sanded them all with a multi-tool, and added small bracket shelf fixings to secure the flat screen in place.

Working out how the circuitry from the flat screen could be controlled by the rotary knobs of the older TV involved tracing the switch circuit from the wire connectors to the microswitches, and mapping out which combinations were needed for the TV controls. For the volume control, he retained the existing slider assembly and mounted a lever microswitch at each end. The space for the webcam replaces an unused spot on the Sanyo frame – perhaps a fancier model had something there, Martin speculates. →

Above
Taking everything to pieces and getting rid of the old cathode-ray tube were the priorities

FURNITURE

REUPHOLSTERING A CHAIR

hsmag.cc/ChairReupholster

There are plenty of options for updating a dated sofa, including replacing its legs with something more contemporary, and adding button studs to tighten up the sagging fabric. This can also be done with a chair but, along with covering the existing seat fabric, the frame will also usually need some proper TLC.

Vancouver-based Charlie Miller is a contributor to **upcyclemystuff.com**, which seeks to connect fellow restoration and upcycling aficionados. Having inherited some antique furniture, she decided to restore a chair and honour her grandparents' memory. She chose an Art Deco fabric to match the age of the chair and her home's colour scheme.

Charlie decided not to paint the chair's frame, as she remembered that her grandfather was not a fan of painted furniture. She also wanted the chair to retain its original look, despite being clad in a striking new fabric. She began by completely taking apart the chair so she could assess what repairs were needed, and also see how everything had been assembled in the first place. It's important to take lots of photos of the process so that you know how to put everything back together again later.

Below
The reason the armrests had always been so uncomfortable... Charlie sanded down the edges, and added padding during her restoration

Above
The completed chair respects Charlie's family heritage, but has been brought up to date to match her own decor

The nails and staples holding the existing fabric in place were removed, and the padding and fabric both retained. This meant the old fabric could be used as a template for the replacement chair covering. The original padding was compacted, so Charlie replaced it with fresh cotton padding, thereby doubling the thickness of the original padding to improve the chair's comfort. "I went as thick as I felt I could go with it, and ended up adding a couple of layers," she says. Excess padding was simply removed using a craft knife.

While disassembling the old chair, Charlie had discovered that the height of the armrests had been raised with the addition of blocks of wood. This discovery solved the mystery of why they'd always seemed hard and uncomfortable. She sanded down the edges of these wooden blocks using 60 grit sandpaper, and Charlie then covered each wooden block with an old sock, finding they were a perfect fit. Cotton padding was then stapled over them and around the armrest.

Attaching the replacement cover fabric was a fiddly process due to the presence of the new padding, which began to push the fabric out of shape. However, having the original staple holes as a guide and working from the sides inwards helped ensure the fabric was evenly secured in place, and also limited the number of punch holes in the chair back. Next came a smart trim, which would cover up any evidence of upholsterers' workmanship. A string of hammered metal studs worked well with the chair's style and fabric. Gaps with nail holes every few studs made the process of applying the studded trim easy, as a matching stud could be hammered in place.

The final task was to repair the underneath of the chair. Extra padding was easily added by pushing it through the hessian grid and then smoothed out over the springs. Charlie had salvaged a piece of the original chair fabric and used it to cover up the underside of the chair seat. "I used [the] piece that was in the best condition and added it to cover the underside. I thought this was a little 'added upcycle' and also a way of keeping a bit of the chair's history!" she comments.

"I was nervous recovering such a family heirloom," she admits, but, "I think my grandparents would be so happy I am keeping their chair in the family!"

FURNITURE

VINTAGE BUTCHER'S BLOCK

hsmag.cc/ButchersBlock

A butcher's block that had been stored in a mine in Alaska for 70 years was painstakingly repaired by carpenter and wood restoration expert Chris Devo, so it could be brought back into use in the owner's kitchen. Weighing around 400 lbs, the wooden block showed plenty of evidence of use, and was coming apart because the wood was drying out. Over approximately 100 hours, Chris sanded it down, revealing the intricate construction used in its assembly, and bringing out the grain that gives it its character.

Viewers of the YouTube video detailing the restoration process have recounted tales of having worked in butchers' shops where such blocks were used, with the inordinately thick wooden blocks allowing for periodic – roughly every decade – sawing off of the worn-down top layer, and a flat new surface sanded down.

Above
Castors and new base added, the sheer weight of the block meant it needed two people to turn it right side up

For his restoration, Chris used 80 grit sandpaper and a circular sander to remove the top layer and any minor scratches. He chose not to flatten the block, as he was keen to keep as much character and history as possible. As he worked on the project, Chris encountered tell-tale markings branded into the base of the block revealing it dated from December 1942.

Having scraped out and cleaned splits in the wood, Chris filled them in with epoxy before coating the butcher's block's surface in oil to preserve it. He says some of the epoxy is in the big cracks that run all the way through to the top. Food-grade mineral oil and butcher's block conditioner were used on the rest of the block, making it fit for food preparation use again.

Chris took the block apart in order to get at each surface, manually scraping off layers of grot and embedded food detritus.

Below
The finished block, with turned wood base and more than twenty finishing coats, takes pride of place in its owner's home

The poles holding the entire block together had the rust sanded off them, before being replaced and brand-new wooden covers fitted over them. The turned legs were removed, their cracks filled, and the uneven leg lengths made equal. With the owner's agreement, the legs were recoated and epoxyed in place.

Vintage castor wheels were fitted so the refurbished block could be manoeuvred with ease, and were attached to a brand-new base that Chris made from strips of wood. Turning the butcher's block right side up took two people due to its weight. Chris was then able to work on the block's work surface, applying more than twenty coats of finish before he was satisfied.

FREEWHEELING

ROAD BICYCLE

hsmag.cc/OldBicycle

Doing up an old bicycle so you can explore outdoors is a great restoration option and can save you a tidy penny. Daniel Hingston spent about a month overhauling his £40 purchase, replacing the wheels, brake pads, and cables, and giving it a respray. First, he took it apart, undoing bolts and screws and noting where everything fitted together. Photos of the process helped hugely when it came to reassembly. "If you want to remove the crank arms from the bottom bracket (the axle that your pedals rotate around), then you'll probably need a 'crank-puller' tool," his Instructable explains. He used dental floss to remove the head badge to salvage it for later.

Abrasives and chemical paint stripper were used to take off several layers of paint and help remove any corrosion. Aluminium oxide paper was a great help here, in what was a two-day strip-down process. Hard-to-reach corrosion turned black and came off, once Hammerite had been daubed on.

Above
The bike restoration cost more than a good second-hand model, but allowed Daniel to choose the wheels, colour, and decals he really wanted

Daniel suspended the bike from a tree while painting on the primer, applied white spirit to degrease the frame, and masked off anything he didn't want the primer to touch. He applied two coats, then let the primer paint dry out for a few days before rubbing down the frame to get rid of any remaining rust. For the main painting job, Daniel advises to shake the can well and "don't apply too thickly: it's really easy to overdo it and then you'll get thick areas and running drips!" He used four coats of paint, then left the frame for two weeks so the paint could harden. Looking back, he says adding a coat of lacquer would have been a good idea too.

Next, he washed down all the mechanical parts, removing splashes of paint with wire wool and wet and dry paper. The sprockets, pedals, and handlebars came out satisfyingly shiny. The wheels, however, began a musical tinkling each time they were moved due to lots of internal rust, so were consigned to history. New inner tubes and tyres, plus a new saddle, were bought.

Bearings and brackets were degreased with white spirit. The bearings were then packed with grease to lubricate them. Crank arms and axle received similar treatment. Having had to remove the original chain with a hacksaw, a new one was fitted – a two-person job since its grease makes it hard to handle and fitting it around the sprocket, free wheel, and derailleur was troublesome.

To finish the restoration, new brake cables, pads, handlebar tape, and decals were added, and a replica head badge placed on the front bike fork.

Below
Fitting new brake cables and brake pads was an easy process, unlike fitting the new chain!

FREEWHEELING

1970s VESPA SCOOTER

hsmag.cc/Vespa

Riding a scooter through the city streets recalls the positivity of the 1950s and 1960s. The abandoned Vespa, in the brilliant time-lapse restoration video above, doesn't date quite that far back, but certainly boasts plenty of retro charm. Once it was untangled from the grasses that were grown up and around it, its restorers were able to assess the extensive damage the ravages of time had done. The fuel tank was completely rusted away and so much of the rest of the scooter frame was rusted, it was hard to discern its original baby blue colour.

Nonetheless, the scooter was relatively easy to dismantle using spanners and pliers, once the joints had been sprayed with WD40. A curious discovery inside the Vespa was a selection of 1980s floppy disks. Random! The engine was in a parlous state and was also completely dismantled.

Next began the lengthy process of cleaning up, rust removal, and degreasing, aided by painting on solvents and spraying with water. The transformation was impressive: the scooter's shiny metal now reappeared. It wasn't all good news: a new piston was required and the engine needed to be rebuilt.

The wheels were disassembled next. The inner tube from each wheel was removed and appeared to be sound, but the metal wheel frames were extremely rusty. As with the tyres, though, they just needed to be cleaned up. The engine cover and storage box, however, needed to be replaced – this cost just $8, as a suitable part turned up in a scrapyard. Since sand-blasting the entire scooter would have taken hours, a flame was used to remove

Above
After stripping down, repairing the engine, and repainting, the Vespa Piaggio looks as gorgeous as when it was brand-new

the paintwork prior to a respray in a suitably period colour.

With the scooter now naked, its dents were clear and could more accurately be beaten back into shape. Gaps in the fascia were filled, and new metal trim added around the curves. The whole scooter exterior was rubbed down to remove years of rust, then welded inside to strengthen it. Everything was then degreased ready for filling and painting. Grey primer was applied, followed by the final blue paintwork.

The shocks were then worked on – cleaned, de-rusted, and put back in situ with some shock absorber oil to lubricate them. The saddle and its springs, fuel tube, rear reflector, and headlamp were taken apart,

Above
The extent of the rust issue was made clear once the scooter had been dismantled

cleaned, and fitted back. The fuel tank was repaired with some judicious welding; the footboards spot-welded and cleaned up. Finally, new Vespa badges were added and the whole scooter was put back together.

FEATURE

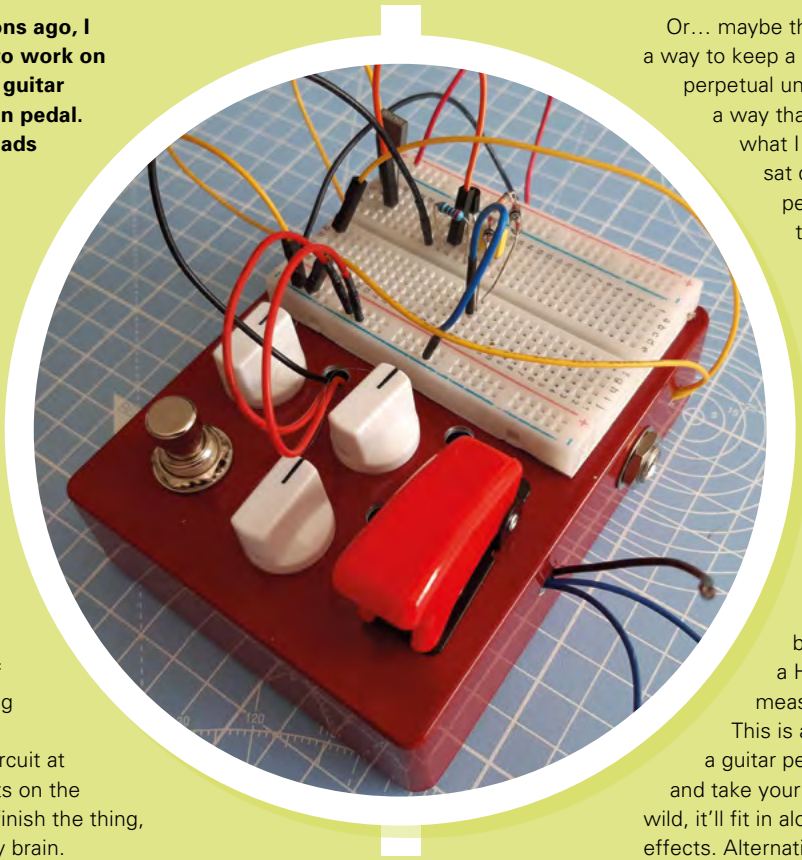
How I Made

A GUITAR PEDAL TESTING RIG

A half-finished electronics project tantalisingly approaches its final form

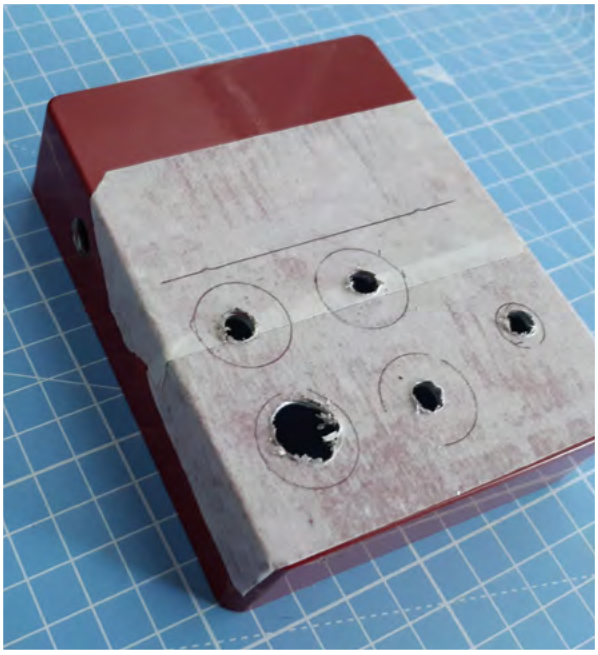
By **Andrew Gregory**

Many moons ago, I started to work on my own guitar distortion pedal. It was loads of fun, most of the components cost pennies, and I could while away hours making ever-so-slightly different fuzzy sounds come out of my guitar amp. Life was good. But then, when the time came to pack it all away and do something else with the dining-room table, things got less good. Resistors fall out of breadboards very easily; things get bent out of shape, and the weight of the guitar cables kept pulling the jumper wires out of the breadboard, breaking the circuit at best, scattering components on the floor at worst. I needed to finish the thing, to get it done and out of my brain.



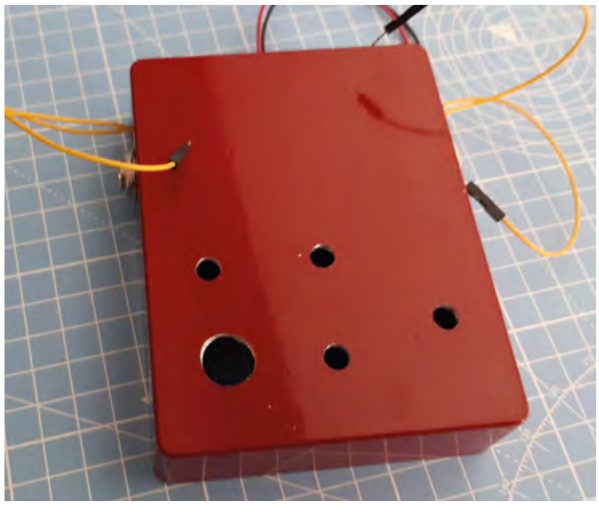
Or… maybe there was a better way… a way to keep a project in a state of perpetual unfinished-ness, but in a way that was usable. That's what I was aiming for when I sat down to build this guitar pedal tester. It's intended to be a half-way house between a breadboard and the finished pedal, with the heavy, chunky components fixed in place and connected to a breadboard, leaving me to mess with different transistors, diodes, and capacitors to make my own perfect sound. Here's how I did it.

First, assemble the bits you'll be using. I used a Hammond 1590 enclosure measuring 145 × 121 × 39 mm. This is a commonly used size for a guitar pedal, so if you ever go crazy and take your pedal prototype into the wild, it'll fit in alongside the rest of your effects. Alternatively, you could use any



Above
Drawing the external component layout on masking tape

> The golden rule is that the best thing for the job is the thing that you have lying around already



Above
Remember kids: keep your work surfaces clean and dust-free

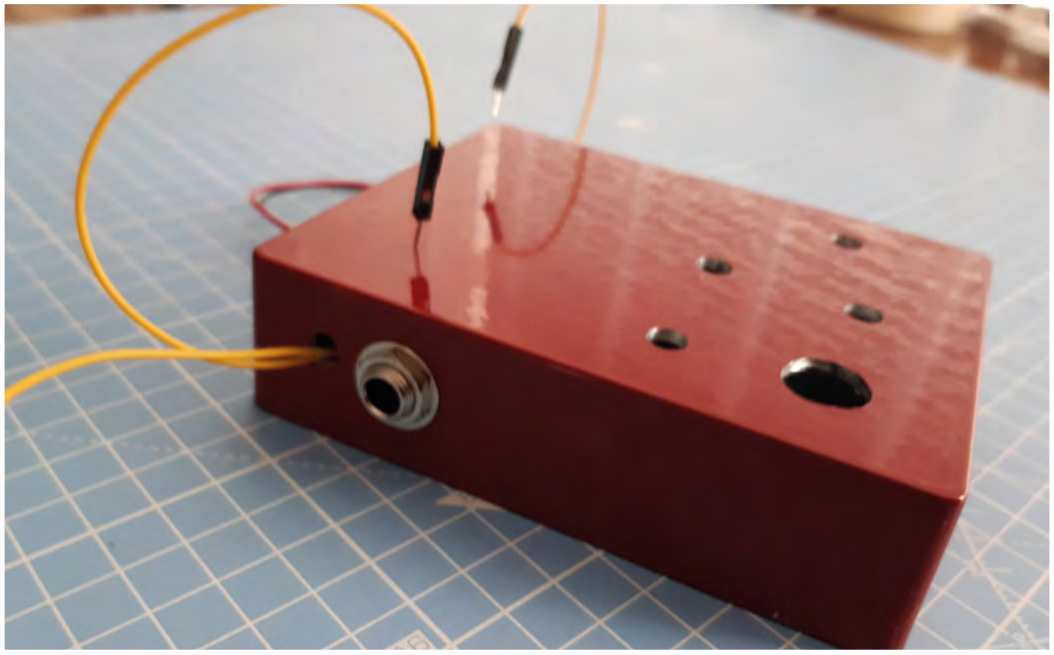
Right
This project was a great excuse to invest in drill bits

kind of box – plastic, wood, metal, as long as it's strong enough to stand on and you can drill holes in it – the golden rule is that the best thing for the job is the thing that you have lying around already.

Second, I put masking tape on the box and marked out where the knobs and switches were going to go. This step took a little trial and error, and eventually, I had to compromise on the number of potentiometers I could include. There was, however, no room for compromise when it came to the red safety toggle switch cover. If you get the chance to make something look like it's come from the cockpit of an F-14 Tomcat, you should always take it.

With the enclosure marked, I drilled the holes. Really, I needn't have bothered planning where the holes were going, as the drill took on a mind of its own, and barely landed me within the same postcode of where I was aiming for. Top tip: use a drill-press for accurate hole drilling.

One very obvious improvement to this design would be to use consistent colouring for the ground and signal wires. When I was messing about with the circuit on a breadboard, I could follow the wires back to the potentiometer, but now that they're hidden in the box, I've had to stick a little piece of tape on one of the wires to remind me which is which – a little bit of →

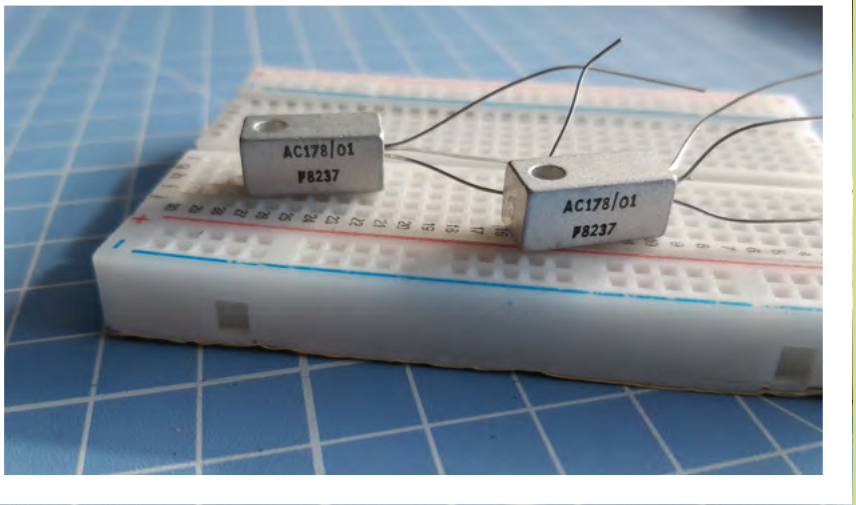


Below
Germanium AC178 transistors – at £2.50 each they're relatively expensive, but worth it if you want to build an authentic Hendrix-era fuzz circuit

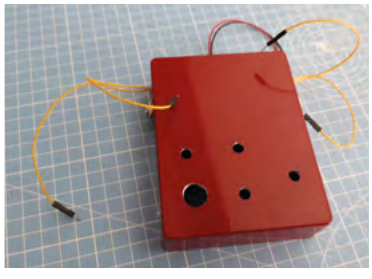
forward-thinking would have prevented the need for this. A second improvement would be to add an LED so I can tell when it's switched on. This is pretty simple, and I'll probably get around to making this fix pretty soon. Another, more advanced, thing that I didn't add is the ability to take mains power. Luckily, the hole I drilled to accept the wires from the 9V battery holder is the right size to take a barrel jack, so I've future-proofed the design.

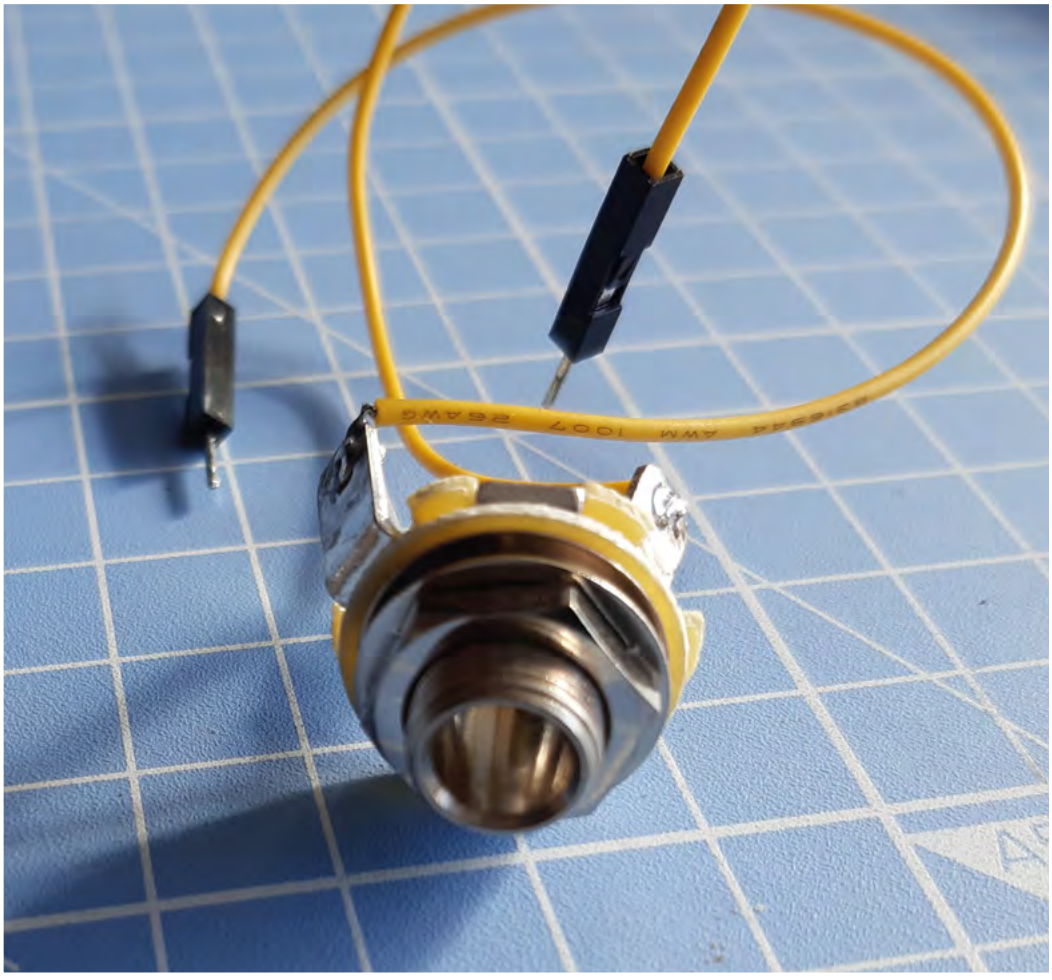
Before I could fit the electromechanical components into the enclosure, I had to attach them to jumper leads. Take one jumper lead with at least one end that fits into a breadboard, then use a pair of wire-cutters to cut off the connector on the other end. Then, use a sharp knife or wire-cutters to strip the last 8mm or so of plastic to expose the bare metal. This is the end you solder on to the jacks, the switch, the potentiometers, and the switches.

There are two types of 3/4-inch audio jack commonly available: stereo and mono. With a mono jack, the inner lug is the ground, and the router lug carries the audio signal. On a stereo jack, there are three lugs: as with mono jacks, inner is ground, outer is signal, and you can safely ignore the middle one. I soldered two partially stripped jump leads to each lug of a pair of ¾ inch jacks, giving me an eventual input from the guitar and an output to the amplifier. Next, I soldered up a two-way toggle switch, which has three lugs on the bottom (in the circuit you can think of it as one input and two outputs that you switch between), then the foot switch. This was the most complicated soldering job, and although it was useful as an exercise, I don't think I'll do this next time. For a simple on-off switch, there are a frankly ridiculous nine lugs that all need



Below
Next time we'll use different coloured leads, as we had a hard time remembering which was which



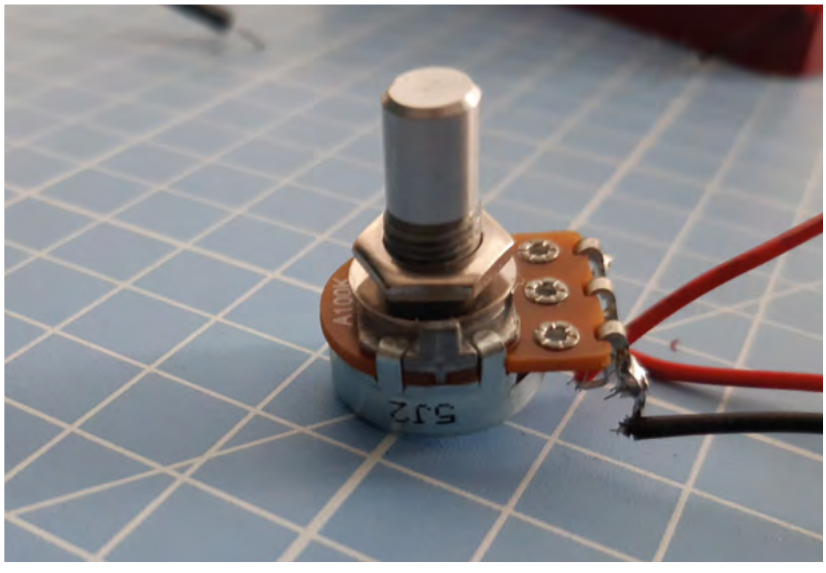


Above
A mono audio jack socket. The outer lug, on the left, takes signal; the inner lug, on the right, is ground

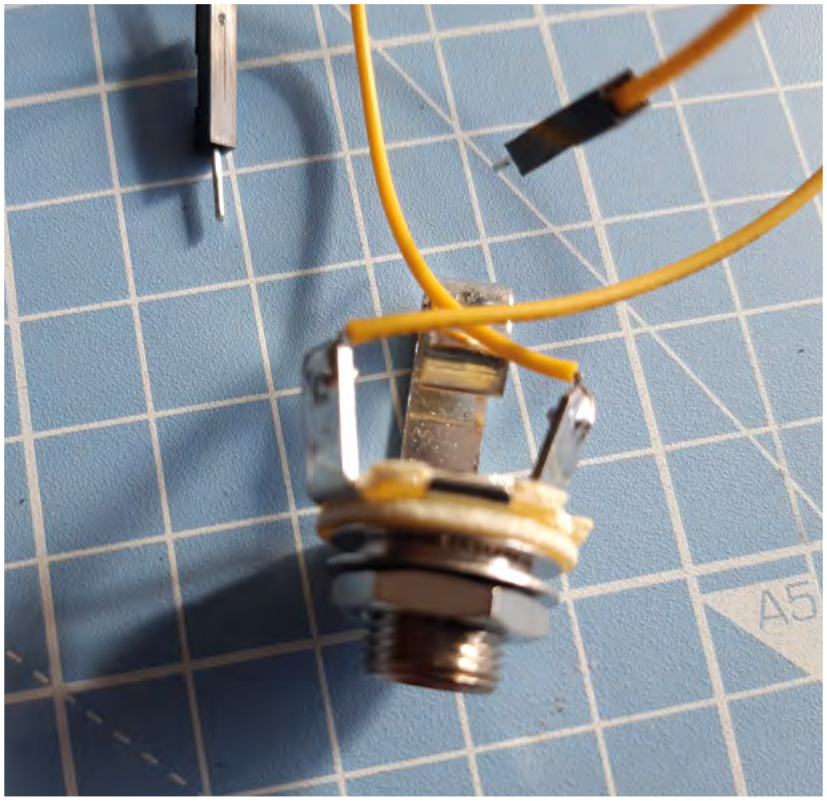
Left
One consequence of having soldered wires attached to nothing but a breadboard is that they will fray. This build aims to prevent that

soldering to jumper leads (actually one of the lugs needs to be connected to the LED, which I'd forgotten to connect anyway). Not only is this a lot of soldering, but it's also a lot of wires going into a breadboard, and as I already have a toggle switch, I eventually decided not to use the foot switch in the final design. It's part of the build; it's just not wired in yet. When I invent the Best Tone Ever, finalise the design, and transfer the whole thing to perfboard, that will be when I add the foot switch – for now, it just gets in the way.

The most important tip I could give anyone who was going to follow in my footsteps would be this: do your drilling before you stick the breadboard on – that way, you'll minimise the risk of bits of swarf getting stuck in your breadboard and making it sound, at best, crackly and, at worst, non-functional.



FEATURE



We're now ready to build the circuit. This is beyond the scope of this article, but there are many, many great guides out there waiting for you to find them. We'd suggest ElectroSmash as a source of accessible information about pedal design, and also that instead of jumping in at the deep end with something that uses an op-amp like a ProCo RAT, you stick to a single transistor, or at most two transistors. The Fuzz Face, as used by pretty much everyone in the 1960s, used a total of eight components plus two potentiometers, including a pair of low-gain transistors.

A brief word on potentiometers – unlike switches and jack sockets, the potentiometers you use will vary according to the circuit you're building, and where in the circuit you're putting them. As a potentiometer is a variable resistor, you could replace every single resistor in any pedal schematic with a potentiometer, play about, and see what you find, but I'm restricting my experimentation to three components: the transistor (the bit that makes the signal

Left
You'll find three types of potentiometers on the market: A (logarithmic); B (linear) and C (reverse logarithmic). Linear pots, like this B1K make sense for gain controls, while log pots work best for volume controls

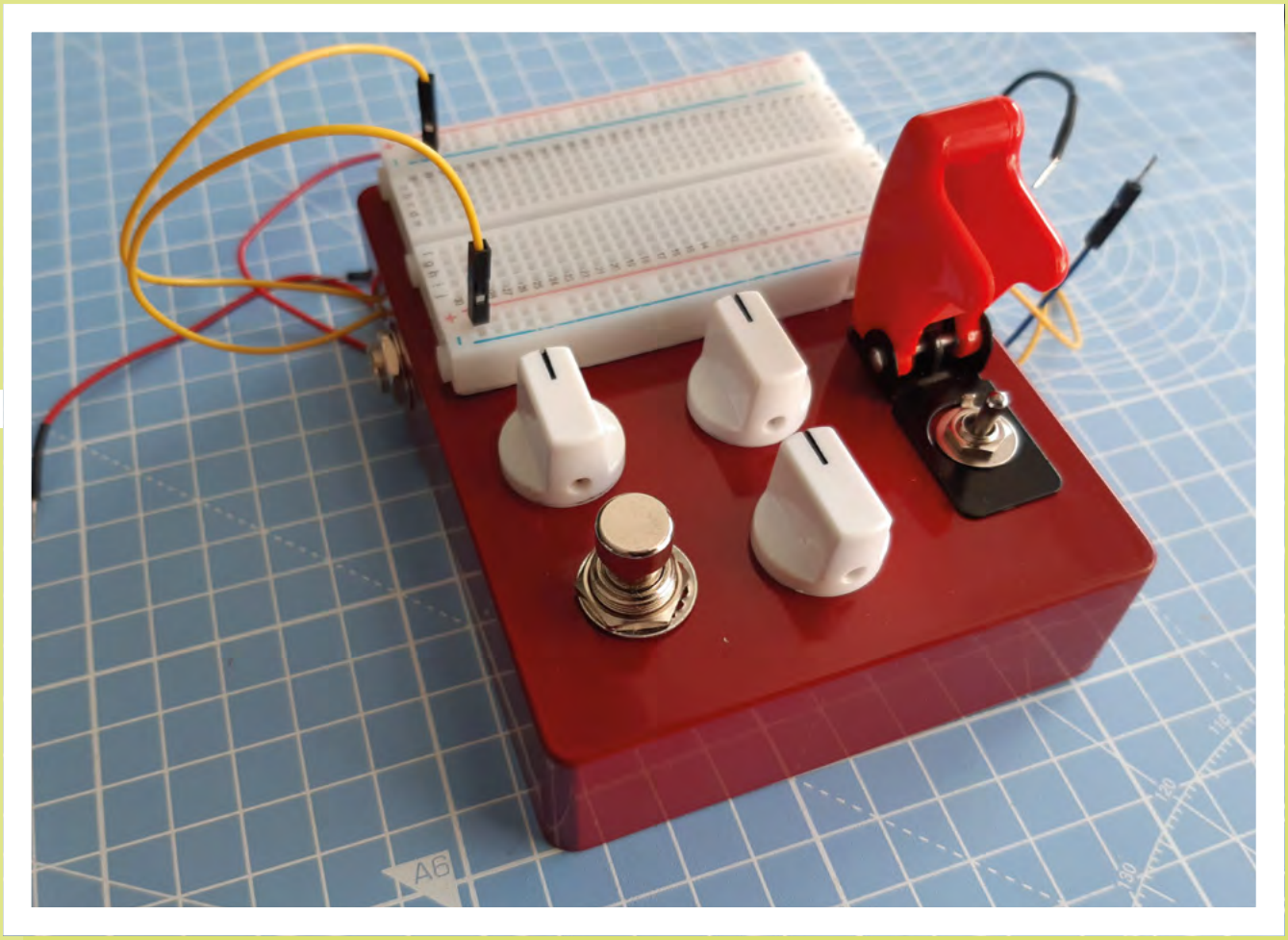
Instead of jumping in at the deep end with something that uses an op-amp like a ProCo RAT, you stick to a single transistor

loud); the diodes (the bits that clip the top and bottom parts off the sound-wave – this makes a huge difference to the quality of the sound); and the capacitors.

The capacitor is the last component before the signal leaves the pedal. Smaller value capacitors result in a thinner sound; larger value capacitors give a bigger sound. One of the classic guitar pedals is the Electro-Harmonix Big Muff. This uses four transistors rather than one, as I've used here, but anyone who can understand what this circuit does will understand the Big Muff. There's a version of the Big Muff that has a darker sound and is particularly favoured by bassists; this is the Russian version, and sounds different solely because there's a larger value capacitor at a crucial stage in the signal path.

That brings us full circle to the reason I built this thing, which is really just a glorified breadboard. Changing one single component makes a huge difference, so I invested around £20 in a bunch of components bought online without knowing what they'd do. Some differences are pretty big – the modern high-gain transistor we've used (it's a 2N5088, available from Mouser for 46p at the time of writing) is a lot louder than the old AC178s I've got kicking around here somewhere. Some differences are minimal, but you have to spend hours A/B testing just to make sure. And sometimes you'll order a bunch of diodes whose wires are so thick they don't fit in the breadboard, and you'll have to get into building robots, just so they don't go to waste.

Below
The missile-safety guard on the toggle switch is overkill, but I was desperate for an excuse to use it



HackSpace magazine meets...

Estefannie Explains It All

Talking electronics, online community, free tech, and being yourself

Recently listed as one of Instagram's Top 7 Women in STEM, software engineer and content creator Estefannie talks to Alex Bate about electronics, her online community, and why she can't stop giving away free tech in her Instagram Live streams.

Based in Texas, Mexican-born Estefannie graduated summa cum laude from the University of Houston with a degree in computer science and a passion for helping people discover computing. Some years later, with an established career as a software engineer under her belt, Estefannie is best-known for her YouTube and Instagram accounts, Estefannie Explains It All, and can often be found with a soldering iron in one hand, a rescue cat in the other, all while sporting the most fabulous pair of circuit board Louboutin heels and laser-cut lightning bolt earrings. Yes, it's fair to say that we all want to be Estefannie. But how did she get here? →

Right
Coming from a software background, Estafannie had had to learn electronics


COLLIDER
THE ART OF DECEPTION

HS You originally made videos on your channel four years ago to make sure that you'd retained the information that you were learning at the time?

Estefannie Mm-hmm, that's right.

HS But why did you decide to move away from the early explainers and start making other types of content, such as your Daft Punk helmet, and running weekly live streams and giveaways? Because I'm assuming that when you were making those early Estefannie Explains It All videos, you didn't plan on becoming an influencer?

E No. The influencer part? Oh, no. I was studying for an interview with Google and I decided to make explainer videos and put them online because I knew people would correct me if I was wrong. And, if they didn't, I knew my explanations were correct and I was better prepared for the interview. The YouTube comments section was the scariest place on earth for me, so that's why I went for YouTube.

Later on, it was close to Halloween, and I was about to have an interview with Microsoft, this time to be a product evangelist. And I knew that IoT, the Internet of Things, was 'the latest buzzword', and I already wanted to dabble with that technology. So, I decided I wanted to make an IoT project and put it on my YouTube channel. That way, when the Microsoft interview arrived, I'd also have that video to show.

Halloween happened and I'd made this stupid pumpkin robot thing that wasn't even IoT, but I put it on YouTube anyway and realised that I'd really liked doing it. I really, really liked it. And that's when I found out about Simone Giertz and other makers, and this whole world I hadn't known about. I thought, 'I really like doing this, so I'm going to keep doing it.' I didn't even care about the interview anymore because I had found 'the thing', the thing that I wanted to do.

Microsoft actually loved the video and they wanted me to keep doing more of them, but on their platform, and they would own the content, which I didn't want. So that's how it transformed from explainers as prep for interviews to wanting to make videos. And the influencer thing happened a little bit differently. It's a bit more Instagram-my.

HS It's more personal. You're creating a brand.

E A brand, yes, I think that's the key. So the Instagram thing happened for two reasons. The first one was that, before YouTube, I was going to start a business making little video games and mobile apps. And I decided to make it an 'umbrella' business so that anything I made could go under there. Because I thought [she laughs], 'they're going to go viral and so I need to be prepared legally.'

And while I was doing all of the business stuff, I realised I also need to learn how to do social media, because I need to promote these video games.

> I decided to make explainer videos and put them online because I knew people would correct me if I was wrong

So I took the time to understand Instagram, follow the people that I thought were interesting or would be doing the same stuff as me. I started out with my personal account as a test and, again, I really liked it. I started seeing people follow me because they were interested in the lifestyle of a software engineer. And I thought it was cool because I would have liked to see how software engineering was as a career before going for it. It was like a window to that world.

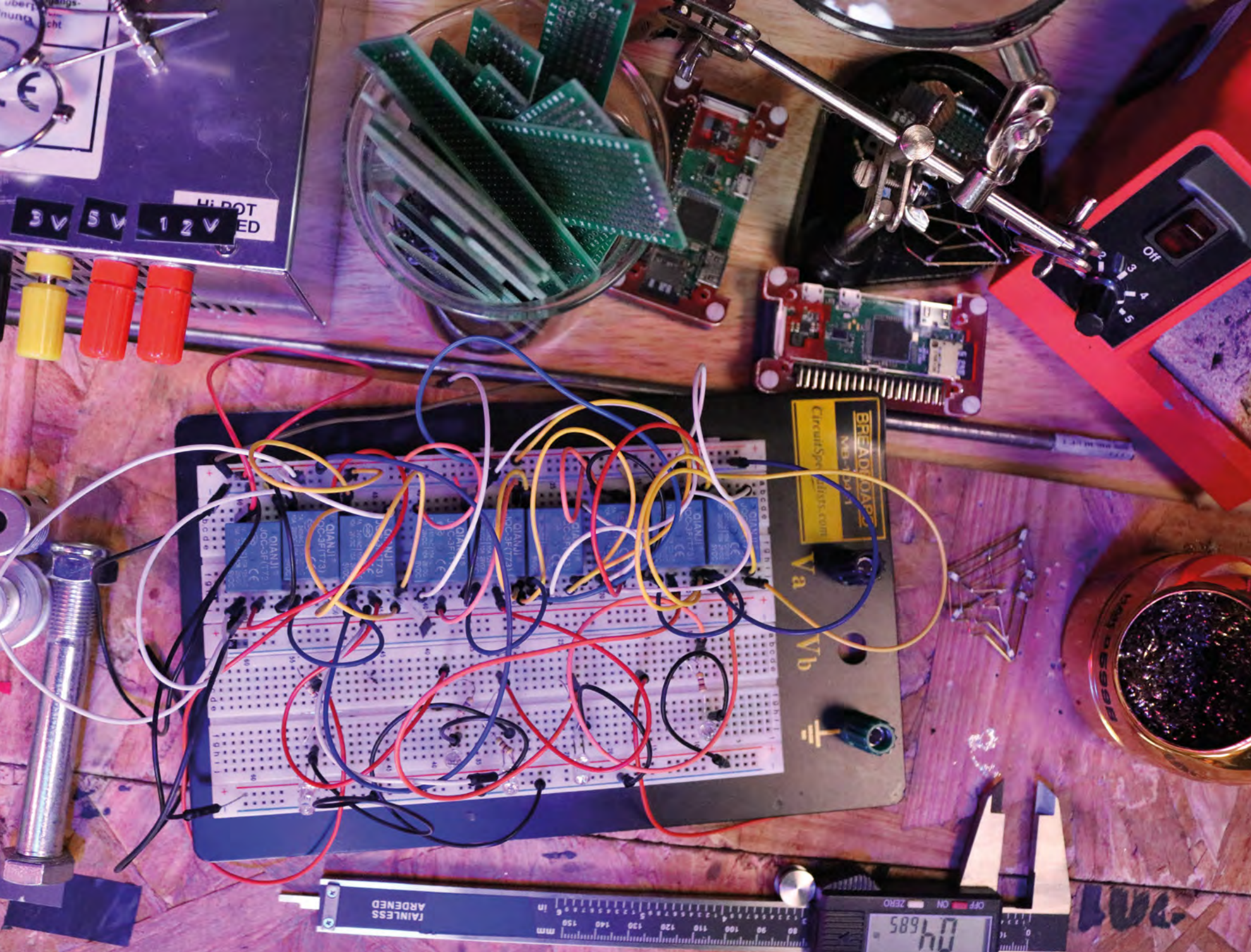
HS Do you think there's been a change, though, because your brand was that you were a software engineer? And now you're not in the same job. You're a full-time creator now. Do you think that's affected who follows you and how people interact with you?

E I was very afraid of that when I quit my job. I tried to not talk about it at first. But it didn't really matter because the people who have followed along, they've seen all the changes. And when I quit my job, they congratulated me because I was now able to do this full-time. So it was like the opposite. They were following 'The Estefannie Experience', ha ha. For a lot of them, it was like, 'Oh, that's another cool path that you can take as an engineer.'

HS What was it like to make the leap from software, from something you can control totally to hardware, an area where things can go wrong all the time?

E Oh, well, software can go wrong all the time, too. When I did that first Halloween pumpkin video, I think that really sparked a new interest in me of like, 'Oh, I should have studied electrical engineering or computer engineering'. Because I am really passionate about the hardware aspect of it. I'd studied a low-level class as part of my computer science degree about gates and how they work. I remember having to draw them out. And I really liked that class and understanding how electricity goes through those gates. But it didn't matter because I was there to learn how to do the programming part. With electronics, it was so fun to go back and actually try it, and I was hurting myself, shocking myself, burning myself. It was great; I love it. It was like I was putting everything in my imagination into real, physical things. And I think that helps me. I like seeing things or touching things.

HS You're a big advocate for celebrating failure and learning from failure. You've →


3V
5V
12V
Hi POT
Off
CircuitSpecialists.com
Va
Vb
ZERO
589 hΩ

Left
Cats can provide emotional support while debugging

done talks about it at Coolest Projects and Maker Faire, and you talk about it in your videos. In the earthquake simulator you built for Becky Stern, you showed the first way of making it and how it didn't work, before showing the final project. Do you think it's important to share failures on YouTube, instead of editing a perfect project build?

E I think so. Yes. It comes from a place within me where, when I wasn't good at something when I tried it for the first time – I'm a nineties kid, I don't know if this is anything to do with it – but you try, and you fail, and you just assumed 'OK, I'm not good at it.' I'm not supposed to be playing piano, or whatever. That's how I grew up thinking. And so, when I became an actual engineer, and I say 'engineer' because studying computer science is one thing, but to become an engineer is something completely different. And when I actually became an engineer, that's when it hit me that you have to really just go for it, stop thinking, stop planning, stop analysing, and just do it and see what happens, and learn from that.

So that was a great lesson in life for me, and I want to show people like me that I make mistakes all the time and that I struggle sometimes, or that it takes several steps; it takes several tries to get somewhere. And so I want to show it for those people who feel maybe like they can't do something because they didn't do it the first time. I want to show them the human side of engineering.

HS That's cool. I liked when you were making the visor for your Daft Punk helmet and it was just a series of Instagram Live videos of you unsuccessfully melting plastic in your oven as you tried to learn how to vacuum-form.

E The plastic melting was so fun, and I learned a lot. I would never do that again, ha ha.

HS Of all the projects you've made and shared, what has been the thing that you've been the proudest of because you managed to overcome an issue?

E I think with most of my projects, I've had to overcome something. Except with the Jurassic Park Goggles. Although it was a pain to do, I already knew what I was doing, and that was because of the Daft Punk helmet. I struggled so much with that one that I knew exactly what do to with the goggles.

I've been working on a smart litter box project for my cats, Teddy and Luna. That one required me to do a lot of woodwork and play with tools that I had never played with before. And so those days terrified me. But, I try to push myself with every project, so they're all scary.

HS You have projects that you've put your blood, sweat, and tears into, that you've worked hard on, that you've written all the code for. Where do you stand on whether you should give that code away for free? Do you provide it all the time? Do you ever think, 'no, I'm going to keep this for myself'?

E Oh, I am a true believer in open source. My plan is to continue to give it all away and put it on my website. This morning, I was finishing up a blog post I'm writing about the Daft Punk helmet. A step-by-step on how to do it, because I know people watch the video, but they might not be able to follow it to make their own. So now I'm going 'here, here's what I use'. And all those links in the post, Home Depot, etc., all the links I'm using, they're not even affiliated. I'm making zero dollars out of that post I've been working on.

I know lots of the people who want to recreate my projects are kids, and they have no money. This is the type of education I wish I had had when I was younger. If I had known about this stuff, I would have started when I was very young. So, I can't charge them. I feel, if they have to buy electronics, there's no way I can charge extra for the schematic and the code. I cannot do that.

It's about being very conscious of who my audience is. I don't want to stop →

them from making it. It's the opposite. That's why I do giveaways every week on Instagram Live. I want to give them the boards. I want to give them everything so they can do it. I didn't have any money growing up, and I know the feeling.

I respect people who want to charge for it. I understand. But I'm not in that boat. Even the smart little box that I'm currently working on, someone who I respect very much said, 'oh, that's a great idea, why don't you patent it and manufacture it? There's a market for it.' And I know there's a market for it, but that's not the point. The point is to show that you can do it. Anything that's in your imagination, you can build it, you can do it, and here are the steps. Yeah, I want more money, but I think I can get there in different ways, through YouTube ads and sponsorships.

HS There are a million different ways to make an LED blink, and none of them is the wrong way, they're just the comfortable way you find to do it. Do you get backlash when you release your code from people saying, 'Well, you should have done it this way'?

E I have never received backlash on code and, in fact, I would encourage people not to be scared to publish their code. I know people who say they want to open-source their code but they have to 'clean it up first', and they're scared to publish it. But the whole point of open source is that you put it out there, you know it works, and it's going to be OK. And it gets better because people will contribute. I'm never afraid of showing code.

Above
Giveaways are ruled by the random wheel of fate, like Boethius' Wheel, but nicer

HS Do you think, when you talk about financial accessibility that that's one of the reasons that's holding you back from starting a Patreon? That you'd be putting a financial wall up against people who can't afford it.

E One hundred percent. I don't want to add to people's financial strain. In fact, I am starting my new cryptocurrency so that I can send tokens to people around the world and, kinda like arcade tickets, they can spend them on things.

> I'm Estefannie who also really, really likes crazy fashion. I like make-up and weird earrings

HS How does that work? How can I spend your cryptocurrency?

E OK, so it has zero monetary value. The idea is that instead of giving out imaginary internet points to people in my live streams, they get actual internet points. And they can exchange them back to me for real items. I'll have a menu of tech – so many points gets you a Pico, or a Raspberry Pi 400, or some other board – and people exchange their internet points for prizes. It helps me see how active someone has been in the live streams so I can say yes, it's worth the $200 to ship this item to someone in India.

HS Ah, I get it. It's like house points in school.

E This is why it takes me so long to release a video because I'm like, let me do the cryptocurrency and then also that live stream, and then also this video about so and so. I just want to have a voice.

HS How do you decide what content to make? Is it just about creating content you think your audience will like? Or more about content you think is important for people to know?

E I think I've always made videos that I felt were important, but I was always trying to, y'know, 'play the algorithm'. And that was happening while I was still working and trying to quit my job so, of course, that was a period of my YouTube career where I was trying as much as I could to get views and hop on trends. Not the trends that were just 'trends', but trends by people I liked. Back then, I was a big fan of a YouTube baker, so I did a project using her stuff in the hopes she would see it. But I'm not really like that any more. If I see a channel I really like, I'll try and do a collab, but not just because it would be beneficial for my channel. None of that any more. Just stuff I like.

One piece of advice that a lot of YouTubers have told me – that I've decided not to follow – is that you have to stick to one thing so that the audience knows what to expect. The same with Instagram. But I disagree, and I've gained more followers by being myself more. I'm Estefannie who also really, really likes crazy fashion. I like make-up and weird earrings, and why should I have to tone that down? Because I'm an engineer? I only post things that I would like. It's not always me soldering. It's not always code.

HS You create the content you want to see, not the content you think people want to see.

E Yes. That would be easy to play that game, but that's not what I want to do.

HS A lot of content creators would create a separate Instagram account or YouTube channel for their other passion, but all that's doing is showing that it has two →

different audiences. I think, especially when you are a woman in tech, if you then separate out the other things that you like, it's almost like you're saying, 'Oh, well, these are two separate things that can't exist together.'

E Exactly. You're saying, 'I go to work. And I'm a scientist, and I look like this. But then I go home, and I look like this'. And it's not true. There are some creators who have a million YouTube channels, and I don't understand why because people really like them for who they are. But it's following the example of how, if you want to do vlogging, you have to have a separate channel, and I don't think you necessarily have to.

HS You are the brand, and people subscribe to you. You love fashion, and I couldn't see you doing a 'come shopping with me down Melrose Place' video because that's not who you are, but I could totally see you trying to make your own lipstick.

E Oh, yeah. Oh, yeah.

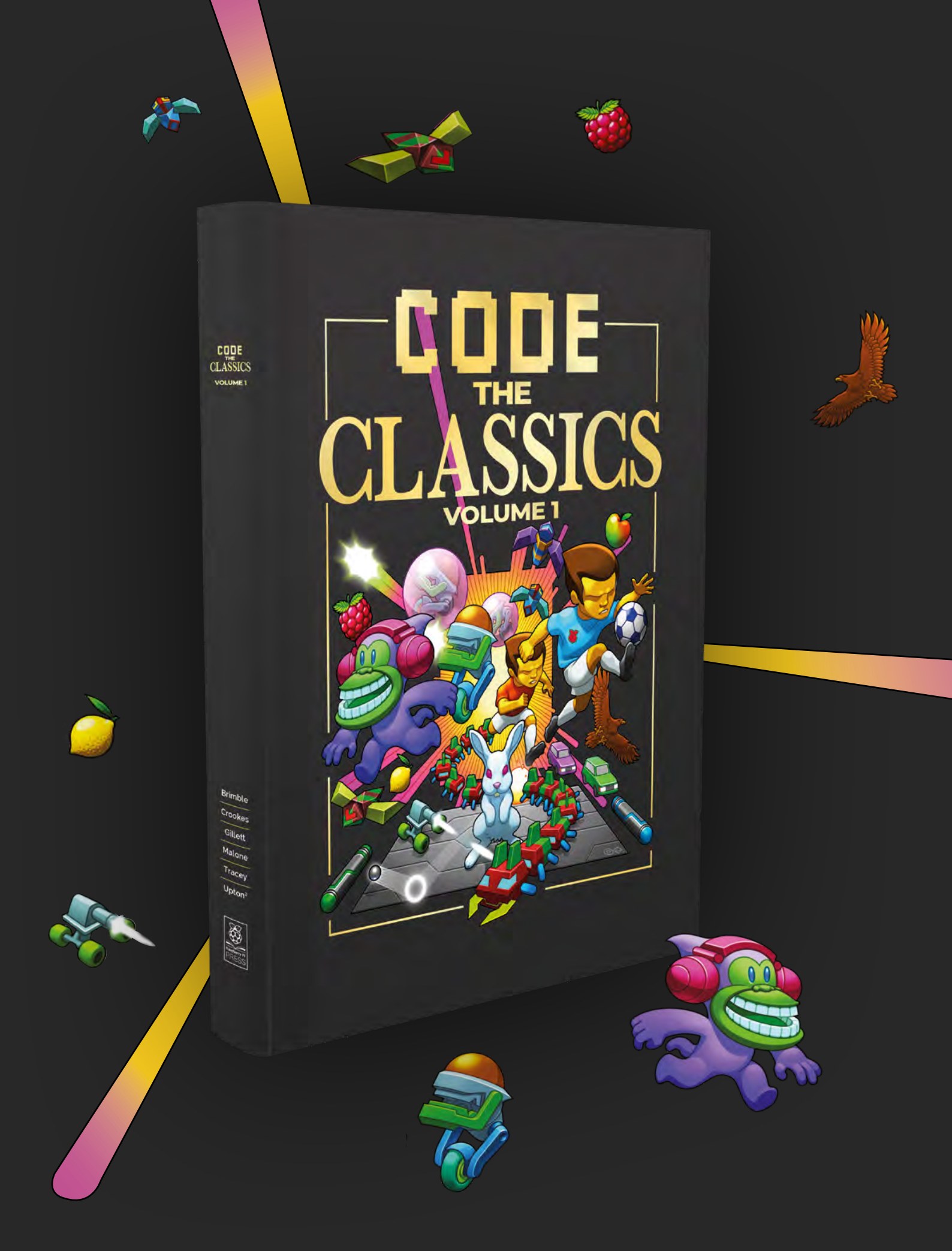
HS You would make that video and your audience would love it because it's you, and you're doing something you're passionate about.

E Yeah, I mean, it's like, the best example for me is Colin Furze. He is who he is. He wears his tie, he's great. That's very transparent. That's him.

There's a maker who influenced the way I dressed for a bit, and I see it on all the other maker women in how they dress. And I didn't even like those clothes. And when I noticed, and I stopped myself, and I was like, 'this is not the Estefannie Experience'. It's the other person experience, and I don't need to replicate that because that's not me. And if I want to wear my giant heels, I'll wear my heels. You have to be yourself.

If people want to be creators, it's OK to be yourself. And if you're the only one and you don't have a team like other creators, that it's OK to take your time and not do it for the algorithm. That's my advice. You don't have to post every week. I mean, you can, but don't kill yourself. It's a one-woman show over here. I do my taxes, I do the website, I do the videos. That's the advice I want to give here. That's what I want people to take from this interview. □

Subscribe to Estefannie on YouTube, and follow her on Instagram. And make sure to take part in her weekly live streams for a chance to win some exclusive Estefannie Internet Points.


CODE
THE
CLASSICS
VOLUME 1
Brimble
Crookes
Gillett
Malone
Tracey
Upton²

FEATURE

MASON JARS

IMPROVISER'S TOOLBOX

Screw some creativity into your builds

Mayank Sharma

@geekybodhi

Mayank is a Padawan maker with an irrational fear of drills. He likes to replicate electronic builds, and gets a kick out of hacking everyday objects creatively.

Given how they are used these days, you'd assume Mason jars were designed for DIYers. However, they came into existence as a simple, utilitarian kitchen staple and were lapped up for the purpose of preserving all kinds of fruits and vegetables.

The Mason jar was named after its inventor, John Landis Mason, who patented them in 1858, while in his mid-20s. Mason, the inventor, came about the jars while searching for a way to improve a process of home canning, which wasn't able to stretch its legs because it lacked a proper medium. Heat-based canning began at the start of the 19th century, thanks primarily to the efforts of French cook Nicolas Appert in his desire to preserve food for longer periods.

Before Mason jars came about, home canning involved using wax to create an airtight seal. As you can imagine, these containers were cumbersome to use and, even after all that effort, their imperfect seals weren't very airtight.

Mason then invented a machine that could cut threads into lids, which made it practical to manufacture a jar with reusable lids that could simply be screwed on. So, while he is credited for the jar, Mason's real invention is the sealing mechanism of the lid – a zinc lid with a rubber ring that created an airtight seal, to be precise.

The jars were a hit but, before consumers, it was Mason's competitors that moved in on his invention. Due to several missteps, Mason's patent expired in 1879, and he is said to have died a pauper at the start of the 20th century. Soon, the arrival of the refrigerator sounded the death knell for the jars.

However, Mason jars never completely went away, and households around the world continue using them in their kitchens, though they are mostly used as drinking glasses, utensil holders, or flower vases. The original ones are also valued as collectors' items.

The earliest Mason jars were made from transparent glass, and, through the years, there've been several variations in shape and cap design. These days the jars are produced in a variety of volumes, including half-pint, pint, quart, and half-gallon. Besides these variations in size and colour, there isn't much room for improvement in the design itself, which is a major part of the Mason jar's appeal.

Because Mason jars aren't just useful but also look beautiful, they have become design icons and lend themselves to many different uses, as we'll see over the next few pages.

CHANDELIER

Using the aesthetically pleasing Mason jars to create a chandelier is such an awesome idea. Amanda and Joe have used ten jars in their build, though you can use more or less, depending on your taste or the surface area you have to work with. The duo have used a wine crate that they got for free at a liquor store. Or, you could create your own with a few pre-cut pieces of MDF or plywood from your local hardware store, and some nails. Then, figure out a pattern for placing the lights on the ceiling plate and

Project Maker
AMANDA AND JOE

Project Link
hsmag.cc/Chandelier

"PASS THE WIRES FOR THE FIXTURES THROUGH THE CEILING PLATE"

drill holes just wide enough to pass the wires through. Similarly, trace the light fixtures on the lids of the jars and cut them out with a knife or Dremel tool. Pass the wires for the fixtures through the ceiling plate. Amanda and Joe have used washers to secure them. Then get all the lead wires in one bundle and the neutral wires in another, and secure them with wire nuts, leaving one of each to connect with the light source in the ceiling. Fix two wooden brackets to the ceiling, and wrap up by attaching the ceiling plate with a couple of screws on either side. →

Right
Double-check that the light bulbs fit inside the jars before you begin and, for best results, get ones that aren't very bright

FEATURE

ISOBARIC LOADED SPEAKERS

Project Maker
JAMIE MATTHEWS

Project Link
hsmag.cc/IsobaricSpeakers

A self-confessed DIY audio nut, Jamie loves putting together speakers and tube amps. It isn't surprising then that he's built himself a pair using Mason jars. Jamie wanted to make a pair of isobaric loaded speakers, to get more oomph from regular Bluetooth speakers, but on a smaller scale, and the Mason jars offered the perfectly sized enclosures. Although Jamie has 3D-printed most of the parts for the build, he imagines they can be easily fabricated either with wood or using plastic sheets. The only modification he's made to the Mason jar is to make a hole in the base of the jar to pipe the USB cable for powering the speaker. If you want to avoid cutting glass, Jamie suggests you can use a 3.7V lithium battery to power the speakers, which also makes the whole thing more portable as a bonus. His Instructable includes details about the electronics that he's used, along with information on wiring the amplifiers and the DAC, and then assembling the whole contraption. Jamie encourages all audiophiles to build themselves a pair: "Not only do they look so much cooler than normal desktop speakers, but they also pack quite the punch."

Right
Jamie has tons of DIY speakers on his Instructables and says his latest obsession is DML flat panels

HANGING STORAGE

This one's a personal favourite, and the one which actually led us to feature Mason jars in this column. While Shannon probably came up with the idea to better utilise the space in her kitchen, This author stumbled upon the project while looking for tips to prevent his two-year-old from grabbing the heavy Mason jars in our kitchen. They nearly created a mini catastrophe when he accidentally dropped one. Shannon's build is pretty straightforward. Unscrew the lids from the jars, and use a nail and hammer to punch a hole in the middle. Instead of the nail, this author used a screw, which he then used to attach the lid to the underside of the upper kitchen cabinets. Applying some superglue under the shelf before screwing in the lids helps ensure a firm hold. Be very mindful of closing the jars properly.

Project Maker
SHANNON QUIMBY

Project Link
hsmag.cc/storagejars

Right
In our experience, this attachment works best with small Mason jars that don't hold anything heavy, or are kept half full

FIGURINE SENSOR LIGHT

Project Maker
YUE SHI

Project Link
hsmag.cc/AstronautLight

Yue is a handbag accessories designer in Sydney, Australia. Although she usually works with leather, Yue's used her creative bent of mind to convert a Mason jar into a very attractive sensor light that's in the shape of an astronaut. She's 3D-printed all the parts of the figurine using white ABS filament, which Yue says makes them easier to glue with acetone. She did her research, before thoughtfully designing the astronaut with bent legs to bear the weight of the jar, and enlarged the feet for balance. Once the parts had been printed, she sanded the seams of all the printed components, then glued them, before applying multiple levels of primer and one layer of white acrylic paint. Once completed, she shoved the battery-operated sensor LED lights inside the Mason jar, and attached its battery and buttons housing as the astronaut's backpack to complete the look. □

Right
Yue won the Grand Prize in Instructables' Mason Jar speed challenge. Check out the other winners for more Mason jar goodness (instructables.com/contest/masonjar2020)

SUBSCRIBE TODAY

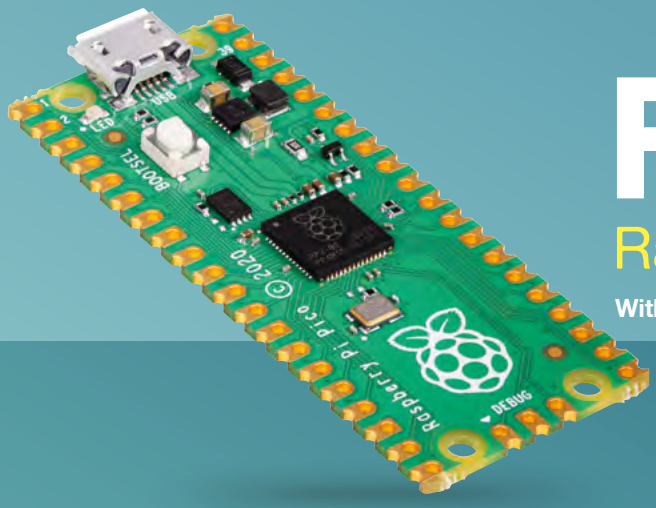
Get 12 issues of HackSpace magazine delivered to your door for just

£55 (UK)

£90 (USA)

£80 (EU)

£90 (Rest of World)



FREE!

Raspberry Pi Pico

With your first 12-month print subscription

This is a limited offer. Not included with renewals.
Offer subject to change or withdrawal at any time.

Subscribe online: hsmag.cc/subscribe

Subscription starts with next issue

HackSpace
TECHNOLOGY IN YOUR HANDS

FORGE

HACK | MAKE | BUILD | CREATE

Improve your skills, learn something new, or just have fun tinkering – we hope you enjoy these hand-picked projects

Custom USB games controllers with Pico

Play games the way you want to

Ben Everard

@ben_everard

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

Games controllers – like keyboards – are very personal things. What works for one person may not work for another. Why, then, should we all use almost identical off-the-shelf controllers? Let's take a look at how to use Pico to create a controller that's just right for you.

We'll use CircuitPython for this as it has excellent support for USB interfaces. The sort of USB devices that we interact with are called human interface devices (HIDs), and there are standard protocols for common HIDs, including keyboards and mice. This is why, for example, you can plug almost any USB keyboard into almost any computer and it will just work, with no need to install drivers.

We'll be using the Keyboard type, as that works best with the sorts of games that this author likes to play, but you can use exactly the same technique to simulate a mouse or a gamepad.

Before we get onto this, though, let's take a look at the buttons and how to wire them up.

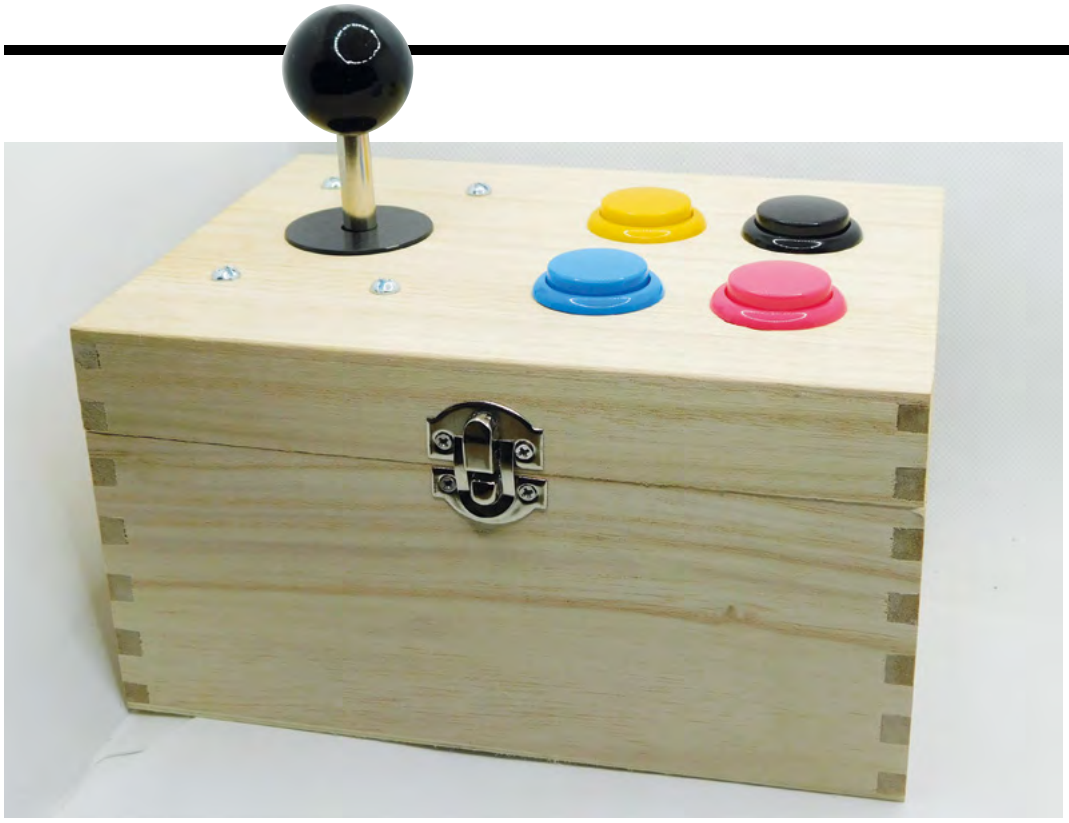
We're going to use eight buttons: four for direction, and four as additional 'action' buttons. We'll connect these between an I/O pin and ground. You can use any I/O pin you like. We're going to use slightly different ones in two different setups, just because they made sense with the physical layout of the hardware. Let's take a look at the hardware we're using. Remember, this is just the hardware we want to use. The whole idea of this is to create a setup that's right for you, so there's no need to use the same. Think about how you want to interact with your games and take a look at the available input devices and build what you want.

The first setup we're creating is an Arcade box. This author would really like an arcade machine in his house. However, space limitations mean that this isn't going to be possible in the near future. The first setup, then, is an attempt to recreate the control setup of an arcade machine, but use it to play games on a laptop rather than a full-sized cabinet.

Arcade controls are quite standard, and you can get them from a range of sources. We used one of Pimoroni's Arcade Parts sets, which includes a joystick and ten buttons (we only used four of these). The important thing about the joystick you pick is that it's a button-based joystick and not an analogue one (sometimes called a dual-axis joystick), as the latter won't work with a keyboard interface. If you want to use an analogue joystick, you'll need to switch the code around to use a mouse or gamepad as an input device.

As well as the electronics, you'll need some way of mounting them. We used a wooden craft box. These are available for about £10 from a range of online or bricks and mortar stores. You can use anything that is strong enough to hold the components.

The second setup we're using is a much simpler button-based system on breadboard-compatible tactile buttons and protoboard. It's smaller, cheaper, and quicker to put together. The protoboard holds everything together, so there's nothing extra to add unless you want to. You can personalise it by selecting different-sized buttons, changing the layout, or building a larger chassis around this.



INSERT COIN TO CONTINUE

Let's take a look at the arcade setup first. The joystick has five pins. One is a common ground and the others are up, down, left, and right. When you push the joystick up, a switch closes, linking ground to the up pin. On our joystick the outermost pin is ground, but it's worth checking on your joystick which pin is which by using a multimeter. Select continuity mode and, if you push the joystick up, you should find a continuous connection between the up pin and ground. A bit of experimentation should confirm which pin is which.

> **The joystick has five pins. One is a common ground** and the others are up, down, left, and right

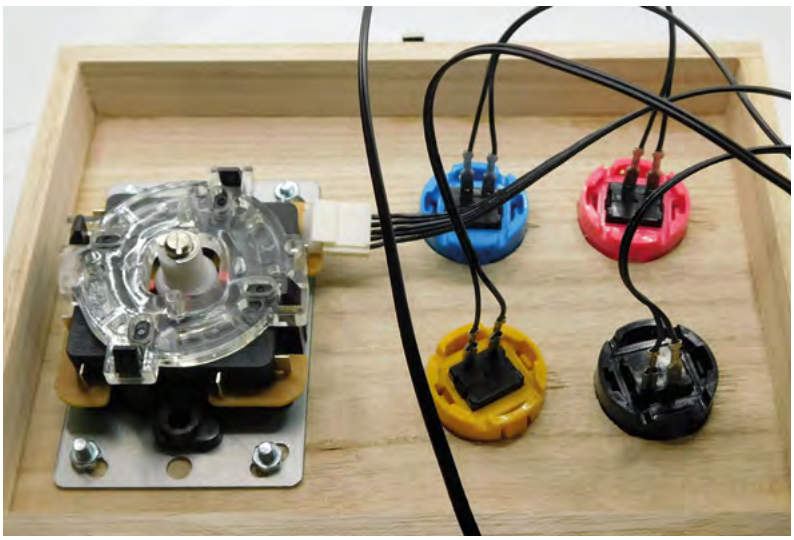
In order to read the pins, we just need to connect the directional output from the joystick to an I/O pin on Pico. We can use one of Pico's internal pull-up resistors to pull the pin high when the button isn't pressed. Then, when the button is pressed, it will connect to ground and read low. The joystick should come with a cable that slots onto the joystick. This should have five outputs, and this conveniently slots into the I/O outputs of Pico with a ground on one end.

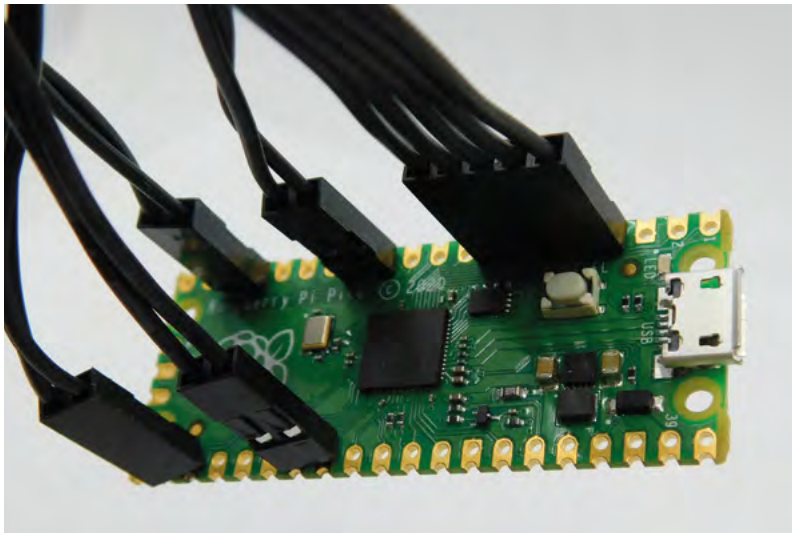
The buttons, similarly, just need to be connected between ground and an I/O pin. These came with cables that pushed onto the button and plugged into adjacent pins. Since Pico has eight grounds available, there are enough that each button can have its own ground, and you don't have to mess around joining cables together.

Once all the cables are soldered together, it's just a case of building the chassis. For this, you need five large holes (one for the joystick and four for the buttons). We didn't have an appropriately sized drill bit and, given how soft the wood on these boxes is, a large drill bit may have split the wood anyway. Instead, we drilled a 20 mm hole and then used a rotary tool with sanding attachment to enlarge the hole until it was the right size. You have to go quite easy with both the drill and the sanding tool to avoid →

Above
Gaming like it's 1989

Below
The connectors should just push onto the buttons and joysticks





Above
You can solder the pin headers straight onto Pico

Right
A little games controller that you can fit in your pocket

turning everything into shards of broken wood. Four small holes then allow bolts to keep the joystick in place (we used M5 bolts). The buttons just push into place.

The only remaining thing was a 12 mm hole for a micro USB cable to pass through to Pico. If you don't have a 12 mm drill bit, two overlapping smaller holes may work if you're careful.

The buttons just push-fit into place, and that's everything ready to go.

A SMALLER APPROACH

Our smaller option used protoboard over the back of Pico. Since we didn't want to block the BOOTSEL button, we only soldered it over part of Pico. However, before soldering it on at all, we soldered the buttons in place.

Tactile switches typically have four connections. Well, really they have two connections, but each connection has two tabs that fit into the protoboard. This means that you have to orientate them correctly. Again, your multimeter's continuity function will confirm which pins are connected and which are switched.

Protoboard is a PCB that contains lots and lots of holes and nothing else. You solder your components into the holes and then you have to create connections between them.

We placed the buttons in the protoboard in positions we liked before worrying about the wiring. First, we looked to connect one side of each switch to ground. To minimise the wiring, we did this in two groups. We connected one side of each of the direction buttons together and then linked them to ground. Then we did the same to all the action buttons.

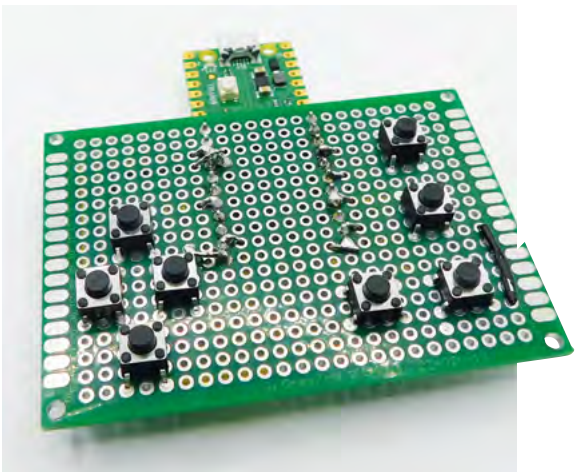
There are two ways of connecting things on protoboard. One is to use jumper wire. This works well if the points are more than a couple of holes apart. For holes that are next to each other, or very close, you can bridge them. On some protoboard (which doesn't have a solder mask), you might simply be able to drag a blob of solder across with your soldering iron so that it joins both holes. On protoboard with solder mask, this doesn't work quite so well, so you need to add a little strand of wire in a surface-mount position between the two points and solder it in. If you've got a pair of tweezers to hold the wire in place while you solder it, it will be much easier.

For longer connections, you'll need to use jumper wire. Sometimes you'll be able to poke it through the protoboard and use the leg to join. Other times you'll have to surface-mount it. This all sounds a bit complicated, but while it can be a bit fiddly, it's all fairly straightforward once you put solder to iron.

> **We placed the buttons in the protoboard in positions** we liked before worrying about the wiring

PROGRAM IT UP

Now that we've got the hardware ready, let's code it up. You'll first need to load CircuitPython onto your Pico. You can download the latest release from **circuitpython.org**. Press the BOOTSEL button as you plug Pico into your USB port, and then drag and drop the downloaded UF2 file onto the RP2 USB drive that should appear.



We'll use Mu to program Pico. If you've not used CircuitPython before, it's probably worth having a quick look through the 'getting started' guide here: **hsmag.cc/CircuitPythonGuide**.

The code to run our games controller is:

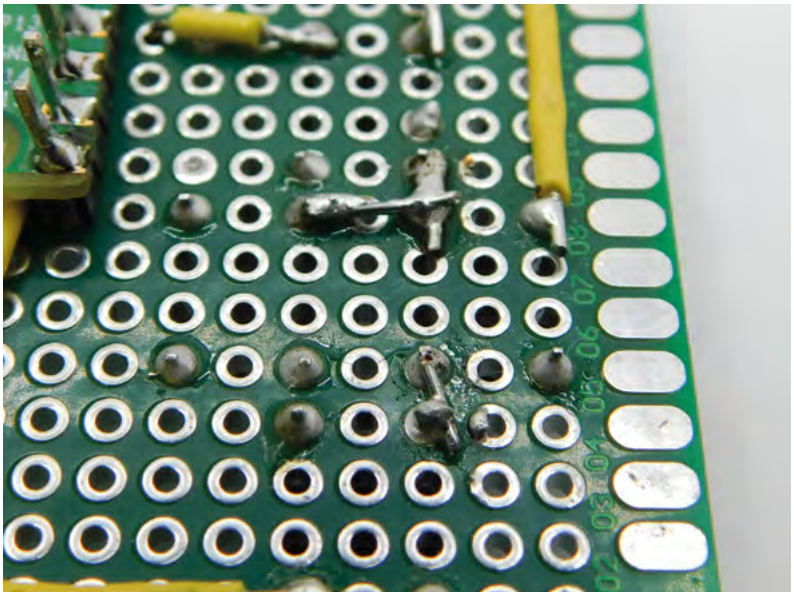
```
import board
import digitalio
import gamepad
import time
import usb_hid
from adafruit_hid.keyboard import Keyboard
from adafruit_hid.keycode import Keycode

kbd = Keyboard(usb_hid.devices)

keycodes = [Keycode.UP_ARROW, Keycode.DOWN_ARROW,
Keycode.LEFT_ARROW, Keycode.RIGHT_ARROW,
    Keycode.X, Keycode.Z, Keycode.SPACE, Keycode.
ENTER]

pad = gamepad.GamePad(
    digitalio.DigitalInOut(board.GP12),
    digitalio.DigitalInOut(board.GP14),
    digitalio.DigitalInOut(board.GP9),
    digitalio.DigitalInOut(board.GP15),
    digitalio.DigitalInOut(board.GP16),
    digitalio.DigitalInOut(board.GP17),
    digitalio.DigitalInOut(board.GP18),
    digitalio.DigitalInOut(board.GP20),
)
last_pressed = 0
while True:
    this_pressed = pad.get_pressed()
    if (this_pressed != last_pressed):
        for i in range(8):
            if (this_pressed & 1<<i) and not
(last_pressed & 1<<i):
                kbd.press(keycodes[i])
            if (last_pressed & 1<<i) and not
(this_pressed & 1<<i):
                kbd.release(keycodes[i])
        last_pressed = this_pressed
    time.sleep(0.01)
```

This uses the HID keyboard object (called **kbd**) to send key press and release events for different key codes depending on what buttons are pressed or released. We've used the gamepad module that is for keeping track of up to eight buttons. When you initialise it, it will automatically add pull-up resistors and set the I/O pins to input. Then, it will keep track of what buttons are pressed. When you call **get_pressed()**, it will return a byte of data where each digit corresponds to an I/O pin. So, the following number (in binary) means that the first and third buttons have been pressed: 00000101. This is a little confusing, because this is the opposite order to how the I/Os are passed when you initialise the GamePad object.



Above
With a combination of small sections of wire and jumpers, you can create whatever pattern of wiring you like on protoboard

The **while** loop may look a little unusual as it's not particularly common to use this sort of binary comparison in Python code, but in essence, it's just looking at one bit at a time and seeing either: it's now pressed but wasn't last time the loop ran (in which case, it's a new button press and we should send it to the computer), or it isn't pressed this loop but was the previous loop (in which case, it's newly released so we can call the release method).

The << operator shifts a value by a number of bits to the left. So, 1<<2 is 100, and 1<<3 is 1000. The & operator is bitwise and so it looks at a binary number and does a logical AND on each bit in turn. Since the right-hand side of the & is all zeros apart from one bit (at a different position depending on the value of **i**), the result will be dependent on whether the value of **this_pressed** or **last_pressed** is 1 or 0 at the position **i**. When you have an **if** condition that's a number, it's true if the number is anything other than 0. So, **(this_pressed & 1<<2)** will evaluate to true if there's a 1 at position 2 in the binary form of **this_pressed**. In our case, that means if the joystick is pushed left.

You can grab this code from the following link – **hsmag.cc/USBKeyboard**. Obviously, you will need to update the GPIO values to the correct ones for your setup when you initialise GamePad.

We've taken a look at two ways to build a gamepad, but it's up to you how you want to design yours.

Restoring machines

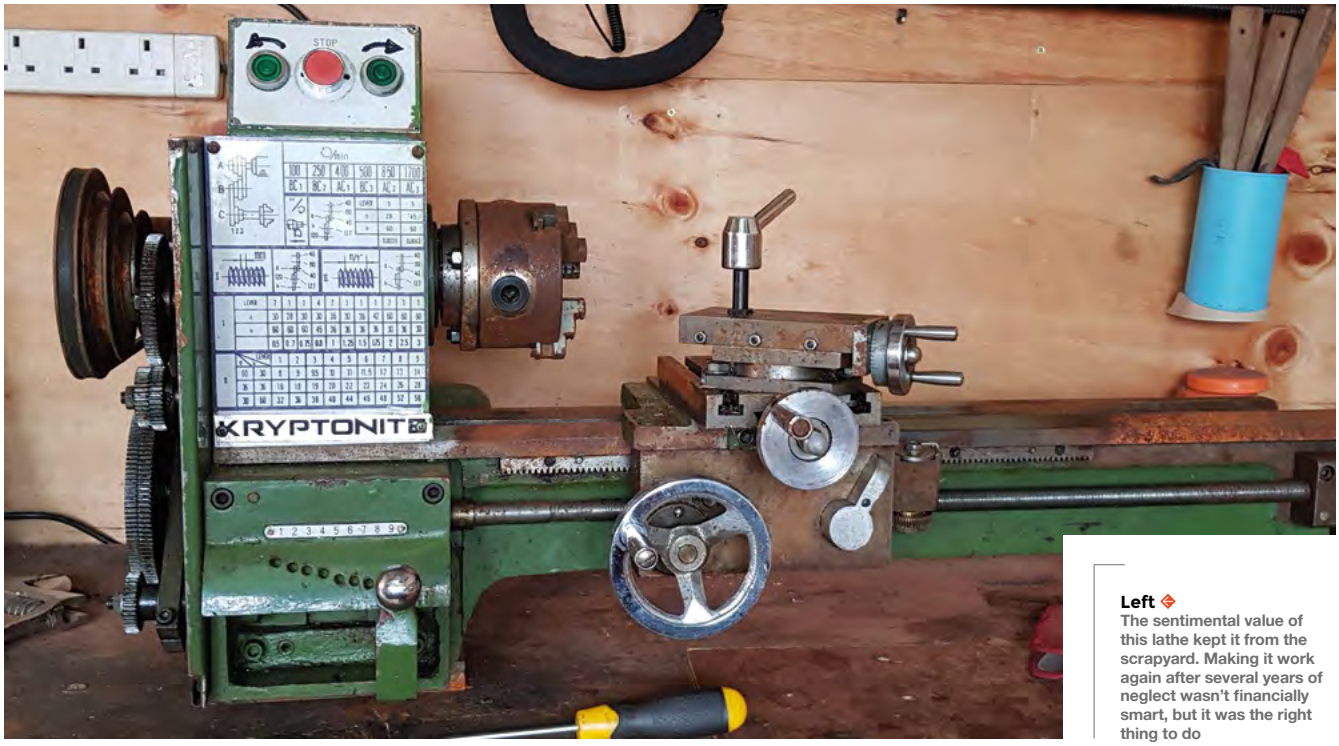
Restore an old tool to make it useful again

Dr Andrew Lewis

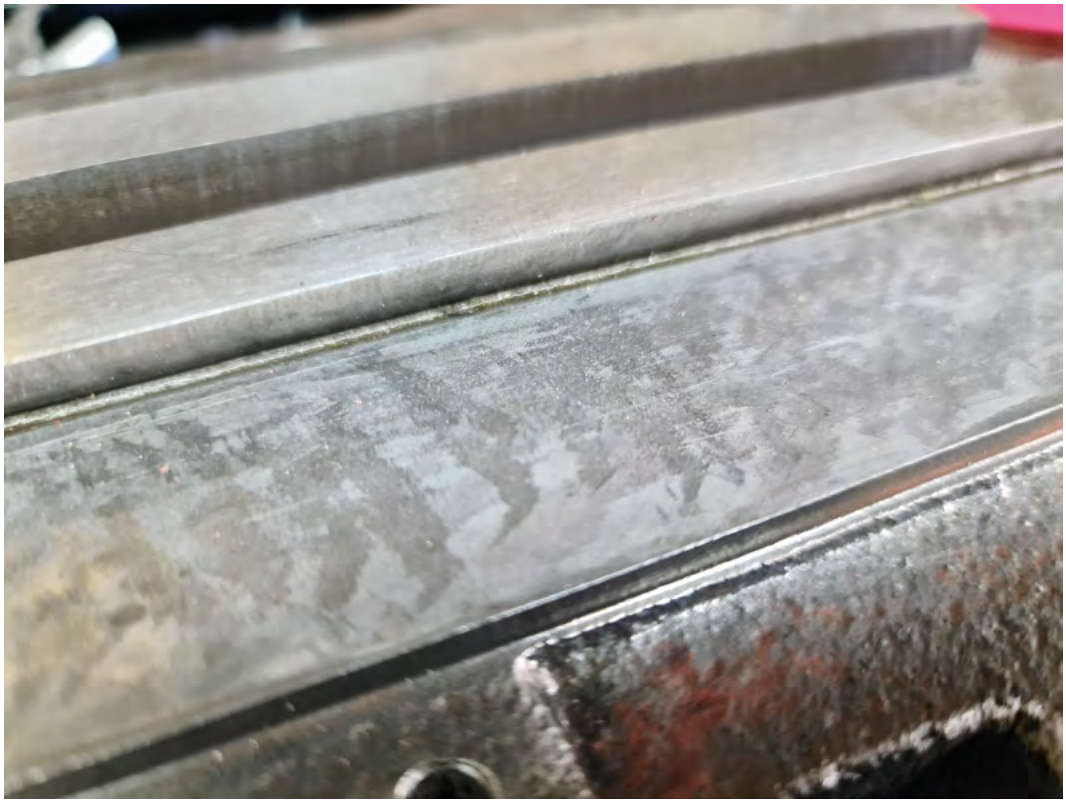
Dr Andrew Lewis is a specialist fabricator and maker, and is the owner of the Andrew Lewis Workshop.

As a professional maker, you take a pragmatic approach to the tools that you choose to work with. Time is money, and it doesn't make sense to restore or repair a second hand or heirloom machine if you're going to have to put in hundreds of hours to make it useful again. Thankfully, we don't live in a world where maximising profit is the only motivation for making, and restoring an old piece of shop equipment often pays back more than the time you put into it. You might learn new skills, get a better understanding of how a tool works, or find yourself a tool that has a more aesthetically pleasing design. You might just want to hang on to a particular tool because it has a sentimental association, and considerations like sunk cost and practicality aren't important. In this article, you'll see some of the steps taken to restore an old lathe with strong sentimental attachments, and turn it into a useful workshop tool.

The thought of restoring a complex tool like a lathe or a milling machine is daunting. It should be. You'll wonder where to start, and what you'll do if you make a mistake. The starting point is actually very simple. The most important thing you need to



Left
The sentimental value of this lathe kept it from the scrapyard. Making it work again after several years of neglect wasn't financially smart, but it was the right thing to do



QUICK TIP

Remember that old machines don't always have motor brakes. Cutting the power might not stop the machine for several seconds. Wear PPE, and be careful.

Left
These surfaces have been scraped to run smooth and level. It would be a mistake to start attacking this surface with anything abrasive

Below
If you can't immerse the thing you're trying to clean in rust remover, soak paper towels in rust remover instead. Place the paper towels on rusty areas and hold them in place by wrapping them with cling film. The cling film will help prevent the rust remover from evaporating

do is look at the machine carefully, and do a proper risk assessment. That includes thinking about the device and the environment the device came from. As an example, let's consider the lathe mentioned earlier in this article. The most obvious issue is that a lathe is very heavy. It's heavier than two people can carry comfortably, and it's not a stable load when it's being moved – heavy parts can slide about or fall off, causing damage to both people and machinery. Aside from the weight of the machine, you need to consider that a lathe is covered in oil and grease, and has been left exposed to water and potential wildlife for several years. Add toxic slurry, rust, electrical damage, and sharp edges to the list of potential dangers. Every machine will be different and will present unique challenges, but the important thing is to be aware of the dangers and how you can minimise them.

After you've figured out how not to get killed by your new project, think about the end goal of your restoration. Do you care more about the appearance than functionality, or is the paint just a coating to prevent rust? Once you've got a clear vision, you can break the project down into manageable chunks and tackle each one separately.

For a lathe, you'll need to tackle mechanics, electronics, and aesthetics. Washing the whole machine with a detergent, a degreaser, and a scrubbing brush is a great way to start. It's a messy job, but it saves a lot of problems later on. Don't worry about tackling flaking paint or rust yet; removing built-up grease, swarf, coolant, oil, and unidentified plant life is more important. Cleaning the machine will make it easier to handle, and will cut down the amount of mess that gets kicked up into the air when you're using power tools and wire brushes.

SPEED ISN'T EVERYTHING

Removing surface rust is next on the list of tasks. The fastest way to remove rust is to use a wire wheel in a drill or a grinder. For non-machined parts →

TUTORIAL

QUICK TIP

Metal roasting tins are great for keeping parts of a machine sub-assembly together. They're cheap, sturdy, and easy to clean.

Above
These dials are set up to measure deflections in the spindle of the lathe. Moving the spindle by hand showed no irregularities, and applying an axial load to the spindle caused no deflection in either direction

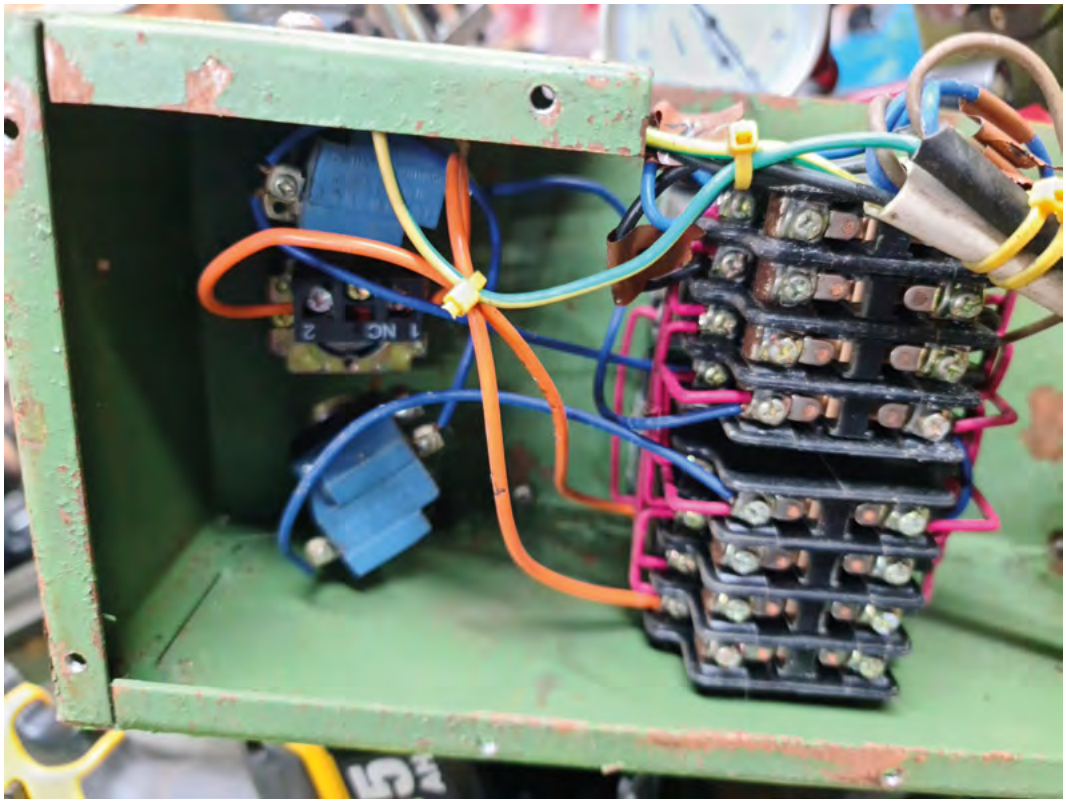
DIAL INDICATOR

Machine tools are precision instruments, and measuring small deflections in bearings and linear rails is important if you want to spot problems and fix them. Dial callipers and steel rules are far too inaccurate to make any useful measurements at this scale; you really need to use dial indicators. There are several types of dial indicator, but the most common types are probe indicators and dial test indicators. Probe indicators have a linear probe and a dial that very accurately measures the movement of the probe over a short distance. Dial test indicators measure the deflection of a lever, and correlate that deflection to a linear movement. Both types of indicator can be used for checking the working tolerances of a machine tool. It's important to remember that most indicators are designed to measure deflections around a particular axis, and tangential motion will not be accurately reported. The operation of the dial indicator is simple – place the indicator into a stand, and place the probe on the surface you are measuring. Movement along the axis of the probe will be shown on the dial. Less movement on the dial means less movement on the surface.

of a lathe, this is fine. However, the cross-slides, ways, and other finely machined parts of the lathe can be damaged by harsh abrasives. For those areas, it's much better to use a non-corrosive rust remover like EVAPO-RUST.

This is a good time to do a sanity check on your machine. Look at the machine with the rust and grease removed, and take some measurements of the critical parts. If you find significant problems like the ways of a lathe being twisted, or the spindle being bent, you might need to think hard about whether you're going to carry on restoring, or cut your losses. The truth is that pretty much any problem can be fixed given enough time and money, but consider whether you want to throw that money down or look for another machine. Some problems like excess backlash in the travel of a lathe axis might seem like a big problem, but there are ways of reducing this, and it's important to remember that backlash doesn't generally affect accuracy as long as you account for it when you're operating a machine. More general looseness in an axis might be caused by poorly adjusted, worn, or missing gibs, which can be fixed easily enough. Worn bearings are usually easy to replace or adjust. Most lathes (except for some mini-lathes) will have tapered roller bearings in the headstock. These bearings need to be preloaded with some compressive force to keep them from wobbling loose in their casing. It might be that you can simply tighten up the bolts on the spindle to fix any problems you're having.

By now, you should have a good idea of what needs to be done to get your machine back into good mechanical working order, and you can move on to checking electrical connections. Finding electrical faults is a complicated topic and won't be covered in detail here, but there are a few simple tips that can help you find most problems without plugging the machine in. Firstly, use a multimeter



to check the chassis and any earthing points are actually connected to the earth wire. Also, check that current-carrying wires do not short to the earth pin. Do a visual inspection of wires. Are they corroded at the connectors? Has the insulating sheath been worn away or become brittle with age? Do switches click on and off as expected? Do motors have the expected resistance around their coils? Do any components look burnt, melted, or damaged? Do any boards look corroded? Once you have done those checks, and are happy that nothing seems to be imminently about to explode, you can consider plugging the machine in to see what happens.

> "The truth is that pretty much any problem can be **fixed given enough time and money**"

Everything done so far has been relatively superficial, but the next stage is to break the machine down into smaller parts that can be worked on separately. For a lathe, this means removing the chuck and adapter plate from the headstock, and removing the headstock itself, along with the →

THREAD BARE

One part of a machine that can pose a real challenge is screw threads. Unless you're very lucky, you'll probably need to replace a few missing bolts or screws. If you're particularly unlucky, you'll find that some of the screws or bolts are corroded into place or stripped out and the threads are damaged. To loosen stuck bolts, you can start by applying a generous spray of penetrating oil and wait for it to do its magic. If you're still not able to loosen the bolt after 24 hours, it's probably time to think about using a MAPP (methylacetylene-propadiene propane) or a butane torch. Heat the bolt for a minute or two, and then try to move it with a wrench. If you don't succeed, try heating the bolt for longer. Then let the bolt cool, and try again. If it's still stuck, you might need to drill the bolt out and then re-tap the thread using a HeliCoil or other thread repair tool. HeliCoils are specifically designed to repair broken threaded holes using a special drill, tap, and insert. Once fitted, a HeliCoil makes a strong and permanent repair to any damaged thread.

If you do manage to get the old bolt out, you'll need to figure out the type of metric or imperial thread used before you can replace it with a new bolt. You might be tempted to clean and reuse the same bolt, but that can be a bad idea. Bolts deform when they are tightened, and a stretched bolt is a weak point that will fail at some point in the future. It's a much better plan to use a thread gauge to find an appropriately sized replacement bolt whenever possible.

Above
The electronics for the lathe mentioned earlier failed the basic electrical tests. The wiring was corroding and brittle, switches were failing to engage properly, and the bushes on the motor were very worn. It was easier to replace everything with an industrial sewing-machine motor and speed controller than to attempt the repair. However, the original parts have been kept so that the conversion could be reversed in the future. The new motor has the advantage of a speed controller, but this advantage comes at the expense of some overall power at low speed

tail-stock, carriage, cross-slide, and power feed. Each of these component parts needs to be cleaned and restored, and then reattached to the lathe. It's best to start the restoration with the largest part of the machine, so that as other parts are completed, they can be reattached to keep them safe and reduce the amount of space needed to store everything. The process from this point is very simple. Take each part, degrease and clean it, disassemble it, and remove any rust. Reassemble the part and paint it, then lightly oil any exposed metal areas and reattach the part to the main machine. Parts like a lathe chuck can be submerged in degreaser and then rust remover for 24 hours before they're disassembled and cleaned with a Scotch-Brite pad and cotton cloth.

> Reassembling the machine isn't the end of the restoration process. **Precision machines need to be calibrated before they can be used**

Reassembling the machine isn't the end of the restoration process. Precision machines need to be calibrated before they can be used. Calibration will be different for every machine. For a lathe, you will need to check the ways are level and the headstock is trammed in properly. You'll also need to make sure the cross-slide is perpendicular, the gibs are adjusted, and any belts are tensioned properly. There are plenty of guides on YouTube on how to set up a lathe properly, and browsing through channels like This Old Tony and Blondihacks should give you all the information that you need to get your equipment running right.

FINISHING TOUCHES

Paint is a remarkably difficult thing to deal with when restoring a tool. Most importantly, you should check to see whether any paint or filler you're looking at contains lead. If it does, you need to take appropriate precautions when removing and disposing of the old paint. The best way to check this is to use a lead paint testing kit, which is available from most DIY and online stores. The kit usually includes a crayon or swab that changes colour in the presence of lead. It's a good bet that most machinery made in the 1970s or earlier will have lead paint on it somewhere. It's less likely, but still possible, that machinery from the 1990s will be covered with lead paint, or will have a red lead primer. In fact, red lead and other leaded paint can still be used today provided that you have a specialist reason for using it.

If you're working on a metal casting, there will probably be a thick layer of primer and filler on the metal to make everything look nice and smooth. If you remove it, you're going to need a lot of car body filler and sandpaper to get that smooth look back. You don't always need to remove every bit of paint, and some people prefer to see the original paintwork, even if it is peeling off in places. You can protect the existing paintwork and metal using waxes or polishes if you'd rather not completely replace the original, or you could just keep the existing paint and add another primer and top-coat.

You need to choose your paints carefully when you're working with machine tools. It's not unusual for a milling machine or lathe to come into contact with solvents that will remove ordinary paint. A good industrial enamel like Tractol should be tough enough for most machine tools. Take note that enamel paints like Tractol have a curing time as well as a drying time, and while the paint is dry to the touch, it might not be at maximum strength for a couple of weeks.

Left
This isn't the ideal environment for painting with coach enamel. Historically, the painting room would be out of bounds to everyone except the painter, and the room would be scrupulously clean. The tradition of painting while wearing nothing but a loin-cloth and covering the whole body with linseed oil was not observed

Far left
Paint stripper is the quietest and most manageable method of paint removal, and it doesn't really aerosolise particles in the same way that sanding or burning with a blow-torch will. Apply paint stripper liberally to the machine, leave for the recommended time, and scrape the paint away into a waste container with a decorator's knife or scraper. Any small missed areas can be dealt with using wire wool or a rotary brush

Left
If you are going back to bare metal, consider using an etching or epoxy primer before your regular paint primer and filler. An etching primer adheres much more effectively to bare metal than a regular primer, and will give you a more durable finish

Part 01

Build an arcade machine: Get the parts

If you've ever wanted to build your own arcade machine, here's your guide. This month: the parts you'll need, how to choose them, and where to buy them

MAKER

K.G. Orphanides

K.G. is a writer, maker of odd games, and software preservation enthusiast. Their family fully supports the idea of an arcade machine in the living room.

@KGOrphanides

Over the coming months, we'll go through the process of sourcing, building, connecting, and installing a Raspberry Pi-based arcade cabinet.

While you can restore and convert a former JAMMA cabinet for use with Raspberry Pi, or build a cab entirely from scratch, we'll be taking the flat-pack route. This lets you build the cabinet of your dreams relatively easily, somewhat cheaply, and without recourse to full-on home woodworking.

This tutorial series will use an LCD screen due to the inconvenience of sourcing and potential issues with installing a CRT model, which carries the risk of a dangerous electric shock if not correctly discharged.

01 Choose your cabinet style

If you're after a classic upright one- or two-player cabinet, then you'll want either an all-in-one model or a 'bartop' cabinet with a pedestal or stand. Bartop cabinets can also be bought without the optional stand and placed on a table.

Flat 'cocktail' or 'coffee table' style cabinets are available in models for between one and four seated players and often use a vertically oriented screen, which can be split by software into two horizontal views for multiplayer games.

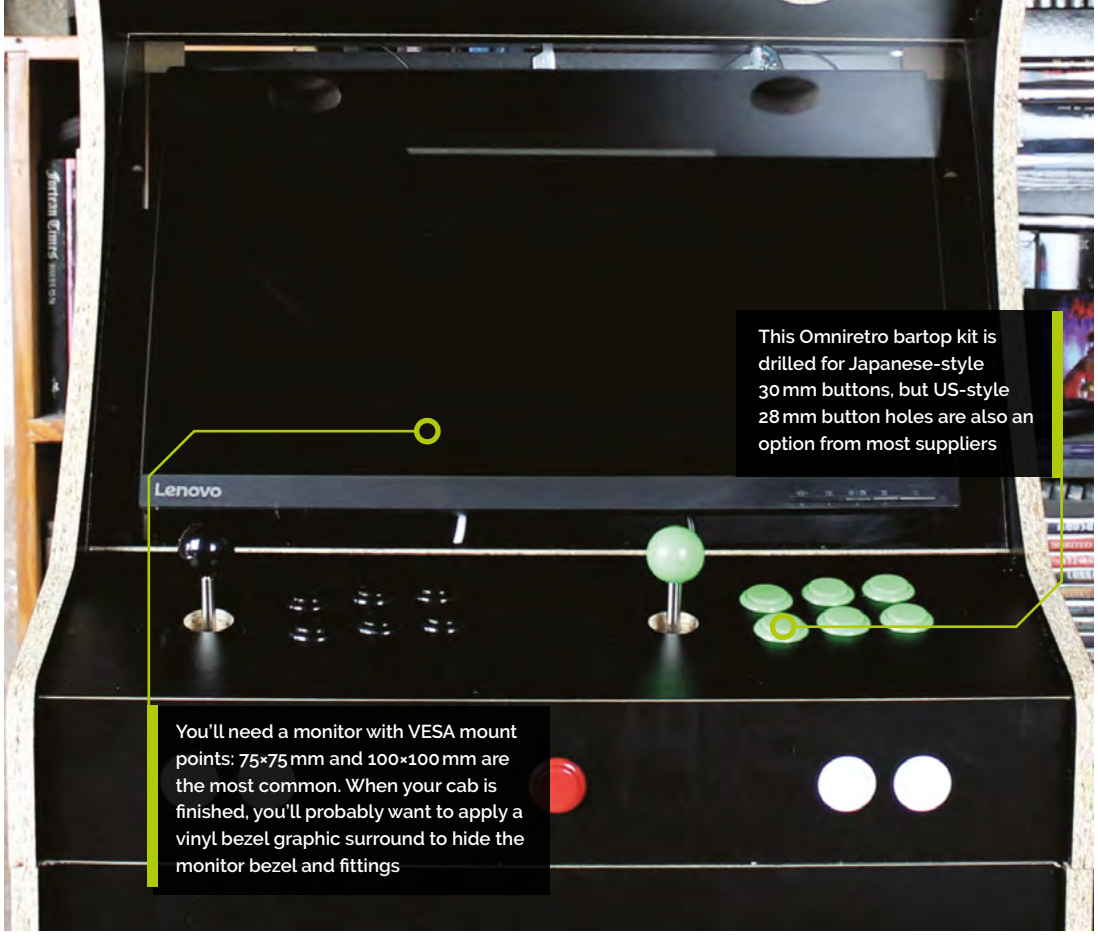
Other models include seated upright cabinets (often designed to take very large screens), angular tabletop models, and mini-bartops with 10-inch displays for those short on space.

02 Big screen glamour?

The size of your screen dictates the size of your cabinet, and vice versa. Before you start shopping, work out where you want the cabinet to live, and take height, width, and depth measurements.

If you're working with a 19-inch monitor, you'll likely get a bartop cab that's a little under 50 cm wide. This is the most practical choice if available space is limited. A 22-inch screen translates to a cabinet of a little under 60 cm, and a 24- or 25-inch screen means a cabinet width of a bit under 65 cm. You're generally fine fitting a smaller screen in a larger cabinet, but the end result won't look quite so polished.

Check the internal measurements of the cabinet against those of the monitor, including its bezel.



Top Tip

Button positioning

We're going with a six-button Japanese-style layout. Check out **magpi.cc/joysticklayout** to see some alternatives.

03 A good fit

Depending on the era of games you want to play, a large 1920×1080 widescreen display may not be the most authentic choice, but it is the most flexible, and modern emulators handle HD displays well.

Most cabinets have a VESA mount, usually in the form of a monitor support bar drilled for 75×75 and 100×100 mount points. Make sure your monitor has mounting points that match.

Finally, ensure that your monitor will work with Raspberry Pi: anything with a standard HDMI input should be fine, but older DVI and VGA displays require inconvenient adapter arrangements.

04 Materials

Self-assembly cabinets are usually made in MDF, but laminate, melamine, and veneer finishes are also widely available.

MDF swells badly if exposed to water, so if you're going to have drinks anywhere near your cabinet, a water-resistant finish is strongly recommended. If you buy an untreated MDF kit, apply and sand down between multiple coats of an MDF-specific solvent-based primer, then paint it to your heart's content, ideally with oil-based paint.

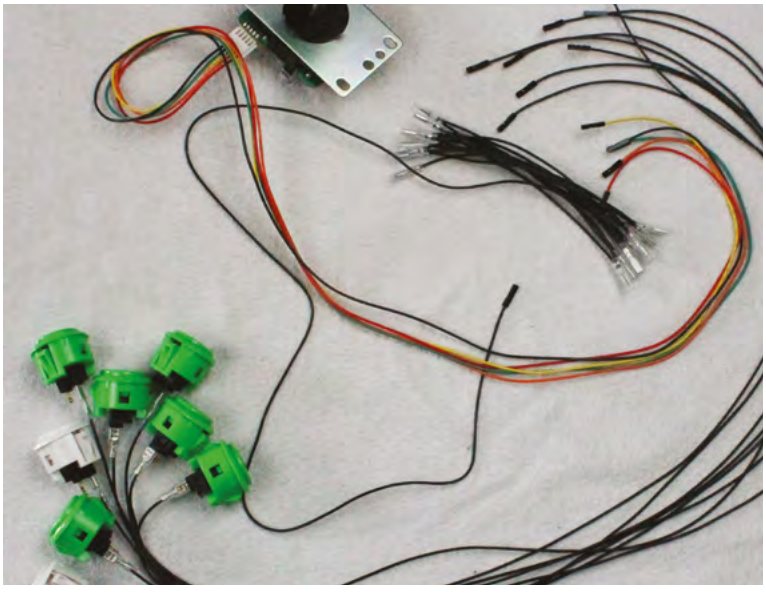
18 mm MDF is common, but you'll find cabinets in anything down to 10 mm for budget models. 18 mm or thicker construction materials may require a longer shaft or extender for your joystick. If in doubt, talk to the kit's supplier.

05 Finish and decoration

Regardless of the materials used, you'll probably want some plastic edging strip. This plastic trim helps to protect the edges of your cabinet, makes it easier to clean, and looks a lot more professional than exposed MDF edges.

Two types are popular. T-Molding is more secure but requires a slot to be cut for it to clip into – some DIY kits have ready-cut slots for this purpose, but budget models frequently do not.

U-Molding just clips over the edge. Cabinet makers will usually tell you how much moulding →



You can get kits containing all the joysticks, buttons, and connectors you'll need; just make sure your button and cabinet hole sizes match

A variety of compact bus- and mains-powered amp and speaker kits are available: this one takes power from the USB port and audio from the 3.5mm port

their kit will need and can usually supply the required quantity and type of edging.

Many arcade cabinet suppliers also sell a range of decorative and protective graphical vinyl sticker wraps. These should be applied with care to an appropriately finished surface (check with the sticker manufacturer for any finish requirements).

06 A giant screen protector

To protect your screen and create a flush finish, you can – and should – opt for an acrylic (polymethyl methacrylate, also known as plexiglass) screen protector. Again, this is something most self-assembly kits are designed to take and the majority of retailers will happily sell you one as either a standard part of the kit or an optional extra. Make sure you do opt in, as cutting your own plexiglass to precise dimensions can be a pain. Toughened glass and UV-resistant polycarbonate can also be used. You may need to add some standoffs to stop front monitor buttons being pressed by the screen protector.

07 The marquee club

Also included in kits as a matter of routine is a strip of acrylic for your cabinet's top marquee. You'll probably want to get a backlight-ready vinyl marquee (available from print shops, arcade suppliers, and on Etsy) to stick to this, but you could also decorate your own.

Sample shopping list

Here is an illustrative price list. The prices include VAT but not shipping or additional costs.

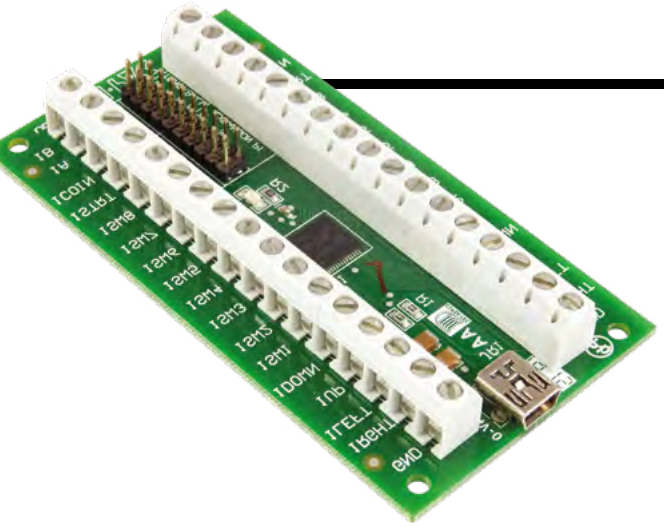
Item	Price
24-inch LCD monitor	£125.00
Bartop cabinet	£170.00
Bartop stand	£100.00
10 m T-Molding	£25.00
Acrylic control panel guard	£25.00
Two-player USB joystick + button kit	£70.00
Amp, speaker & cover kit	£25.00
Amp power supply	£12.00
Printed marquee	£6.00
LED strip lighting	£15.00
Molex power adapter for LEDs	£15.00
5-way plug bar	£15.00
TOTAL	**£603.00**

While you're at it, you may wish to get acrylic or metal panels to surround your buttons and joystick. These can be decorated, and protect your cabinet's surface, as well as providing a smoother feel. Button layouts tend to be standard, but these should ideally be bought from the same supplier as your kit for the best fit.

08 Raid the button tin

We'll be building a cabinet with an eight-way joystick and six 30 mm buttons, plus Start and Select buttons, for each player. A variety of alternative sizes and brands are available, with Sanwa perhaps being the most recognisable. You can order a cabinet with holes for extra side buttons if you're into digital pinball.

An easy cross-platform connection solution is a USB arcade encoder. Models by Zero Delay and Xin-Mo are popular, but the I-PAC 2 keyboard encoder has slightly lower latency.



If you want to use USB, the Ultimarc I-PAC 2 encoder is a popular choice that'll work with most computers. Check out **magpi.cc/ultimarcgit** for advanced configuration

09 Pick a driver

You can connect controls to Raspberry Pi's GPIO, using either the Adafruit Retrogame (**magpi.cc/adaretrogame**) or mk_arcade_joystick_rpi (**magpi.cc/mkjoystick**) drivers – we'll be using the latter.

Arcade joysticks generally use a five-pin JST connector, while non-illuminated buttons each have a pair of quick-connect spade connector fittings, one of which must go to ground. Spade to DuPont GPIO cables are uncommon, but can be bought either individually or as part of a kit from specialist retailers such as SmallCab. Illuminated button kits are available with an extra external PSU.

> LED strip lighting is a popular choice for marquee panels

10 The sound of success

It's a good idea to order your cabinet with a couple of pre-drilled speaker holes and covers to go over them. The most common option for audio is an externally powered stereo amp, connected to Raspberry Pi's 3.5mm port, and 10cm/4-inch speakers, but USB-powered kits are also available. If you have one lying around, you could also consider mounting a compact USB sound bar behind your speaker grilles.

11 More power, Igor!

A major advantage of this kind of arcade machine build is that there are no internal power supplies to bother with. There's enough space to mount a plug bar inside most cabinets, and you can use this to power the monitor, Raspberry Pi, and any extra transformers required for lights or speakers.

Where to buy

There are a number of UK and EU retailers specialising in self-assembly arcade cabinets and components. While it's easiest to get everything in one place, you have to mix and match for specialist components such as GPIO-compatible wiring looms.

- **Arcade World UK** – arcadeworlduk.com – supplies a wide range of kits and components; discount codes available for most non-furniture items
- **Bitcade** – magpi.cc/bitcadekits – UK arcade machine maker that also supplies kits
- **Omnireto** – omniretro.com – Spanish firm with a notable budget range
- **Rockstar Print** – rockstarprint.co.uk – custom marquee and wrap printer
- **SmallCab** – smallcab.net – French supplier of arcade kits and hardware including GPIO-friendly wiring

LED strip lighting is a popular choice for marquee panels, but you'll need to buy a Molex power adapter to go with it, or repurpose a PC power supply. You can run a plug lead out of the back or optionally install an external power socket and switch, if you're comfortable with simple electrical wiring.

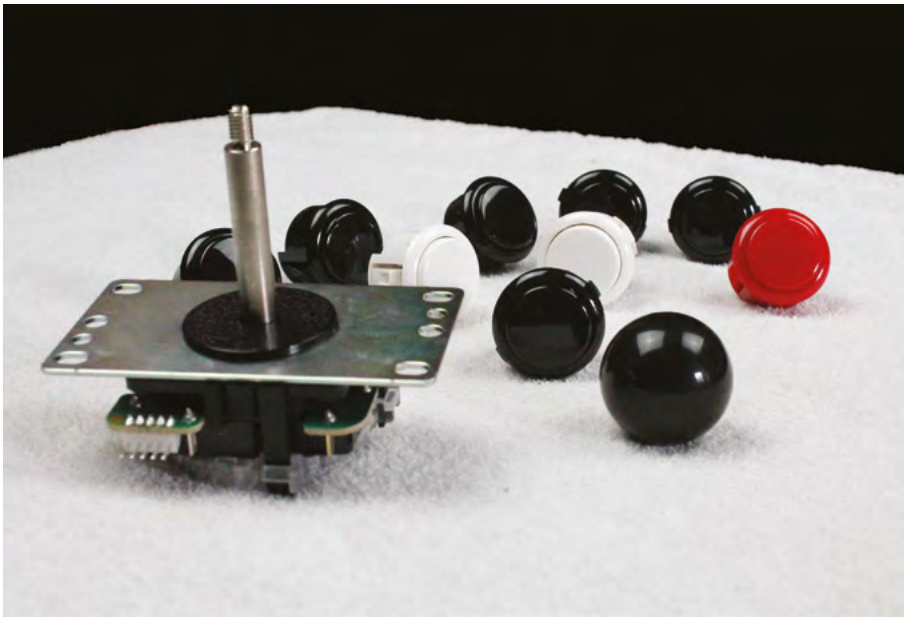
12 Room to build

Before you start ordering, consider not only the space you have to house your cabinet, but also how much room you have to build in. Don't get an untreated MDF cabinet unless you have a large, ventilated (and paint-resistant!) space where you can apply primer to each part, as well as appropriate eye and breathing protection.

Warning!
Paint and dust

When sanding, sawing, or painting, be sure to use appropriate eye and breathing protection in a well-ventilated space.

magpi.cc/diysafety



You'll want to source durable joysticks and buttons for your arcade machine

TUTORIAL

FreeCAD: add-on workbenches and interlocking parts

Use add-on workbenches to make interlocking parts

Jo Hinchliffe

@concreted0g

Jo Hinchliffe is a constant tinkerer and is passionate about all things DIY. He loves designing and scratch-building both model and high-power rockets, and releases the designs and components as open-source. He also has a shed full of lathes and milling machines and CNC kit!

After looking at how we install additional workbenches, we will focus on using an excellent workbench called 'Laser Cut Interlocking' or 'LCInterlocking', which offers some interesting and useful tools for those working on designs destined for a laser cutter or CNC router.

To explore the amazing array of add-on workbenches, you'll need to be connected to the internet. You can view the available add-on workbenches from any workbench in FreeCAD by simply clicking Tools > Addon Manager. The Addon Manager will then check all the available add-on workbenches – it may take a few seconds for the list to appear as it checks it's up to date. You should end up with a list that looks like **Figure 2**.

Before we install the workbench we'll be using in this article, scroll around the list. If you highlight a workbench on the list, information about it will appear on the right-hand side of the window. It's incredible what workbenches there are! Like all of FreeCAD, the add-on workbenches listed in the Addon Manager represent many thousands of hours of voluntary contributions by FreeCAD community developers, covering a vast array of subjects and interests. From aeroplane design tools to computational fluid dynamics to 3D print slicing engines – there's a lot to explore. Installing a workbench is as simple as selecting it in the list and then clicking Install. Behind the scenes, FreeCAD connects to the workbench code repository online and downloads and installs the latest version. It's then simple to update a workbench when new features are released. It's just a case of clicking 'Install/update selected' on the relevant workbench in the Addon Manager.

The workbench we are going to look at is called 'LCInterlocking' – it's described as the 'FreeCAD Laser Cut Interlocking Module'. Go ahead and click install. Once installed, the Addon Manager will prompt you to close and restart FreeCAD to finish the installation. Once FreeCAD has restarted, let's create a small project to explore the tools on this new workbench.

The LCInterlocking workbench has tools that allow a collection of parts in FreeCAD to be pulled apart and laid out flat. It then has tools that enable us to create a two-dimensional projection of the part shapes that we can export in various file formats (DXF, SVG, etc.). While it's predominantly, as the name suggests, aimed at laser cutting, it also can

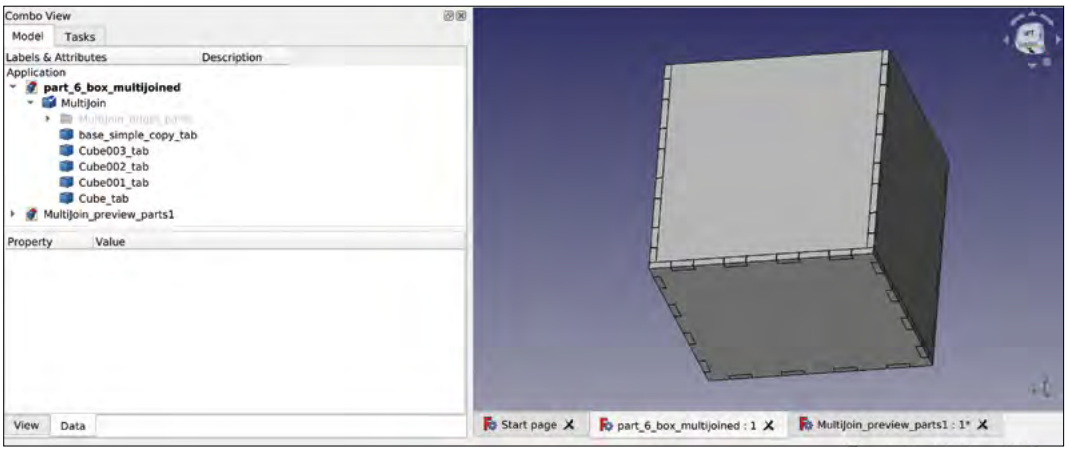


Figure 1
Our box, complete with automatically generated interlocking tabs, and ready to be flattened and exported from the LCInterlocking workbench

Figure 2
The Addon Manager has an astonishing list of amazing workbenches with toolsets for all kinds of projects in FreeCAD

be useful for other processes, such as preparing files and objects to set up toolpaths for CNC routing. The 'interlocking' part of the LCInterlocking name hints at another handy feature: the workbench has tools that can automatically create tabbed joints in objects where one part has tabs and the other part has receiving slots.

To explore these tools, let's create a collection of parts that form the base and sides of a simple box. In the Sketcher workbench, draw a sketch in the XY plane of a square that is 100 mm on each side, and let's constrain it with the lower-left corner onto the 0,0 point of the axis.

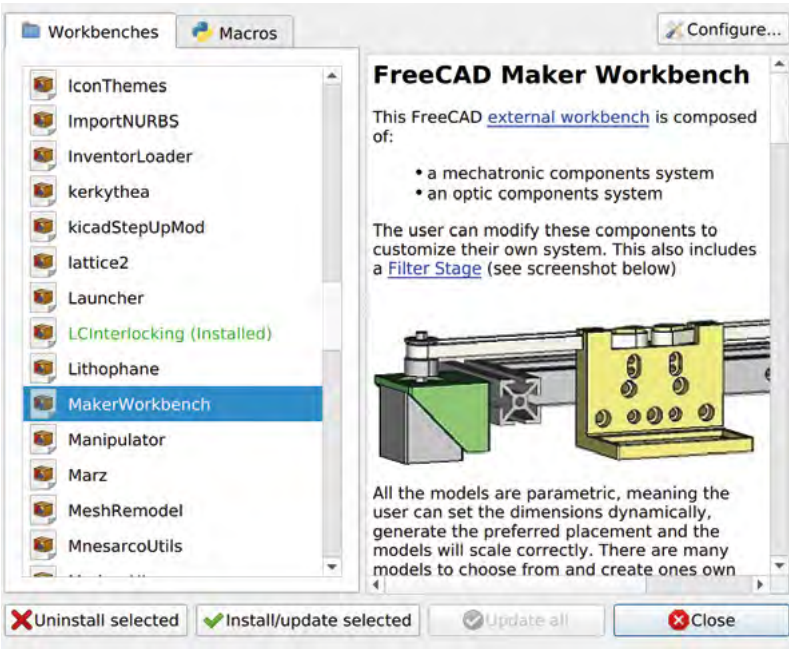
> From aeroplane design tools to computational fluid dynamics **to 3D print slicing engines – there's a lot to explore**

Having drawn the box sketch, use the 'extrude/pad' tool on the Part workbench to extrude the sketch to a thickness of 3 mm. Using 3 mm means we can imagine we are going to laser-cut our tabbed box out of 3 mm plastic or plywood. We could make this base part in a much easier way – namely, we could use the 'Create a cube solid' tool. However, as an example, we wanted one part to be made from an extrusion as we need to treat extruded parts a little differently when we get to the LCInterlocking workbench. We can use the cube generator to create the sides of our box, however. First, let's make a cube by clicking the 'Create a cube solid' tool. Double-click the object in the Combo View file tree and then change its dimensional parameters. Let's make the length 100 mm, height 97 mm, and width 3 mm. Next, let's right-click this cube in the file tree and then select Transform – use the arrows in the preview window to bring the side up on the Z-axis by 3 mm so that it sits exactly on top of the base we made earlier (**Figure 3**, overleaf).

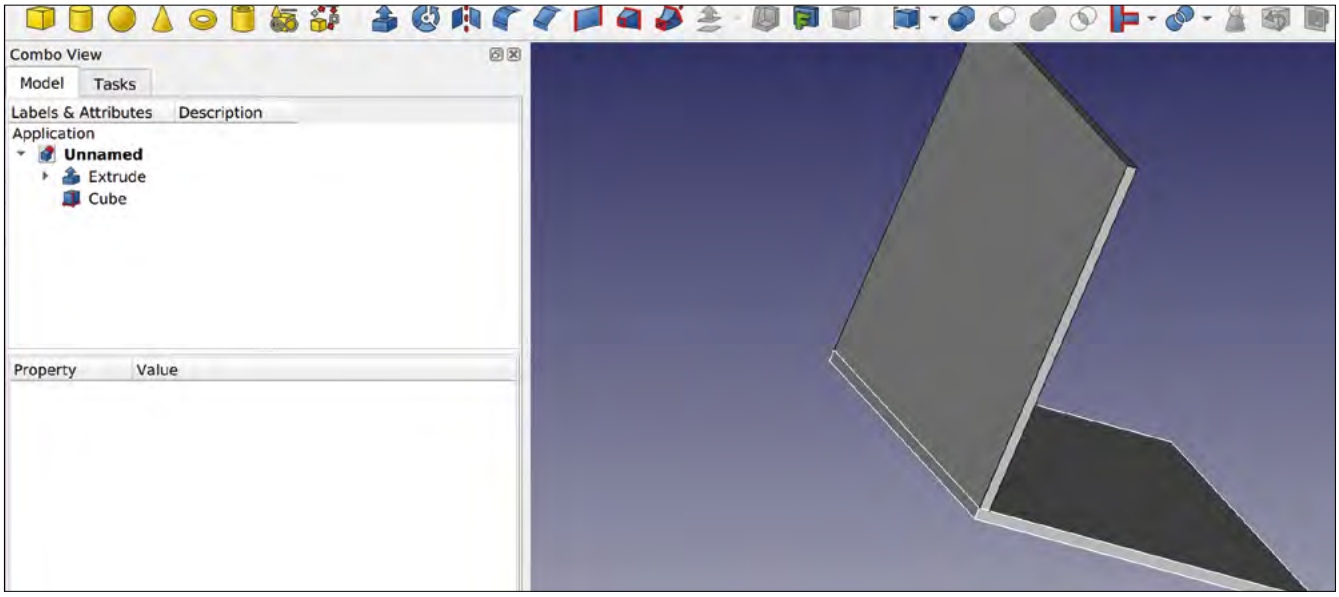
Make the opposite side of your box by either repeating the process and moving it to the opposite side, or simply copy and paste and move a duplicate of the first side. Next, repeat the process to make the final two sides of the simple box, making the height 97 mm, width 94 mm, and length 3 mm. Move these in a similar way using the 'Transform' →

YOU'LL NEED

- **Computer with FreeCAD 0.19 and Inkscape installed**



TUTORIAL



QUICK TIP

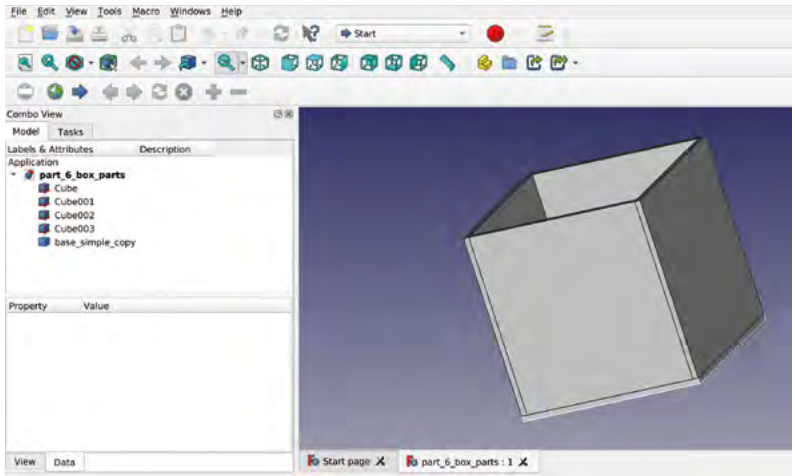
Since we started this series in issue 37, FreeCAD has changed how you move a part on the Part workbench; you now right-click the part in the file tree and then select Transform.

Figure 3
Adding sides to our extruded base using the 'Create a cube solid' tool

Figure 4
Our simple box base and sides, created and aligned on the Part workbench

tool to move these sides into the correct positions lined up with the edges of (and sat on) the base, as in **Figure 4**.

Before we move over to the LCInterlocking workbench, we need to convert the base into a simple part. LCInterlocking prefers to work with parts that are simple objects rather than parts that appear as a stack of operations in the file tree view. We could just draw the base with a cube, but if you're working with more complex shapes, this might help you remember to convert parts into simple copies before opening the LCInterlocking workbench. So, before proceeding, highlight the base part in the file tree, and click Part > Create a Copy > Create a Simple Copy. Delete the original extrusion and sketch in the file tree to keep things simple and clutter-free. It's a good idea to right-click on the simple copy of the base and rename it to something recognisable, such as 'Base' (**Figure 4**).

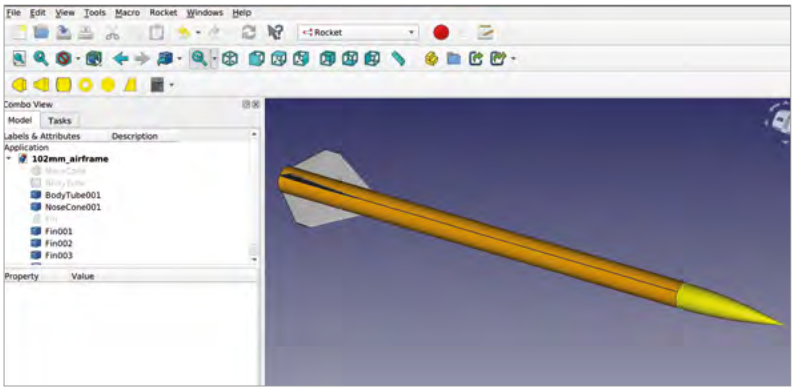


Next, let's move to the LCInterlocking workbench by selecting it from the drop-down menu. The first task in the new workbench is to create some tabs and slots to ensure strong joints in the box.

To get started, highlight the five parts that form our open box in the file tree, and then click the grey 'Interlocking' tool icon. In the dialog box that

> "Dog bone holes are where the machine is instructed to **cut a little further into the corners on both axes**"

appears, you will see a button that says 'Add parts'. Click this button and you will see the five selected parts appear in the window (**Figure 5**). This list of parts in the dialog box is similar to the file tree in the combo view in that you can highlight anything in the list – you can press the **SPACE** bar to toggle visibility. This is very handy for the next task. We need to tell the 'Interlocking' tool which faces of our box are going to interlock. Let's begin with the faces that will form the tabs that extend into the base. Select the 'Base' part and then press the **SPACE** bar to make it disappear – do this for three of the sides. Next, select one of the thin faces on the remaining side of the box, making sure it is the face that is touching the base when the base is visible (**Figure 6**, overleaf). With that face highlighted, click the 'Add faces' button in the dialog. You should see the added face highlighted in the list, filed under the part that it is attached to. If you scroll down in the



ROCKET WORKBENCH

One add-on workbench we wanted to give a special mention to was the Rocket workbench. The Rocket workbench is in active development, and contains tools that help you design rocket parts parametrically. It has an exciting road map ahead that includes features like importing files from other rocket design environments such as OpenRocket, RockSim, and RASAero. This will open up great possibilities for rocket design, flight simulation, the realisation of parts via 3D printing, CNC milling, and more. We featured rocketry, including a tutorial on OpenRocket, back in issue 12 if you're interested in getting started with model rockets and rocket design.

dialog box, you will see a menu relating to that face. In this, you can input the details of the tabs that you wish to generate on this face.

Add the number of tabs – you can make your own choices, but we went with four. We set the 'width of tabs' to 10 mm, 'shift' was left at 0.00, and the 'interval ratio' was set to 1.00. You'll see there's a couple of checkbox items: 'Dog bone hole' and 'Tab dog bone hole' (**Figure 7**, overleaf). Dog bone holes are a method often used in parts that are CNC routed to get rid of a problem created by the fact that most router tools are round. If you send a round end mill cutter along a path to cut a 90-degree internal corner, you are left with the radius of the tool in the corner of the cut. If you are cutting tabs into material in this way, then the tabs won't fully seat into the slots due to this excess material. Dog bone holes are where the machine is instructed to cut a little further into the corners on both axes; this slight overcut creates two small, round cuts in a corner that look like a stereotypical dog's bone, giving the process its unusual name.

We deselected both of the checkboxes as we don't need them for this example.

Having input the tab parameters, scroll back up to the top of the interlocking dialog box and click the 'Preview' button. This will launch a new tab in the preview window, and you should see that our box appears (regardless of which parts are visible or invisible in our other tab). If we look at the joint between the base and our tabbed face, there are now four tabs interlocking into the base (**Figure 8**, overleaf). We can now repeat the above process of selecting and adding faces to the interlocking dialog and configuring tabs. Working our way through the model, we added tabs to the other →

QUICK TIP

The approaches we use to draw parts for our box are techniques were covered in the first and second parts of this series, starting in issue 37.

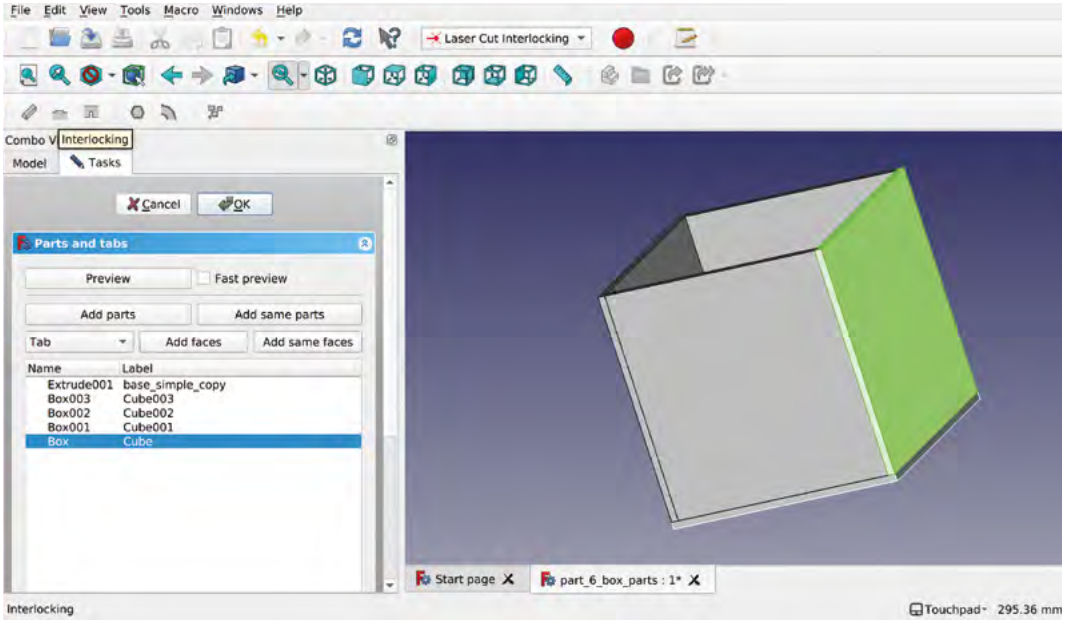


Figure 5
Adding the parts of our box to create tabs and slots using the 'interlocking' tool

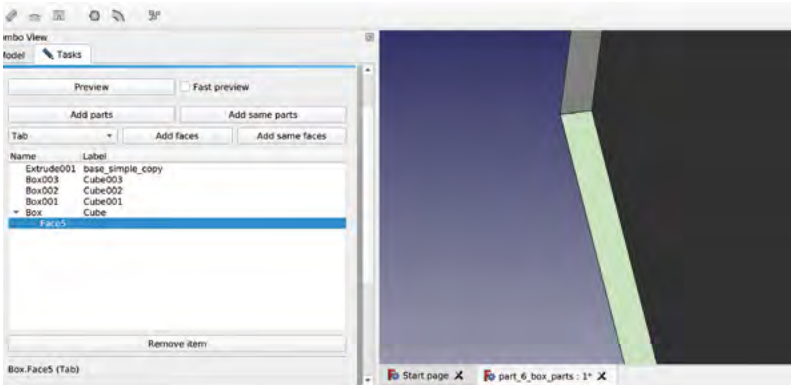


Figure 6
We toggled the visibility so that only one side was visible, then selected the face of that side that touches the base, and then clicked the 'Add faces' button

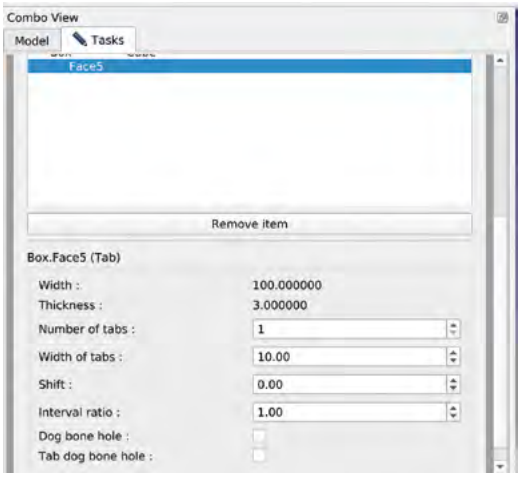


Figure 7
Adding tabs to a face is as simple as inputting a few options about the number and size of the tabs

Figure 8
Previewing the added tabs in a separate preview window to check they are correct

three faces that interlock with the base, and then added tabs to two of the side panels to create tabbed joints on every interface of our box.

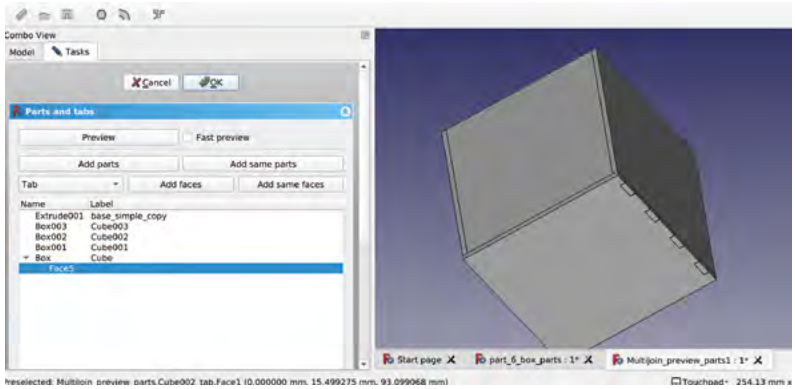
Once we are satisfied with our added tabs in the preview, click the 'OK' button to apply the interlocking tool to the parts. In the Combo View under our main document, there is now an object called 'MultiJoin' (**Figure 1**). Within this file tree, there are now parts that are the tabbed version of our original parts, and there is also an invisible folder that contains the original non-tabbed parts. The preview tab also stays available – you can save this as a separate project if you like; however, we can close the preview tab without saving it for this example.

The next task is to apply the 'Export' tool to the tabbed parts we have generated. Rather than actually export a file, this tool explodes our box apart, lays the parts out as flat parts, and automatically creates a drawn shape projection of the parts. In the file tree, select all the new tabbed parts we created under the MultiJoin object, and then click the 'Export' tool icon (**Figure 9**).

Once again, FreeCAD will open a new preview window tab – this will contain all the parts of your box separated and laid out on a single plane. You will also see some new objects in the file tree if you rotate the plane in the preview, as we have in **Figure 10**. These are the 'Shape2DView' objects –

QUICK TIP

As in all the other parts of this series, we have described tool icons using the text that appears as you hover the cursor over them.



line projections of the outline of your parts. While this might initially seem confusing, having both versions of the parts is incredibly useful, depending on what you would like to do to create the parts.

We wrote a piece (*Designing parts for CNC milling*) on FreeCAD outside of this series in issue 25 about creating toolpaths with FreeCAD version 0.18.4. Since then, the Path workbench has had a massive amount of work carried out by the community, with many new features and advanced milling approaches. As such, we would like to revisit the newer versions of the Path workbench in a separate article. However, for now, it's true to say that if we wanted to cut the parts for our tabbed box on a CNC router, we could easily use the Path workbench to create toolpaths using the 3D objects that the LCInterlocking workbench export tool has laid out.

Using the Shape2DView parts, however, we can create 2D output files that are suitable to cut this design using a laser cutter. First, in the file tree, let's toggle the visibility of the 3D parts so that we just have the Shape2DView objects visible in the preview. Next, highlight all the Shape2DView parts in the file tree, and then click File > Export. In the export dialog, select a location to export to, and then from the drop-down menu, select 'Flattened SVG' as the file type. Give your export a name followed by '.svg' and then click the Save button.

You should now have saved an SVG file containing a vector line drawing of the parts we created. The beauty of an SVG export is that we don't lose any dimensional accuracy, and we can open this file for editing in many graphics packages. We are huge fans of the free, open-source Inkscape package here at HackSpace magazine, so let's take a quick look at our SVG using that.

Find your file and open it in Inkscape. Note that you can select and move each of the parts individually. This is excellent, as often we will

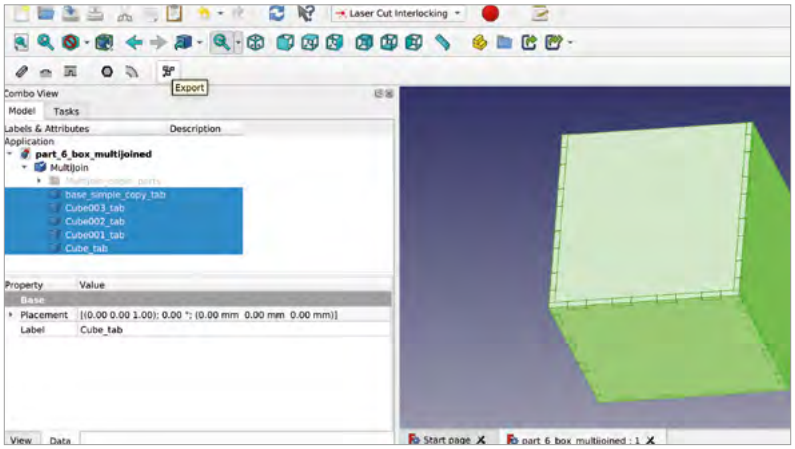


Figure 9
Selecting the newly interlocking tabbed parts, and clicking the 'Export' tool

QUICK TIP

As a reminder – all through this series, we are using version 0.19 of FreeCAD.

want to move parts around on an Inkscape canvas to arrange our components so that we are as economical as possible when cutting the parts on our laser cutter. That might be the only edit you need to make, but often you may need to customise the SVG file to work with the settings of your laser cutter. We can think of a couple of different laser cutters that we have access to that have slightly different requirements. One needs any line that the laser is going to perform a cutting/vector action to be a 'hairline' thickness of 0.0254 mm or thinner; another machine isn't worried about the thickness applied to a stroke on a path but wants all cut lines to be red in colour. These changes are trivial to make in Inkscape. Of course, as a fully-fledged vector graphics package, Inkscape can also be useful to embellish your parts with decorations that the laser cutter will engrave/raster; again, this is simple to realise in Inkscape, as we have done in **Figure 11**. Having made our changes in Inkscape, we can resave the file as an SVG or, of course, Inkscape is capable of producing many other file types that may be of use to you depending on your making process. Remember, sometimes simple is best – you could always print the box part design out on paper as a template to cut out! ◻

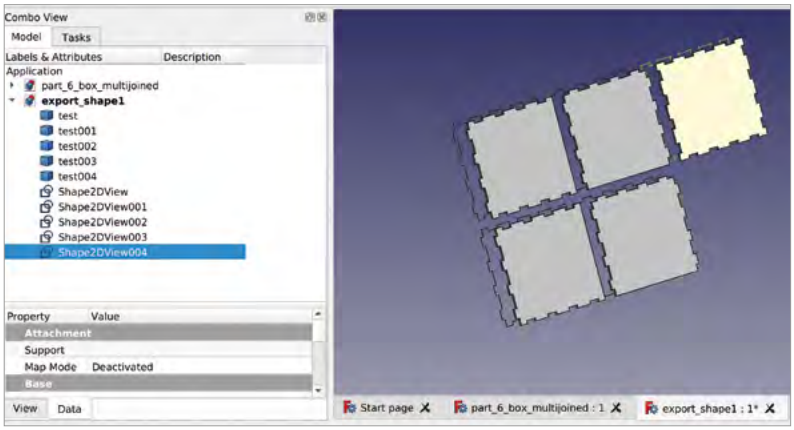
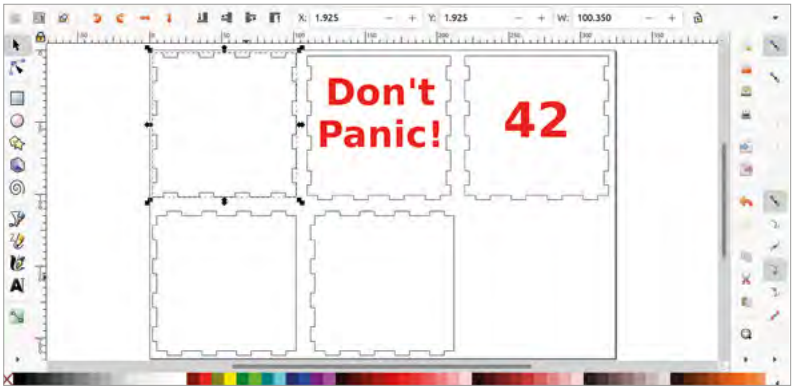


Figure 10
Using the export tool in Laser Cut Interlocking creates 3D and 2D flattened versions of all your interlocking parts

Figure 11
Editing our exported SVG of the Shape2DView objects in Inkscape



COMMUNITY FORUM

Asking for help with FreeCAD is something everyone who uses FreeCAD does or has done, and a great place to request assistance is on the FreeCAD community forum. The golden rule to remember is that everyone working on FreeCAD is a volunteer, so we need to do our best to make life easy, and be nice! Before you post, do a search on the forum for the topic you want to post about – the forum has been running for a long time, and chances are someone else has raised a similar discussion. We find that we barely need to post on the forum when we search first. We have also discovered all kinds of interesting approaches and techniques. Secondly, it's really important when asking for some assistance that you describe which version of FreeCAD you are using and on which operating system. FreeCAD makes this really easy to do: just click Help > About FreeCAD, and you will see all the details of your installation listed. There's a 'Copy to clipboard' button; if you click it, you can then paste those details into your forum post before going on to ask your question. You should also do this if you are answering another thread or comment with additional information relevant to the post. While you are on the forum, remember every now and again to say thanks to the developers for voluntarily creating such great tools for us to use.

TUTORIAL

Getting into CNC with the CNC 3018 Pro

In this series, we are going to look at the CNC 3018 Pro – a ubiquitous, cheap, and small CNC router kit – and use it as a platform to learn about CNC approaches

Jo Hinchliffe

@concreted0g

Jo Hinchliffe is a constant tinkerer and is passionate about all things DIY. He loves designing and scratch-building both model and high-power rockets, and releases the designs and components as open-source. He also has a shed full of lathes and milling machines and CNC kit!

We wanted to explore whether the CNC 3018 Pro was a good machine on which to learn CNC routing and milling, and also to try to maximise the potential of this admittedly budget machine. We're interested in seeing what we can get out of the CNC, and exploring and developing some of the skills that will translate to any other CNC machine. Each part of the series should stand alone, and in this first part we will explore the CNC 3018 Pro and build it!

The CNC 3018 Pro is a budget machine, where the 3018 refers to the dimensions of the working area of the machine bed. It's a kind of generic kit, with lots of different manufacturers making the CNC 3018 Pro, or at least rebranding the same kit. The most common CNC 3018 Pro kit is from SainSmart and is called the Genmitsu CNC Router 3018-PRO, but ours is branded a MYSWEETY CNC 3018 Pro (**Figure 1**). There is some variety in pricing, but they are often available around £200. Ours was slightly more, at £235, as it included a 5-watt laser module to turn the CNC into a rudimentary laser engraver. We'll check this out as part

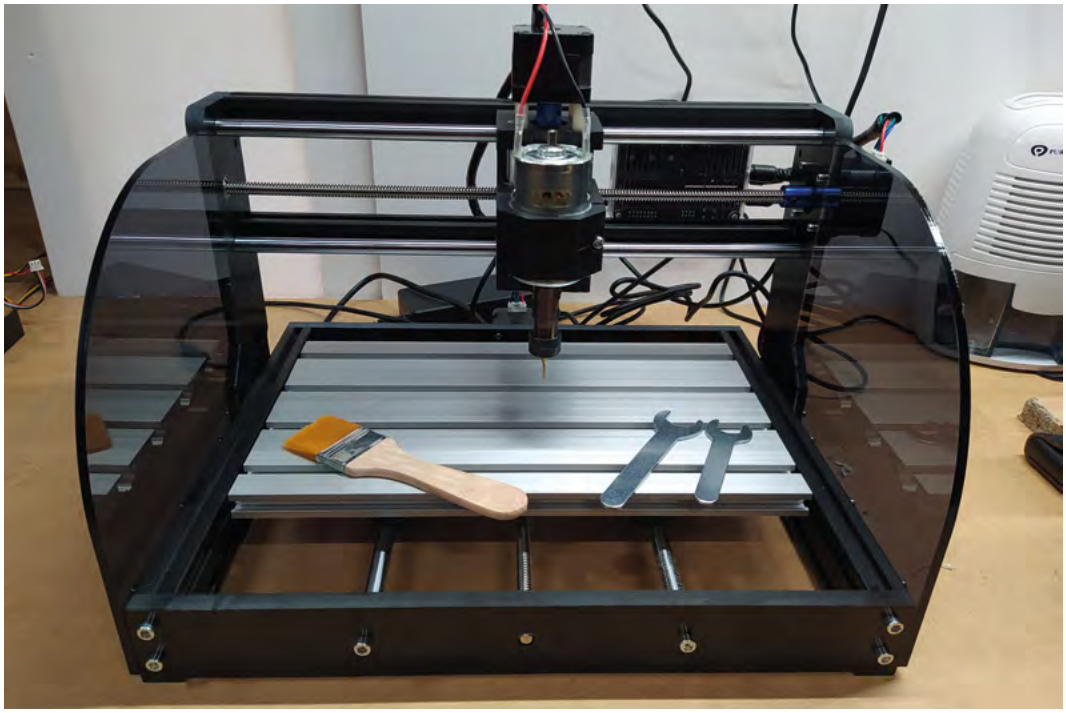


Figure 1 Our fully assembled machine

of the series, but it's fair to say that these shouldn't be considered laser cutters that can cut material. At best, they are laser engravers. They lack almost all the safety features a proper laser cutter/engraver has, so beware!

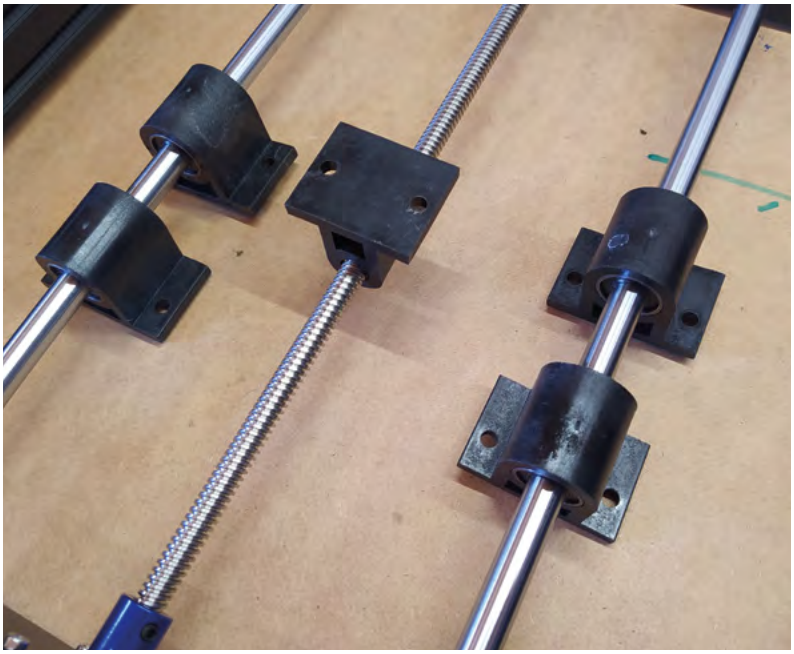
On arrival, we were surprised at the number of items that came with our CNC 3018 Pro **(Figure 2)**. It's equipped with an 'offline controller', enabling operation of the machine without it being tethered to a computer. There is an SD card for files in the offline controller, and also a USB pen drive in the box, with the software and some drivers to set up control software on windows.

In our kit, there were some cutting tools provided, a small collection of Allen keys covering all the sizes you need to build the machine, and some cable wrap to help tidy the wiring loom. Finally, there are some flat metal spanners that can be used to loosen and tighten the tool holder on the spindle, and a small brush for cleaning up! As our kit has the laser module, it also included some generic laser safety glasses, which is welcome, but they didn't include any regular eye protection for when using the machine as a CNC router.

The first part of the build is to assemble the base frame, incorporating the slide rails for the Y axis and the Y axis acme threaded lead-screw. The Y axis slide rails and the lead-screw are slightly shorter than the X axis ones, so it's pretty easy to identify them.

The front and back panels attach to the side sections are made from 4020 aluminium extrusion using the 16mm M5 bolts, which you can identify by laying the threaded section next to a ruler.

We assembled the back and sides loosely and then added the 10mm rods that act as slide rails, having slipped the linear bearings in their housings over the rails. The bearing blocks, and indeed lots of parts of the Z axis and spindle mount, are an interesting plastic. It's quite rugged, but also feels like it may have a little bit of flexibility. →



BACKLASH

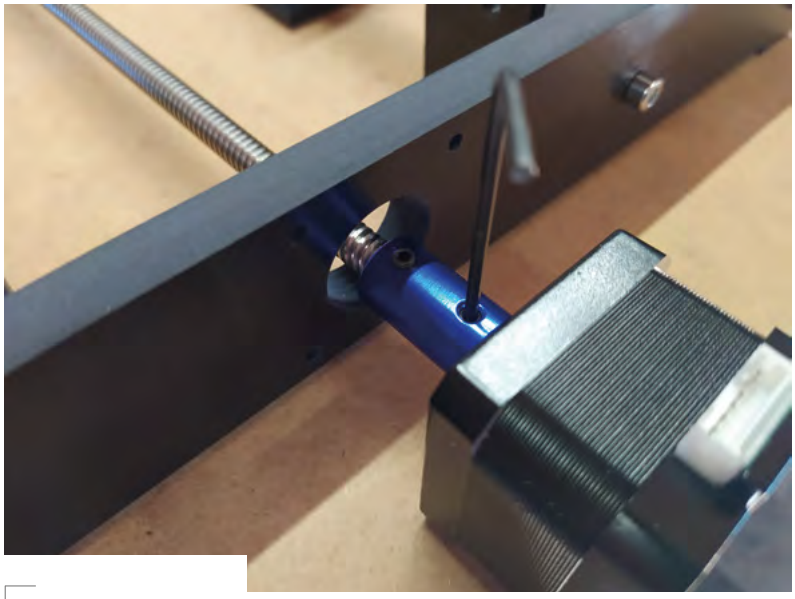
The captive nut design in the lead-screw blocks is designed to minimise backlash. Backlash is the kind of slack in a drive system. Even in a brand new threaded system, if you place a single nut on a bar, there is a slight gap in the system which allows the nut to move. However, that space also means that the lead-screw will turn slightly before the bed will start to move, and will also do this each time the lead-screw changes direction. It can result, therefore, in inaccurate parts. To overcome this, two separate nuts are installed in the block with a spring in between them pushing the nuts apart. This opposing force attempts to minimise backlash by closing the gap on the threaded bar at each end of the system. After a couple of experiments, we found that the nut needed fully compressing on the spring and then the lead-screw threading through. If a gap was left, the backlash wasn't removed, and the nut and spring creaked a little when moving.

Figure 2 The CNC 3018 Pro came well-packed, with lots of parts, tools, and accessories to get up and running with

Figure 3 Sliding on the linear bearing block housings

YOU'LL NEED

- A CNC 3018 Pro kit
- A ruler
- Engineer's square
- Flat-head screwdriver



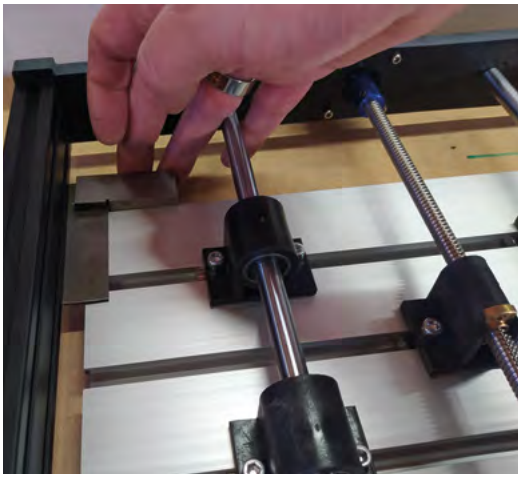
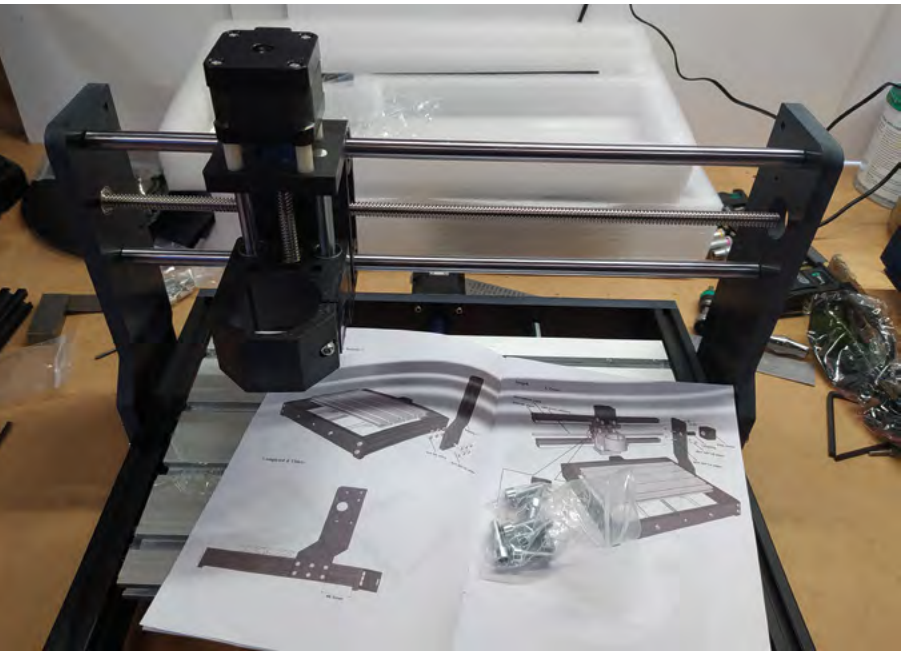


Figure 4
Attaching the Y axis stepper motor coupler to the lead-screw and stepper motor

Figure 5
Trying to make the bed as square and as evenly distributed to the frame as possible

Figure 6
The gantry sides are made from the bakelite material and pre-cut with all mounting points and holes

The bearing blocks each have a pair of bolt holes, and they should all be towards the edges of the machine rather than the centre. In **Figure 3**, you can see that we had the upper right bearing block on the wrong way around. Once we corrected this, we tightened all the bolts to bring the base and rails together. We were pleased to note that our base was pretty square and also all the holes aligned well. The next task is to fit the lead-screw for the Y axis into the base, but instead of a bearing block, the Y axis has a fixed block that attaches to the bed; this block contains a captive nut arrangement so that when the lead-screw is turned, the motion is transferred to the machine bed.



ATTACHING THE PARTS

Once the lead-screw and block are together, you can insert them into position by slipping one end back through the larger hole that is the stepper motor mount. Insert the other end into the bearing, and then slip the coupler onto the lead-screw shaft and tighten the grub-screws to keep it in place. The lead-screw couplers are stepped inside, with one end matching the lead-screw diameter and the other end the stepper motor shaft. We inserted the coupler fully onto the lead-screw, and pushed the motor shaft in through the stepper mount hole. It is easiest to move the lead-screw back and forth a bit to mount the coupler whilst the stepper wasn't attached, as the grub-screws on the stepper motor side could be partly obscured by the frame assembly (**Figure 4**). We then bolted the stepper motor in place using 14mm M3 bolts.

With the rails and the lead-screw assembled, it's time to add the machine bed. The bed attaches to the four bearing blocks and the lead-screw block, with more 16mm M5 bolts tightened into a captive nut in the slots in the bed. We placed the bed flat on our build table and inserted all the nuts using a small screwdriver to slide them into the correct position. We then inverted the base frame assembly, placing it on top of the bed and began to insert the bolts. We took our time to tighten diagonally opposite bolts on the bed in turn so that we didn't pull the bed to one side by tightening a group together. We used an engineer's square and the steel ruler to make the bed as central and as square to the frame as possible (**Figure 5**).

Turning the frame and bed back over, we turned the lead-screw by hand to make sure that everything seemed to be moving correctly. The next job is to attach the gantry that holds the X and Z axes. The side panels that form the gantry uprights are made from

the bakelite-like material. The uprights are bolted to the sides on the base unit using six bolts per side, each with a captive nut in the tee slot of the aluminium extrusion. The captive nuts for this differ, however, in that they can be dropped into the slot rather than slid in from an open end, which we obviously don't have access to. When you fasten a bolt into these captive nuts, they rotate to near vertical, but the nuts are too long to completely turn around. The instructions call for the gantry uprights to be positioned 46.5mm from the rear edge of the aluminium extrusion, not the outer edge of the bakelite plate. Again, we used a steel ruler with 0.5mm graduations to position them. The instructions call for one side to be attached and then all the X axis to be attached before adding the other gantry upright. In practice, we found that we attached one upright firmly and the other more loosely and then fitted the cross rails and the lead-screw and the Z axis assembly, before tightening the second gantry upright into position (**Figure 6**). The Z axis assembly is pre-built and simply slides onto the X axis rails, and you thread through the lead-screw using the same anti-backlash nut system as in the Y axis. Finally in this step, we inserted the 4020 extrusion across the gantry and then tightened everything up (**Figure 7**).

Figure 7
The Z and X axes are easily assembled, with the Z axis supplied pre-built

Next, we fitted the spindle assembly to the Z axis mount. The spindle is simply a brushed DC motor with an adapter fitted to it which allows it to be fitted with an ER11 collet. The spindle is supplied with one collet designed to grip an ⅛" diameter tool, which is a good starter collet as many, many small CNC tools are supplied with this size shaft. ER11 collet sets are available online for not very much money (£10) and can be found in a range of metric sizes up to 7mm. It's worth considering a set as you begin to experiment with different tools.

Fitting the spindle motor requires you to insert something to pry open the gap in the spindle housing moulding. We used a flat-head screwdriver to pull ours open and, once we did, the motor slipped in quite →

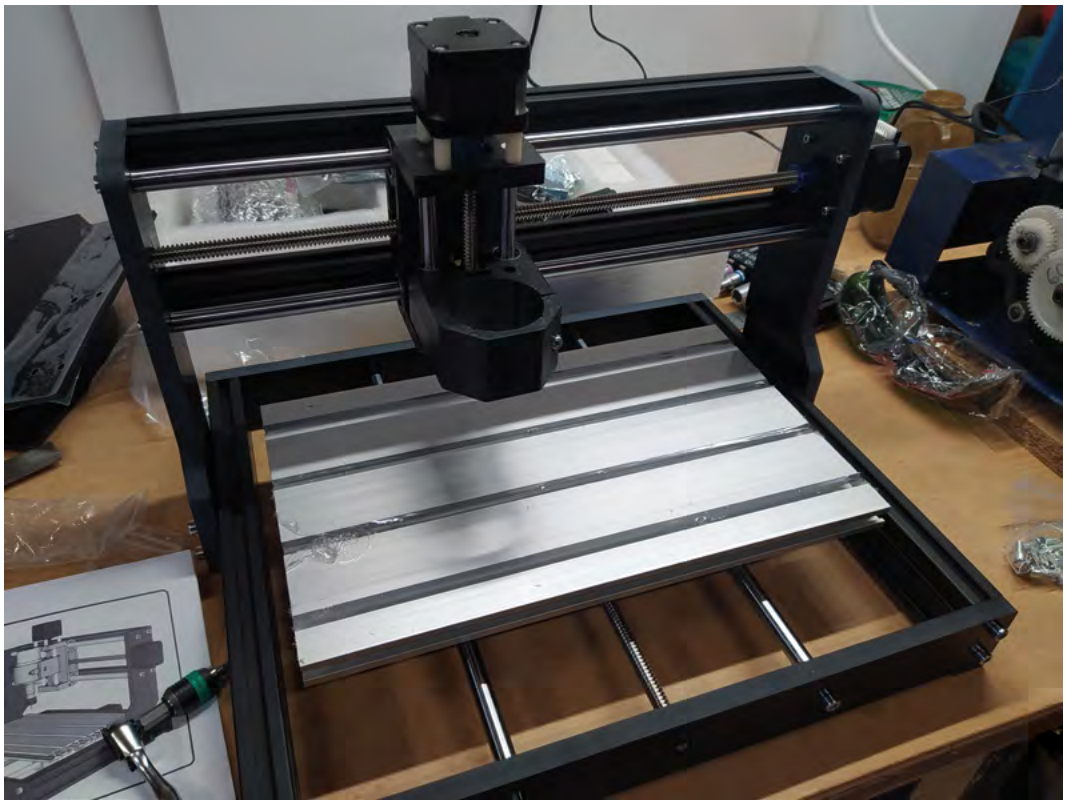
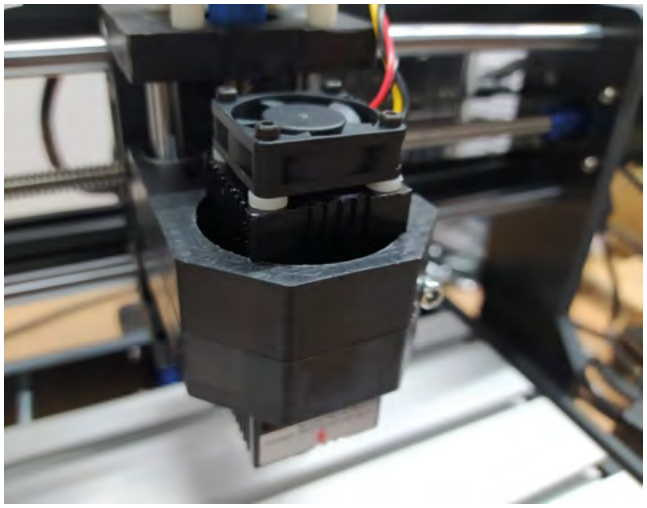


Figure 8
The spindle is straightforward to fit using something like a flat-headed screwdriver to prise apart the spindle mount

QUICK TIP

'CNC' stands for 'computer numerical control', and describes many types of machine such as 3D printers, laser cutters, pen plotters, computer-controlled embroidery machines, and more!



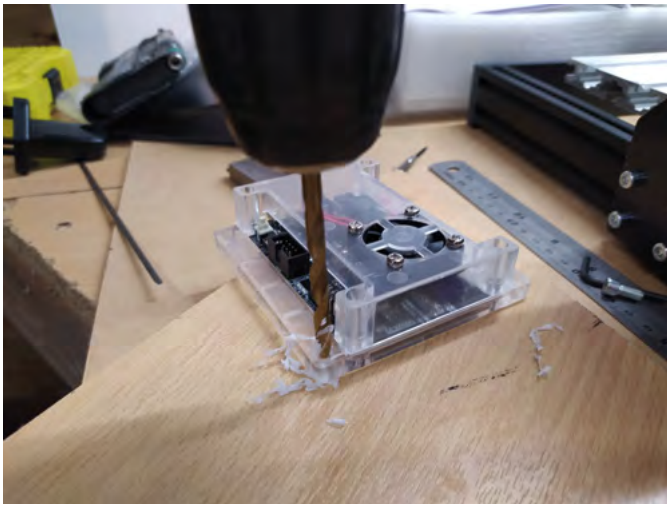


Figure 9
The spindle mount housing has small internal corners, meaning it can snugly hold the laser module

Figure 10
We found we needed to slightly widen the holes in the controller board case to allow the bolts to pass through clearly

easily (**Figure 8**). As a first pass, we slipped the motor in so that the wider sleeve of the motor was flush with the top of the spindle housing moulding, and then tightened the retaining bolt. Note that, as you place the motor in, the spindle housing has some little corners cut into the motor/spindle hole. This is so that you can easily place the laser module into the same housing (**Figure 9**). Finally, the ER11 collet holder adapter is mounted to the motor mount using some grub-screws. It's worth making sure that it's fixed on tightly, as we wouldn't want it to suddenly wriggle loose when the spindle is powered up.

> **The motor cables are all the same length, which makes it** easier in that you don't need to worry about which is which

Next, we set about fixing the controller PCB and the case to the rear of the gantry extrusions. For this, it used M5 bolts and the turning captive nuts. However, we found the enclosure for our PCB had mount holes that were slightly too small for the bolts to fit through easily. The first bolt we tried was cutting its own thread into the plastic. Whilst this would probably have been fine, we didn't want to run the risk of cracking the enclosure. We solved this by simply running a 5mm drill through the holes. The bolts then nicely cleared the panel, and the enclosure went on perfectly (**Figure 10**).

The information for wiring up the system was pretty lacking in our manual, but it isn't hard to work out. There are three cables for the stepper motors, and they have a different connector at the board end and motor end, and each of those connectors can only be inserted in the correct orientation. It's important to match the axis labels on the sockets on the control board with the responding motor for the correct axis, but it's all clearly laid out. The motor cables are all the same length, which makes it easier in that you don't need to worry about which is which, but for the Y and X axis, it means you have far too much cable. The other cable that needs fitting is for the spindle, and it's a case of slipping the spade connectors over the terminals on the motor and then again at the control board. There is only one socket that the spindle wiring will fit into.

To tidy the cables, our kit came with some cable tidy wrap material which works OK. A more popular choice and modification that we have seen is for people to add a drag-chain which folds and unfolds across the X axis that contains the cables, and protects them from getting caught. We'd left off the laser-cut side panels, as we imagined they would get in the way if we needed to do any disassembly, but we added them as a final stage again using bolts and captive nuts. We are sure that they in no way should be considered as

QUICK TIP

Whilst assembling the CNC 3018 Pro, we found we needed a few extra tools – an accurate steel ruler, a flat-headed screwdriver for slight prying, and a 5mm drill bit and drill.

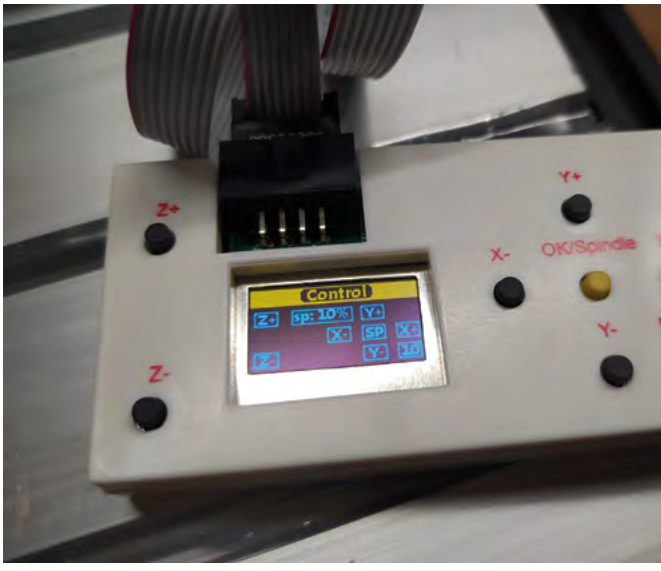


Figure 11
The offline controller can be used to jog the machine, and also to load files to cut from an included SD card

panels that provide any protection if you are using a laser module.

Before testing whether the machine worked, we turned the lead-screws by hand on all three axes to move the machine to its midpoints.

THERE'S NO LIMIT

As it stands, the machine isn't fitted with any limit switches. No limit switches means that if the machine were to be instructed to keep moving beyond the limits of its travel, it would try to do so and crash into the end of itself and try and keep going. If we move all the axes to centre, then it means if something goes wrong, we have maximised the chances of us being able to turn off the machine before it crashes.

We connected the 'offline controller', and we also connected the power supply and turned on the machine (**Figure 11**). The machine doesn't have an emergency stop system, so we made sure that we had our hand on the plug socket switch to switch everything off if things started to move incorrectly! At power-on, our unit started up, with the only signs of life being the noise of the fan starting on the control board and the screen on the 'offline controller' starting to light up, offering a simple menu with two choices: 'Control' and 'File'. On our offline controller, we clicked the OK button to select the 'control' option. In the control menu, you can set the unit of distance of travel per jog button-press. We set the travel to 10mm, and then used the controls to check each axis of the machine could move in the correct direction.

Having checked that each axis moved, by making small movements with the controller, we also enabled the spindle in order to check the direction of rotation was correct, i.e. clockwise. On the offline controller, if you go into the File menu, our machine had a test file on it to engrave the word 'iPhone' onto something. We performed an 'air cutting' test, where we ensured that the Z axis was set to the midpoint, and then jogged the X and Y towards the lower left-hand corner of the bed. Then, with no tool inserted in the spindle, we ran the job with the machine cutting in air. Air cutting is a good way to test files and machines.

Finally for this part of the series, we hooked up a laptop and did a tiny first cut into some scrap MDF, just to make sure everything was working. In the next part, we'll look at the software that comes with the machine, alternatives you might like to try, and some simple approaches to making G-code files with toolpaths for your own designs (**Figure 12**). ◻

QUICK TIP

Even if you are just testing the spindle with no tool fitted, ensure that you have tightened the collet holder, or removed it, so that it can't fly off.

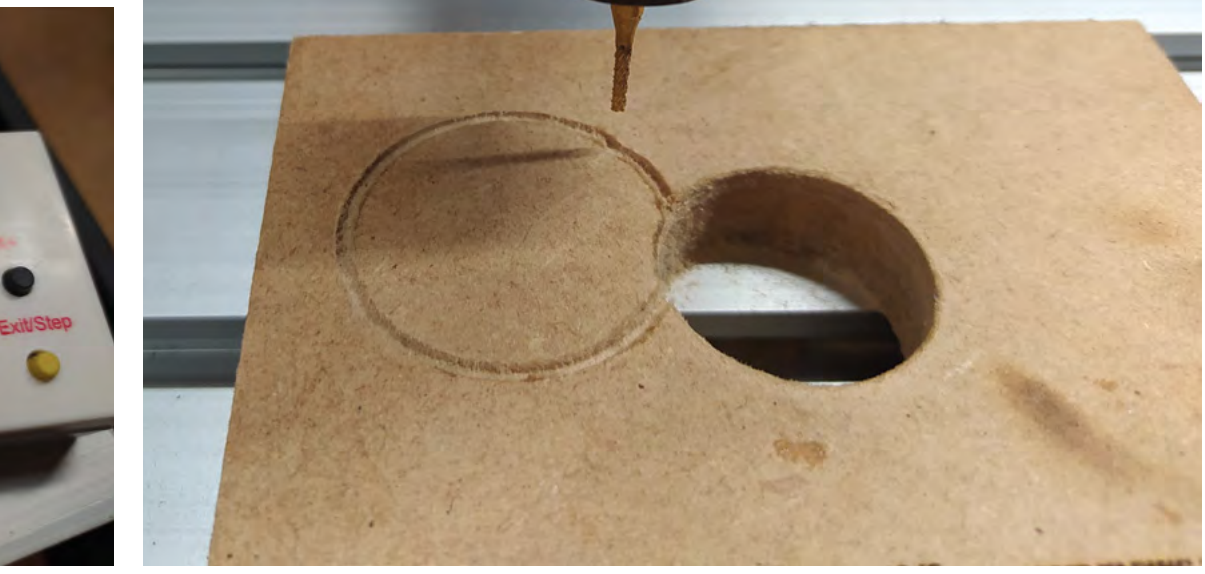


Figure 12
After confirming our machine was working correctly with some simple jog movements and some 'air cuts', we did a tiny test cut into some scrap MDF

HackSpace
TECHNOLOGY IN YOUR HANDS

FIELD TEST

HACK | MAKE | BUILD | CREATE

Hacker gear poked, prodded, taken apart, and investigated

ONLY THE BEST

Vintage tech for your modern project

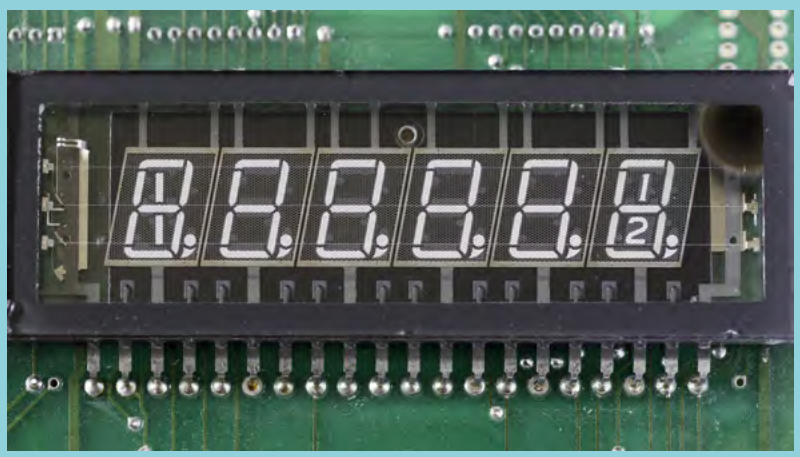
A roundup of vacuum fluorescent displays

By **Marc de Vinck** @devinck

Vacuum fluorescent displays (VFDs), originally developed in the late 1950s and more widely used in the 1960s to 1980s, have been a very popular addition to many DIY electronic enthusiasts' projects since they were first introduced. They have an amazingly bright output compared to a typical LCD, and a vintage look that's tough to beat.

VFDs work through the cathodoluminescence, which is very similar to how a cathode-ray tube TV from the same era operates. They can have multiple segments, allowing numerical, alphanumeric, or custom symbols to be displayed. And they are available in different colours too! You could find them everywhere in the 1980s, from handheld games to cars and so many household electronic devices. It's hard to find a piece of home audio from the 1980s that didn't have at least one VFD showing the volume level or VU meter. When the less power-consuming and more efficient LCD and LED technologies matured, the beautiful and high-contrast VFDs faded away.

And although there are a few OEM VFD manufacturers around, most of them have high minimum order quantities, so look for third-party resellers for small orders. If you are looking for a unique VFD, maybe some new old stock, be sure to head over to an online marketplace like eBay. Just keep in mind that most of them will not come with any instructions or guarantees, so buyer beware! But if you are looking for a truly unique-looking retro display for your next cyberpunk project, it's a great place to look. Just be ready to do a lot of searching and experimenting to get any piece of vintage tech to work properly.



2 × 20 character VFD Character Module vs Fluorescence IV-6 Digital VFD Tube Clock

NEWHAVEN $37.40 | hawkusa.com

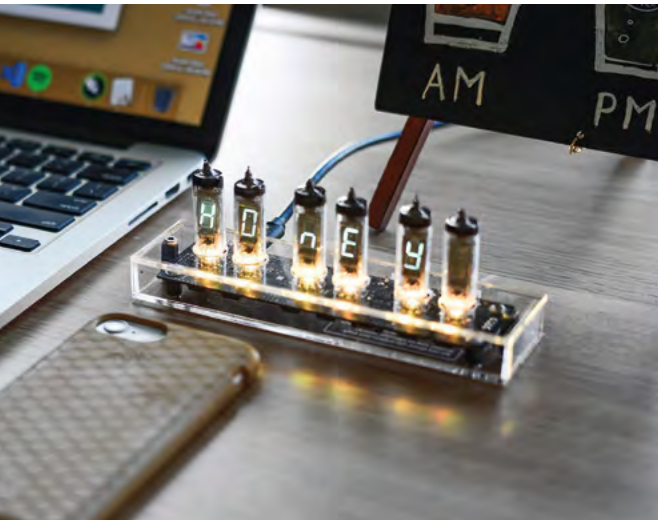
THE VFD COLLECTIVE $189 | tindie.com

You can still purchase a variety of VFDs from manufacturers and distributors. This 5 × 8 matrix version made by Newhaven, and available at Hawk Electronics, looks like a nice plug-and-play device for your next retro project. In many circumstances, picking up a new VFD is a lot easier than sourcing a used one. And although they cost a bit more, you get a data sheet, and lots of other useful information that will save you hours of experimenting.

Newhaven makes a variety of displays, most of which use serial/parallel communications. In this model, you can display two lines of text, 20 characters on each line – very similar to the ubiquitous 16 × 2 LCDs available anywhere that you pick up electronics components. And just like the standard 16 × 2, you can always scroll the text or make custom characters that span more than one line or section. But unlike the 16 × 2, the VFD will be much brighter, crisper, and have that cyber look that just can't be replicated any other way.

Left
A compact data display

Below
One of the quirkiest ways to show text



Fluorescence by The VFD Collective on Tindie is a digital clock kit with six Soviet vacuum fluorescent display tubes that allows you to display time, or even simple messages.

Because these are VFD tubes, they operate at a lower and safer voltage than a typical Nixie tube clock.

Each vintage Soviet vacuum tube features its own microchip, which the creator says allows for an intense, uncompromising, and flicker-free brightness, even in bright daylight. The clock features an accuracy of less than ±63 seconds per year, and is leap year compensated until year 2100. DST needs to be set manually. Be sure to check out the website for more information, including the source code, design files, BOM, and data sheets. It's nice to see a well-documented open-source product!

VERDICT

2 × 20 character VFD Character Module

If you want new, this is a good choice.

8/10

Fluorescence IV-6 Digital VFD Tube Clock

A beautiful kit.

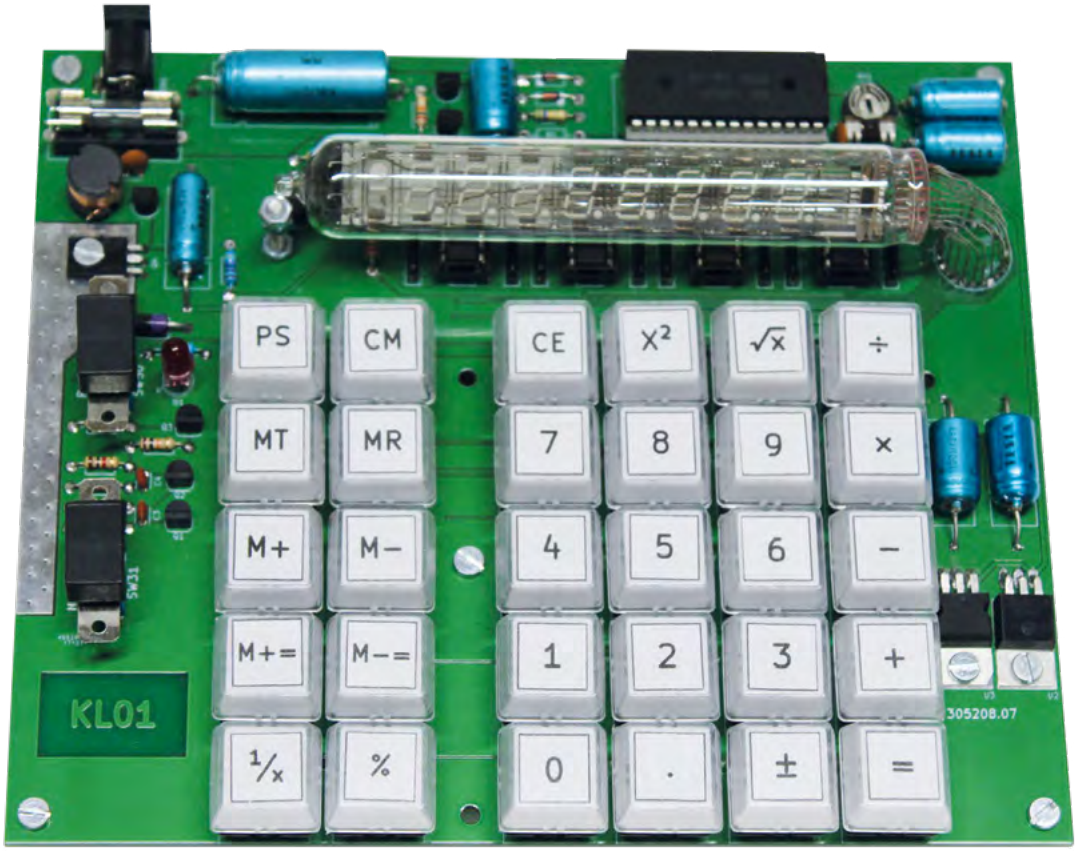
8/10

Retro calculator with VFD

PULSAR LABS ◈ **$300** | **tindie.com**

Yeah, we know, this one is definitely expensive! But it's also the ultimate desk accessory for anyone into the vintage electronic or cyberpunk look. This is a modern calculator build that features vintage Soviet parts and a mechanical keyboard. It looks great, although it also seems a bit exposed!

The creator, Pulsar Labs, tried to use as many vintage parts as possible when designing the calculator. It uses an MC14007 Polish calculator application-specific integrated circuit (ASIC), a vintage Soviet VFD, and Czechoslovakian passive components. This author really likes the look of this calculator; just don't forget you'll also need to design an enclosure to protect it! Maybe a clear laser-cut case, since you don't want to hide the beauty of the internal components.



Left ◈ Calculate like it's 1969

VERDICT

Retro calculator with VFD

Want a VFD showpiece? Then this is for you!

6/10

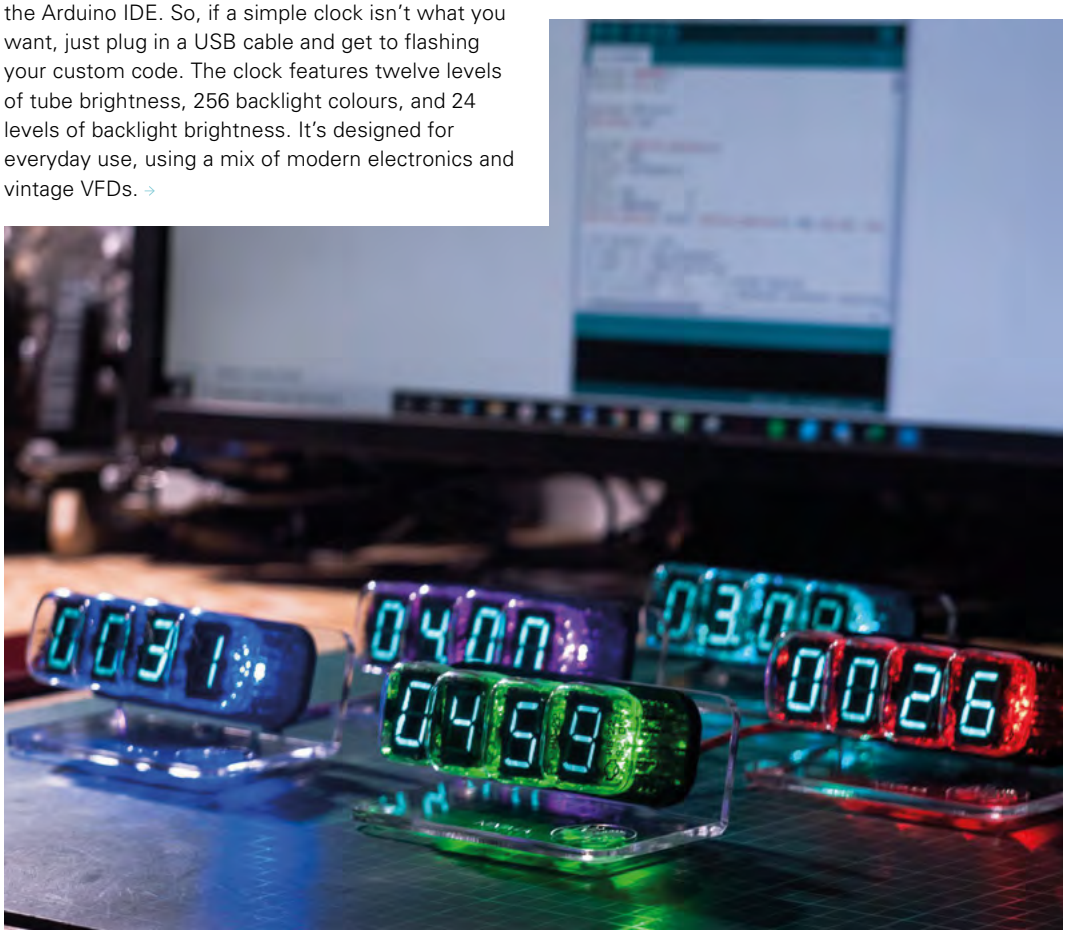
VFD Arduino Nixie tube clock

NIXIMA ◈ **$95** | tindie.com

The VFD Arduino Nixie tube clock, designed by Nixima, is one of your author's favourite VFD-based clocks. So many tube-type kits are based on a vertical design. They look great, but this one has a unique angled display, which really stands out.

At the core of the clock is an ATmega32U4, so you can easily implement your own unique programs in the Arduino IDE. So, if a simple clock isn't what you want, just plug in a USB cable and get to flashing your custom code. The clock features twelve levels of tube brightness, 256 backlight colours, and 24 levels of backlight brightness. It's designed for everyday use, using a mix of modern electronics and vintage VFDs. →

> **If a simple clock isn't what you want, just plug** in a USB cable and get to flashing your custom code



Left ◈
Clocks don't need to be boring

VERDICT

VFD Arduino Nixie tube clock

Beautiful and a bit different.

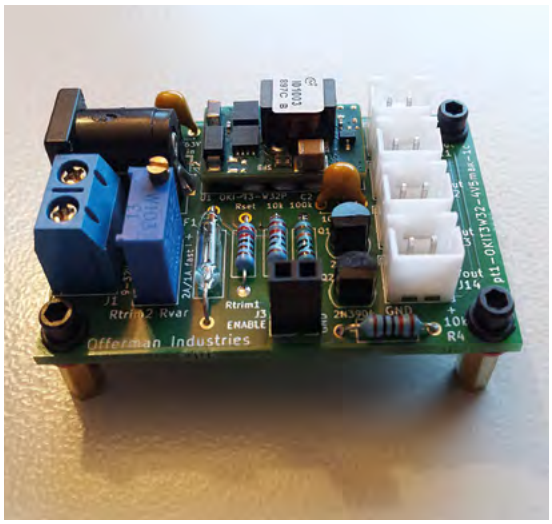
9/10

0.75-4.5V adj DC-DC Power Supply, 9-32V in, 3A out

OFFERMAN INDUSTRIES ◈ $37 | tindie.com

This product doesn't have a snappy name, but at least it's descriptive! The '0.75-4.5V adj DC-DC Power Supply, 9-32V in, 3A' board from Offerman Industries is the perfect companion to many of the VFDs on the market. It provides stable and robust power, which is critical for VFDs. This version accepts 9–32V input, and has four outputs, adjustable from 0.75V to 4.5V, at a maximum of 3A in total. It doesn't require any heatsinks, has auto-restart after a short, and comes fully assembled and tested.

The designer created the power supply for their own LED and VFD projects, so you know it's been tested specifically on VFDs. And if this specific board doesn't fit your needs, they offer a variety of other versions with different ranges. Check out their Tindie site for all the details. □



Left ◈
Get your electrons VFD-ready

VERDICT

0.75-4.5V adj DC-DC Power Supply, 9-32V in, 3A out

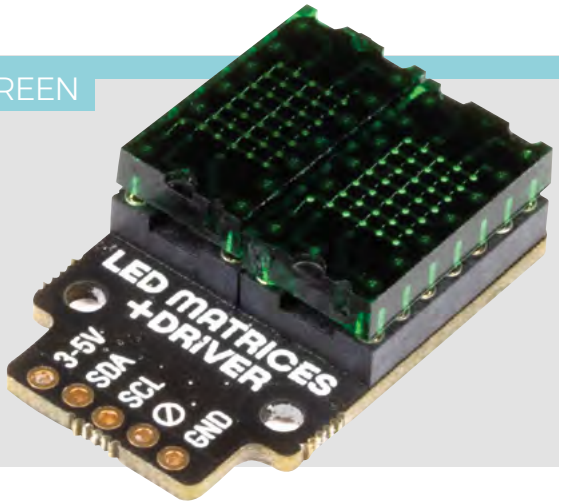
A good solution for powering your VFD-based project.

9/10

LED DOT MATRIX BREAKOUT – GREEN

PIMORONI ◈ $14.83 | pimoroni.com

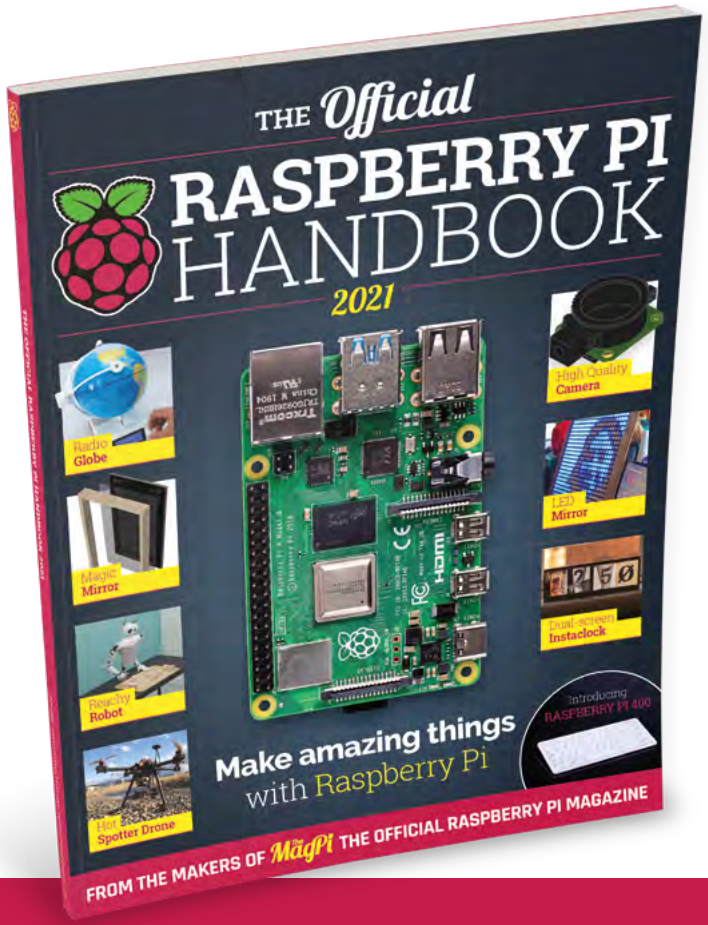
Yes, we know this is not a vacuum fluorescent display, but keep in mind how difficult they can be to work with, and hard to source. Why not get the look of a VFD without all the hassle! The LED Dot Matrix Breakout from Pimoroni gives you the look of a retro VFD, but way less hassle. These boards are 3V to 5V-compatible, and communicate via an I2C interface, making them an easy addition to your next Raspberry Pi or Arduino project. This author has a few of them in his studio and loves how they look.

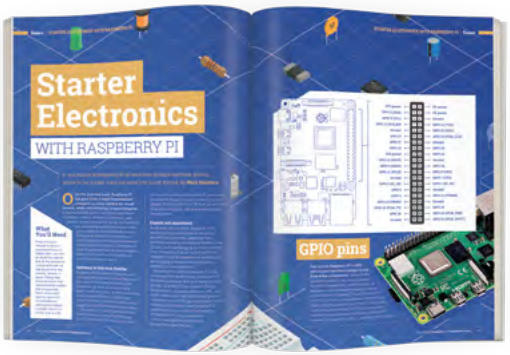


THE *Official* RASPBERRY PI HANDBOOK 2021

200 PAGES OF RASPBERRY PI

- Get started with Raspberry Pi, electronics, and more
- Be inspired by incredible projects made by other people
- Learn how to code and make with our step-by-step tutorials
- Find out about the top kits and accessories for your projects





Buy online: magpi.cc/store

REVIEW

The secret life of components

An in-depth look at how to use different parts

TIM HUNKIN ◈ Free | hsmag.cc/THunkin

By Ben Everard @ben_everard

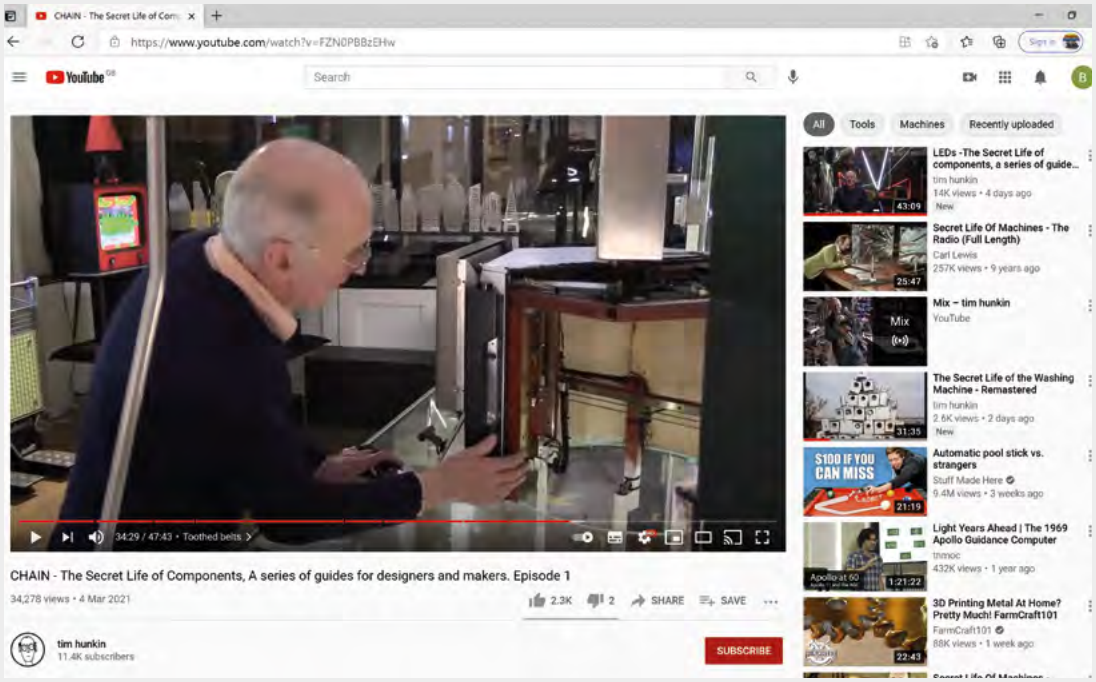
Tim Hunkin exists somewhere in the confluence of art, engineering, and inventing. He's perhaps best known in the UK for his 1980s series *The Secret Life of Machines* which showed how various household machines (such as washing machines and sewing machines) work. These shows have since been remastered and are on Tim's YouTube account. They're well worth a watch, but it's not these that we're looking at in this review.

Perhaps the second thing that Tim is famous for is his automata. These electromechanical arcade machines are typically used to poke fun at modern life, and can usually be found at Novelty Automation in London and Southwold Pier. His work is also in museums, art galleries, and other public spaces around the world, including the clock at the Exploratorium in San Francisco.

In the YouTube series *The Secret Life of Components*, Tim passes on his knowledge of the bits and pieces he's built up over the years of making these automata (and other machines). A new episode – each focusing on a different type of component – will be released every Thursday from 4 March 2021 to 22 April 2021. Each episode looks at one type of component. The majority of the series focuses on the mechanical side of things (such as chains, hinges, springs, connectors, and glue), but there are also a couple of episodes on the electronic side: LEDs and switches. The videos are free to watch, but there is the option to donate to support Tim. While he doesn't push the donations particularly hard, it's worth bearing in mind both of his Novelty Automation shows have been shut during the Covid lockdowns.

Tim says of the series: "It's impossible to teach 'experience'. I obviously have the experience to make complicated machines, but I don't know exactly what it is that I know. So much of it is non-verbal or 'tacit'. I work with my hands, and at times, they just seem to take over.

Above ◈
Pick the right LED strip for your project

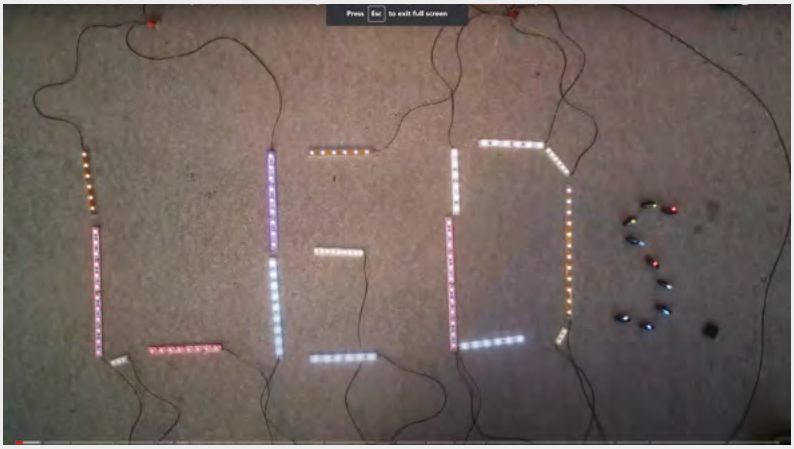


Left
Chains provide a great way for moving parts around a scene if you can control them

Below
LEDs are featured in all their forms – strips, domes, bulbs, SMDs, and more

"In the past, when people asked me how to learn practical skills, I've told them they just have to make things badly to start with, but to keep going and they will improve. I made things badly for the first half of my life. However, I now learn a lot from watching practical YouTube videos, and realise that they can teach the sort of informal tips that used to be part of traditional apprenticeships. So I'm delighted to be contributing to this wonderful new learning resource! I hope my videos, each about 45 minutes long, are entertaining enough to be fun for beginners, but also detailed enough to be useful for pros."

> "Be prepared to feel the hard to resist pull **of a new project idea germinating in your mind**"



Each of these videos is a treasure trove of information about the components. Tim covers the very basics of how to use a thing but, more importantly, he looks at the full range of options available commercially and talks about when he uses them and what problems he encounters. Alongside this, he shows examples of how he's used them in his automata.

By the time you read this, all the episodes should be available, but at the time of writing, we've been able to watch *CHAIN* and *LEDs*. As a keen rider of vintage bikes, this reviewer has spent plenty of time tinkering with the former, and he has an enormous collection of LEDs of almost every type, shape, and form. However, despite this, he gained a lot from the videos.

Tim's also hugely inspiring. Not in a shouty, you-can-do-it sort of way, but by helping you understand how he's built his machines, it's impossible not to think up your own plans for machines and contraptions. Be prepared to feel the hard-to-resist pull of a new project idea germinating in your mind.

We're hugely looking forward to the rest of the series, but by the time you read this, you have an advantage – the whole series is already there, ready for you to binge-watch. Brace yourself, as it may draw you into *The Secret Life of Machines* as well. ◻

VERDICT

30 years of mechanical experience distilled into six hours of videos.

9/10

REVIEW

Hantek 2C72 Oscilloscope

The little scope with big ambitions

HANTEK Around £130 | hantek.com

By **Ben Everard** @ben_everard

Oscilloscopes are one of those tools that start at fairly reasonable prices, and go up to almost any price you can think of, as you get scopes with more and more features. The Hantek 2000 series cost between around £90 and £140, depending on what features you have. A 2 or 4 at the start indicates the number of channels. C or D models come without or with (respectively) a waveform generator. The final two digits can be either 42 or 72, representing 40MHz or 70MHz bandwidth. The model we have is 2-channel, 70MHz, with no waveform generator.

As a handheld oscilloscope, the device has everything you'd expect from a basic scope. You can display the two waveforms, use a trigger to synchronise the display, and it will automatically calculate the frequency and maximum values. It does the basic job of displaying a waveform reasonably well.

Connect the scope to a computer and, using the companion app, you get more functionality. You can automatically calculate a lot more data about the signal, such as period, rise time, pulse width, peak-to-peak voltages, and more. Also on the app (but not on the scope), you can add a trace for a calculated value such as channel 1 – channel 2.

Right
The oscilloscope is just about small enough to fit in your hand, but still has a screen large enough to be useful

This oscilloscope takes its power over USB-C, so you can charge it from a normal USB charger (one is included, but ours came with a European plug, not a UK one), and it can also charge while connected to a computer.

While using the app does give you a lot more functionality, it does come with one big disadvantage – it slows everything down. Not the sample rate – you can still go on capturing at the same rate. However, it will capture bursts of samples rather than continuously taking in values. You get a new burst of values about once a second, so you're always a couple of seconds behind what's going on in the circuit. This isn't the end of the world as, most of the time, if you've got your triggers set up properly, you should be able to grab the bit of information you're interested in and focus on that. The app only grabs one screen's worth of information at a time (regardless of what time period you set the screen to), so you can't scroll backwards or forwards to find what you're looking for. It's probably this small data capture that's the biggest drawback to this oscilloscope.

The device can also act as a digital multimeter, which it does fine (though a little slow). Again, the app adds extra features here as you can use it to log data at a rate of about 2Hz. A pretty slow speed, but fine for slower-moving electrical changes.

Our unit arrived in a hard case, and it feels firm in the hand. It's hard to tell how long something will last until it breaks, but it feels sturdy and solidly made. It came with leads for the multimeter connections, and a hook-tipped probe and a crocodile clip probe – basically all you need to get started. The one thing it didn't come with was a manual or any useful documentation. The manual is available online at **hantek.com/DownLoad**, though it's not particularly useful. If you're new to oscilloscopes, you'll probably want to find some other guide to help you get started. If you're familiar with oscilloscopes,

> **The menu system isn't particularly intuitive, but** once you get the hang of it, it's fairly quick to use

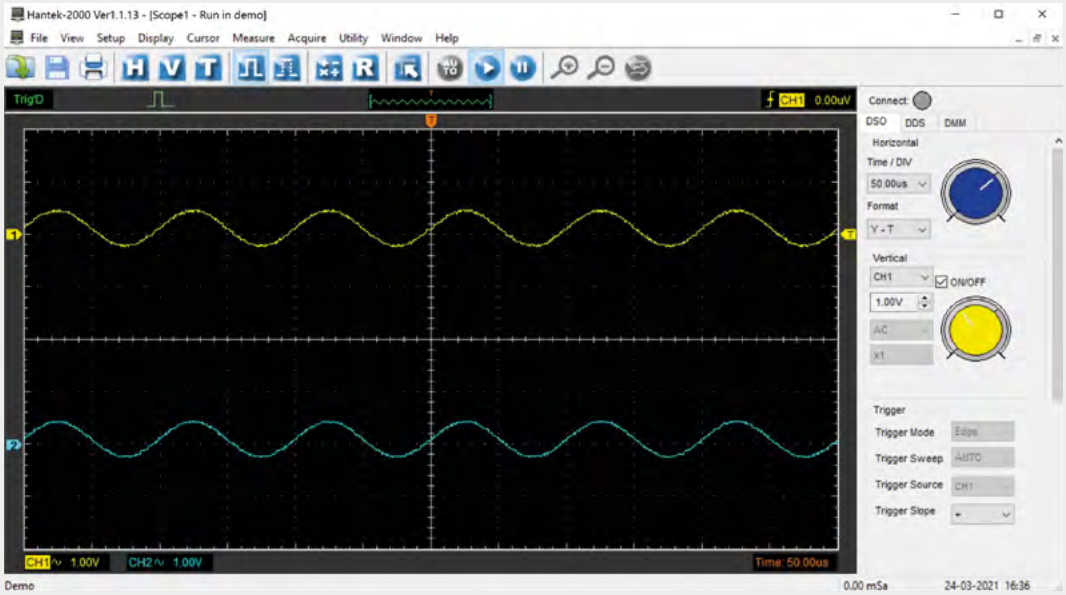
you'll probably work out how to use it by clicking around a bit. The menu system isn't particularly intuitive, but once you get the hang of it, it's quick to use. Having bench scope-style knobs to twiddle would make it far easier to use – alas, there's no space for such things on a portable machine like this.

There is an SD card slot on the case, but this doesn't seem to have an SD card port attached to it, and any card pushed in just falls loosely into the case. There is also a blocked-off section marked 'USB'. We didn't have any problem getting data out of the USB port labelled 'Power'.

There are plenty of things to like about this oscilloscope. On its own, it's small and portable, but still functional without a computer. Add in a computer and you get a whole bunch of additional functionality, at the expense of some speed. The main problem with this scope is the storage depth and transfer speed (neither of which we can find specifications for and they seem inconsistent between settings). This isn't going to replace an expensive bench scope, but for hobbyist use, or for on-the-go use where a bench scope can't go, this could be a good option. □

Above
The little image showing where to attach the multimeter probes is a nice touch

Below
The app adds a lot of features not available on the scope itself



VERDICT

An entry-level portable scope, but you'll need a PC to get the most out of it.

8/10

REVIEW

Kitronik Pico Discovery Kit review

Getting started with your new microcontroller

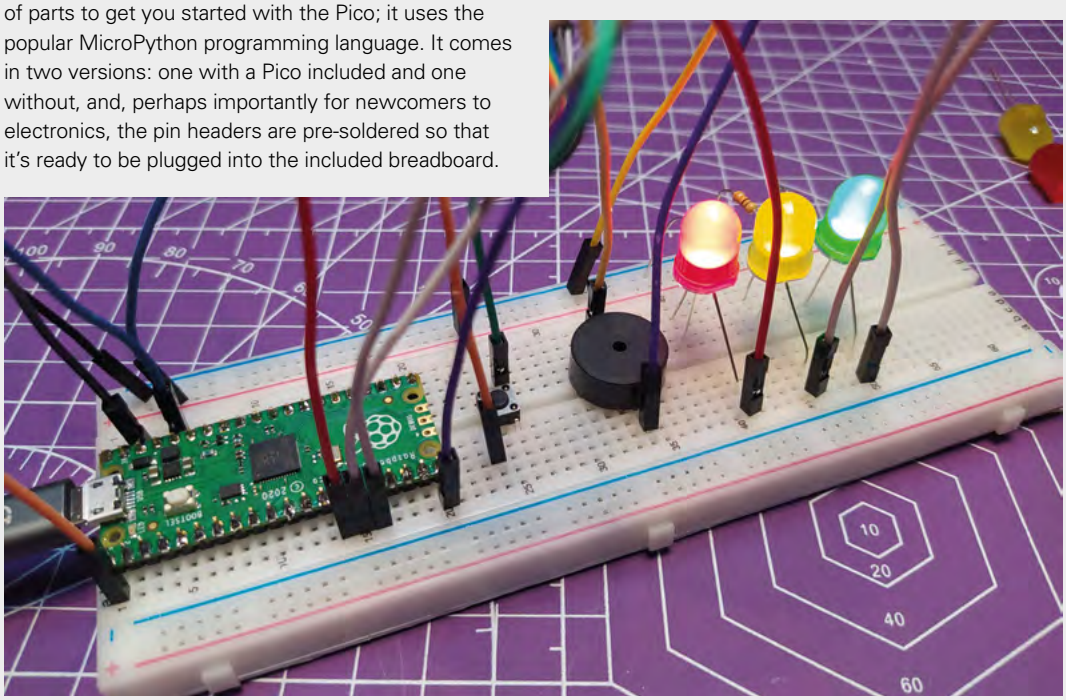
KITRONIK ◆ **£18.00 inc VAT** | **hsmag.cc/KitronikPico**

By **Jo Hinchliffe** @concreted0g

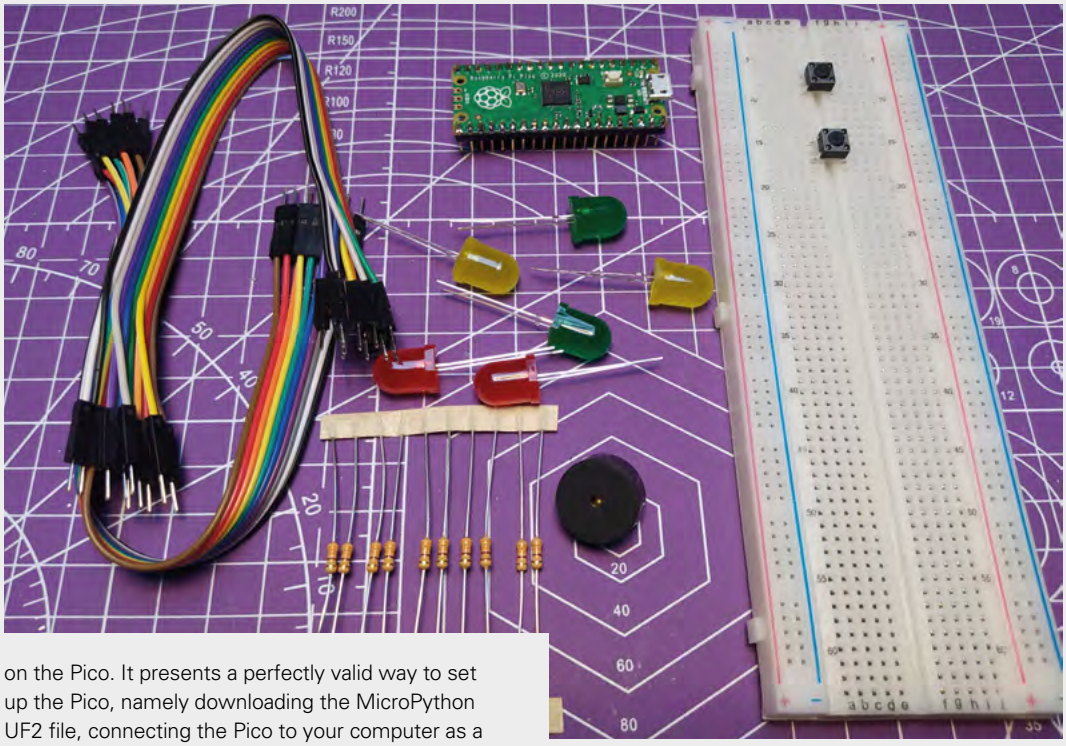
For many of us, the new Raspberry Pi Pico microcontroller is another board to tinker on that sits nicely in our collection of microcontrollers, components, and accessories. For others, though, the Pico may be the first foray into the world of electronics and microcontrollers. Kitronik has created the Pico Discovery Kit with the second group in mind, a collection of 'getting started' projects and components.

The Kitronik Pico Discovery Kit contains a range of parts to get you started with the Pico; it uses the popular MicroPython programming language. It comes in two versions: one with a Pico included and one without, and, perhaps importantly for newcomers to electronics, the pin headers are pre-soldered so that it's ready to be plugged into the included breadboard. The only thing people need to add is a micro USB cable and, of course, a computer to code on.

Alongside the breadboard and Pico are 20 DuPont connectors, three pairs of chunky 10mm LEDs, a small buzzer, some resistors, and a pair of momentary push-buttons. You'll also find a 34-page booklet with instructions and a nice collection of example projects. The book begins with a section explaining how to download and install Thonny, which is the recommended coding environment or IDE (integrated development environment) when using MicroPython



Right ◆ Working through the projects gives you a great grounding in using the Pico, and includes some quite advanced techniques



Left
The kit contents, including a pre-soldered Pico – just add a computer and a USB cable

on the Pico. It presents a perfectly valid way to set up the Pico, namely downloading the MicroPython UF2 file, connecting the Pico to your computer as a USB drive, and dragging and dropping the file over. We did note, however, that if you're working with the brand new Pico from the kit, on first connection to a computer, it automatically attaches as a connected drive (without having to press the BOOTSEL button), and then if you launch Thonny, it automatically detects the drive and asks if you want to install MicroPython. If, at a later date, you wanted to try a different language with the Pico (CircuitPython or C/C++), you'd have to use the method described in the book to reinstall MicroPython, so it's worth noting the process.

> It has a great section orienting new users **to breadboard layout and connectors**

The booklet is great – it explains the projects clearly and adds detail when needed about the electronics aspects of the kit. For example, it has a great section orienting new users to breadboard layout and connectors. At key points in projects, it explains things like forward voltages for LEDs, current limiting resistors, and more.

The projects in the book are nicely curated, starting with the ubiquitous 'blink the on-board LED' and then journeying through a process of learning that includes using GPIO, interrupts, and dual processes in a range of projects. We worked through a few of the examples and found that the instructions are easy to follow with both 'fritzing style' breadboard diagrams, as well as more schematic representations. It would certainly give a reasonable grounding on how to read simple schematics as a by-product of working through the activities. While they don't feel overtly educational, each project starts by declaring some aims. For example, experiment five has two aims: 'to learn about LEDs and current limit resistors' and 'how to make independent interrupts and use them to control independent outputs'. In turn, at the end of each experiment, there's a 'What's going on' section that sums up the processes in the experiment. Again, in experiment five, there is a well-written explanation of LEDs and Ohm's law. Speaking of LEDs, the use of 10mm LEDs in the projects is a good choice – they are easy to handle, and their size makes it simple to identify their polarity, as well as them looking attractive on the breadboard.

Despite being decidedly a kit for beginners, the Pico Discovery Kit manages to explore a wide range of systems the Pico is capable of creating. It particularly handles the explanation of interrupts well, and getting as far as using both processors on the Pico for separate threads in a beginners kit is impressive.

The code in the book is nicely laid out and well-commented. We certainly felt that anyone working through all the examples, and taking the time to understand the code, would have a solid foundation of understanding the Pico. ◻

VERDICT

An excellent kit for those new to microcontrollers, or new to Raspberry Pi Pico.

9/10

next month

issue #43 ON SALE 20 MAY

INTERNET OF THINGS

ALSO

- TEST EQUIPMENT
- RASPBERRY PI
- 3D PRINTING
- MUSIC
- AND MUCH MORE

DON'T MISS OUT

hsmag.cc/subscribe

So farewell then, Daft Punk (1993–2021). Beloved hit-makers, groove inspirers, and wearers of helmets. Forever with us, and especially when we watch Estefannie's video (**hsmag.cc/DaftPunk**) in which she recreates her own Daft Punk-inspired helmet full of RGB LEDs and over 136 hours' worth of 3D-printed parts. Harder, better, faster, stronger indeed.

IN A WORLD OF PLANNED OBSOLESCENCE, REPAIR IS A REVOLUTIONARY ACT