

MAKE | BUILD | HACK | CREATE

132  
PAGES  
OF MAKING

# HackSpace

TECHNOLOGY IN YOUR HANDS

hsmag.cc

November 2019

Issue #24

## RASPBERRY PI **TIME** MACHINE

Keep calm and carry on  
with a portal to the past



TURN VEGETABLE MATTER INTO

ESTD

2019

## WEATHER FORECASTER

Stay warm with a  
connected display

Nov. 2019  
Issue #24 £6



# BREWING

BEER • CIDER • MEAD • KOMBUCHA

**BRIAN LOUGH**

Power, control, and Tindie:  
how to scale up

## WUTHERING BYTES

Learning tech on the  
wily, windy moors

**DIY ANTENNA**  
Optimise your airwaves

DELICIOUS ALCOHOLIC DRINKS

## 3D PRINTING

Design, refine, and fabricate  
jewellery using Fusion 360

**PLUS**

**ARBOR PRESS**  
Press things into little holes

DIY COMPUTERS BINDER CLIPS RADIOS



9 772515 514006

1,500,000+ PRODUCTS IN STOCK | 7.9 MILLION+ PRODUCTS ONLINE



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



0800 587 0991  
**DIGIKEY.CO.UK**

**Digi-Key®**  
ELECTRONICS

800+ 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. © 2019 Digi-Key Electronics, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA

ECIA MEMBER  
Supporting The Authorized Channel



# Welcome to HackSpace magazine

This time, 24 months ago, we were preparing to launch a new magazine to the world. We had so many questions – would people be interested in a magazine for makers, were there enough projects to fill 132 pages every month, could we find enough great writers to create the articles? It turns out that the answer to all those questions was an emphatic yes! Two years on, we're still constantly amazed by the

**Two years on, we're still constantly**  
amazed by the ingenuity and creativity  
**of the maker community**

ingenuity and creativity of the maker community. Whether it's electronics, woodwork, metalwork, 3D printing, or some other form

of fabrication, there's so much to discover, play with and turn into great projects, products, and curios.

The maker and hacker community is a constant source of inspiration to us as we put the magazine together, and we hope we can share a little bit of that inspiration with you each month.

## BEN EVERARD

**Editor** [ben.everard@raspberrypi.org](mailto:ben.everard@raspberrypi.org)

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

get in touch at  
[hsmag.cc/hello](http://hsmag.cc/hello)

## GET IN TOUCH

[hackspace@raspberrypi.org](mailto:hackspace@raspberrypi.org)  
[hackspacemag](http://hackspacemag)  
[hackspacemag](http://hackspacemag)

## ONLINE

[hsmag.cc](http://hsmag.cc)

Available on the  
App Store

GET ON  
Google Play



## EDITORIAL

### Editor

Ben Everard  
[ben.everard@raspberrypi.org](mailto:ben.everard@raspberrypi.org)

### Features Editor

Andrew Gregory  
[andrew.gregory@raspberrypi.org](mailto:andrew.gregory@raspberrypi.org)

### Sub Editors

David Higgs, Nicola King

## DESIGN

### Critical Media

[criticalmedia.co.uk](http://criticalmedia.co.uk)

### Head of Design

Lee Allen

### Designers

Ty Logan

### Photography

Brian O'Halloran

## CONTRIBUTORS

Lucy Rogers, Andrew Huang, Jo Hinchliffe, Adam Clark, Mayank Sharma, Andrew Lewis, Sophy Wong, Gareth Branwyn, Les Pounder, Marc de Vinck

## PUBLISHING

### Publishing Director

Russell Barnes  
[russell@raspberrypi.org](mailto:russell@raspberrypi.org)

### Advertising

Charlie Milligan  
[charlotte.milligan@raspberrypi.org](mailto:charlotte.milligan@raspberrypi.org)

## DISTRIBUTION

Seymour Distribution Ltd  
2 East Poultry Ave,  
London EC1A 9PT  
[+44 \(0\)207 429 4000](tel:+44(0)2074294000)

## SUBSCRIPTIONS

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

### To subscribe

[01293 312189](tel:01293312189)  
[hsmag.cc/subscribe](http://hsmag.cc/subscribe)

### Subscription queries

[hackspace@subscriptionhelpline.co.uk](mailto:hackspace@subscriptionhelpline.co.uk)



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

## 06 SPARK

- 06 Top Projects**  
The Ferens Gallery of DIY projects
- 14 Objet 3d'art**  
A 3D-printed concrete construction
- 18 Meet the Maker: Brian Lough**  
Homemade electronics to scratch an itch
- 22 Columns**  
How not to get taken for a ride when fixing things
- 24 Letters**  
Quick! Turn on BBC iPlayer now!
- 26 Kickstarting**  
The cutest way of checking the surf conditions
- 28 Space of the month STEAMhouse**  
Innovation in the shadow of the Bullring
- 32 Wuthering Bytes**  
Open-source learning from the northern hills

## Cover Feature



36

100

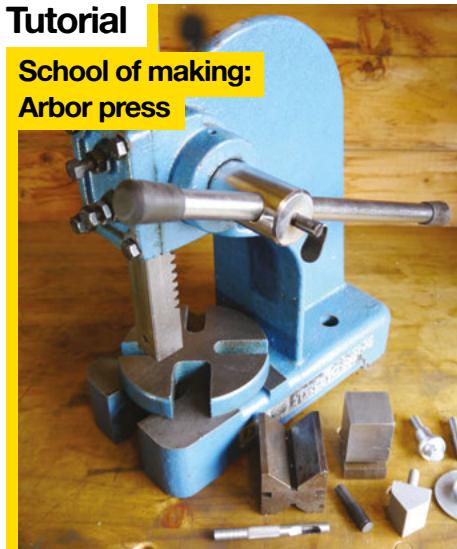


## 35 LENS

- 36 Brewing**  
The art and science of making your own drinks
- 56 How I Made: WW2 time machine radio**  
Use a Raspberry Pi to hear messages from the past
- 62 In the Workshop: Raspberry Pi laptop**  
Hack together a tailor-made computing solution
- 66 Interview: Eben Upton**  
Pity the man who has no time to build robots...
- 74 Improviser's Toolbox** Binder clips  
Making things out of little levered metal springs

## Tutorial

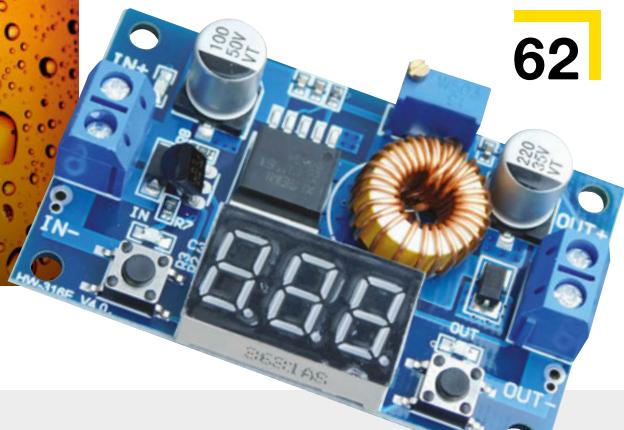
School of making:  
Arbor press



82

Add extra capabilities to this simple metalworking tool

62



**Best of Breed****Lidar****116**

Find neolithic monuments in villages near you

**26****14****124****Interview****Eben Upton****66**

Why manufacturing, like football, is coming home

**28****79****FORCE****80 SoM LED matrix**

Add 64 pixels of output with Arduino or CircuitPython

**82 SoM Arbor press**

Squeeze half a ton of pressure into bearings

**88 Tutorial Optimise your antennas**

Reach the parts other radios cannot reach

**94 Tutorial Forecast the weather**

Build an at-a-glance climate visualiser

**98 Tutorial Superglue**

How not to stick your fingers together

**100 Tutorial Workshop turntable**

Control every angle of your work

**104 Tutorial FM radio**

Build your own programmable radio receiver

**106 Tutorial 3D-printed jewellery**

Design and print in multiple filaments

**113****FIELD TEST****114 Direct from Shenzhen Bluetooth module**

Resurrect old speakers with the power of Bluetooth audio

**116 Best of Breed**

The best lidar scanners for geo-scanning

**122 Can I Hack It?**

Rule your next networking event with a video business card

**124 Review Tool sharpener**

A tiny grinder for your non-essential sharp things

**126 Review Dremel router attachment**

A simple gadget to bring more life to your rotary tool

**128 Review Template maker**

Winter is coming! Prepare with this festive box-designer

**129 Book Review Booze: River Cottage Handbook**

How to make delicious drinks, in book form

Some of the tools and techniques shown in HackSpace Magazine are dangerous unless used with skill, experience and appropriate personal protection equipment. While we attempt to guide the reader, ultimately you are responsible for your own safety and understanding the limits of yourself and your equipment. HackSpace Magazine is intended for an adult audience and some projects may be dangerous for children. Raspberry Pi (Trading) Ltd does not accept responsibility for any injuries, damage to equipment, or costs incurred from projects, tutorials or suggestions in HackSpace Magazine. Laws and regulations covering many of the topics in HackSpace Magazine are different between countries, and are always subject to change. You are responsible for understanding the requirements in your jurisdiction and ensuring that you comply with them. Some manufacturers place limits on the use of their hardware which some projects or suggestions in HackSpace Magazine may go beyond. It is your responsibility to understand the manufacturer's limits.

# ILC1-1/8L Clock

By ChristineNZ

 [hsmag.cc/IrqVOC](http://hsmag.cc/IrqVOC)

This Arduino Mega-powered clock/weather station combo (featuring humidity, pressure, and temperature readings) is a great example of the power of old technology. The large display digits are provided by six ILC1-1/8L VFD tubes, which is a technology similar to electronic valves, running at a much lower voltage. The tubes that Christine used are still available as new old stock from Ukraine via eBay, and if you like the retro look of Nixies, but aren't confident with the opening voltages they use, VFD is a useful intermediate technology to cut your teeth on. □

**Right ↗**

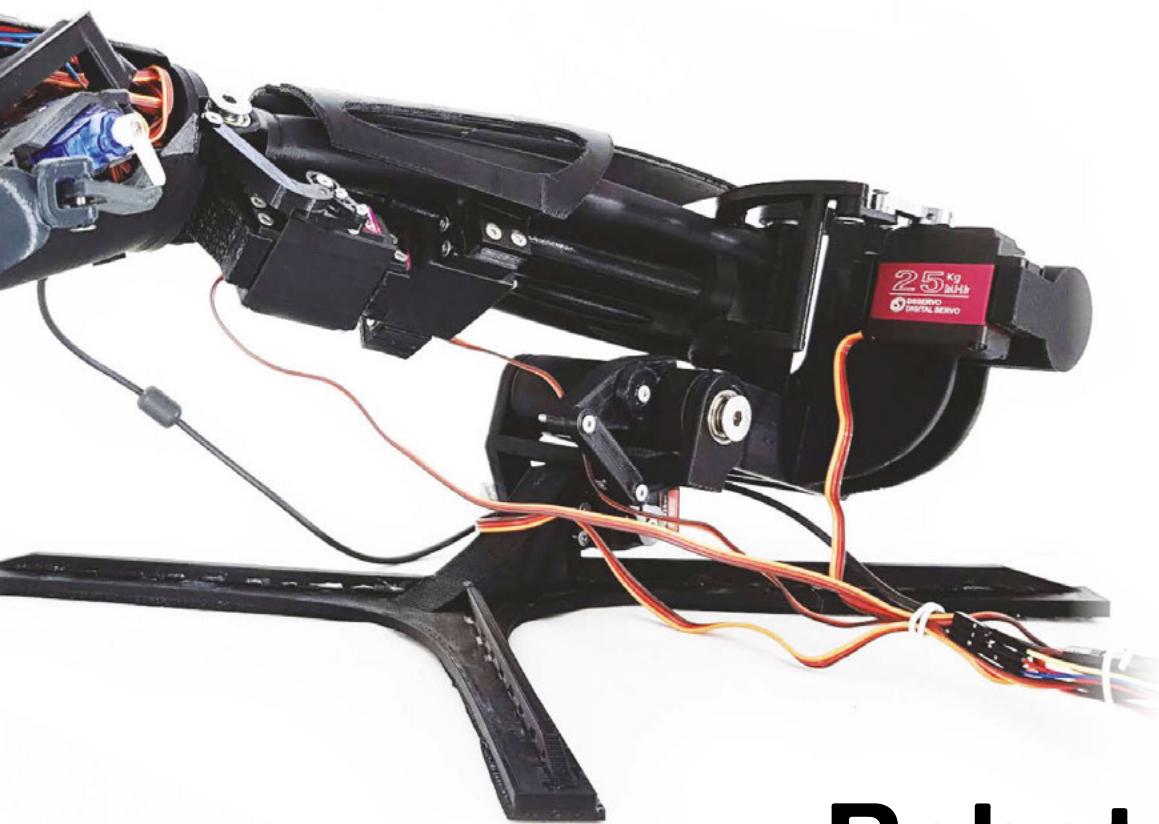
Big displays are perfect for telling the time at night when you don't have your glasses on





**Above**

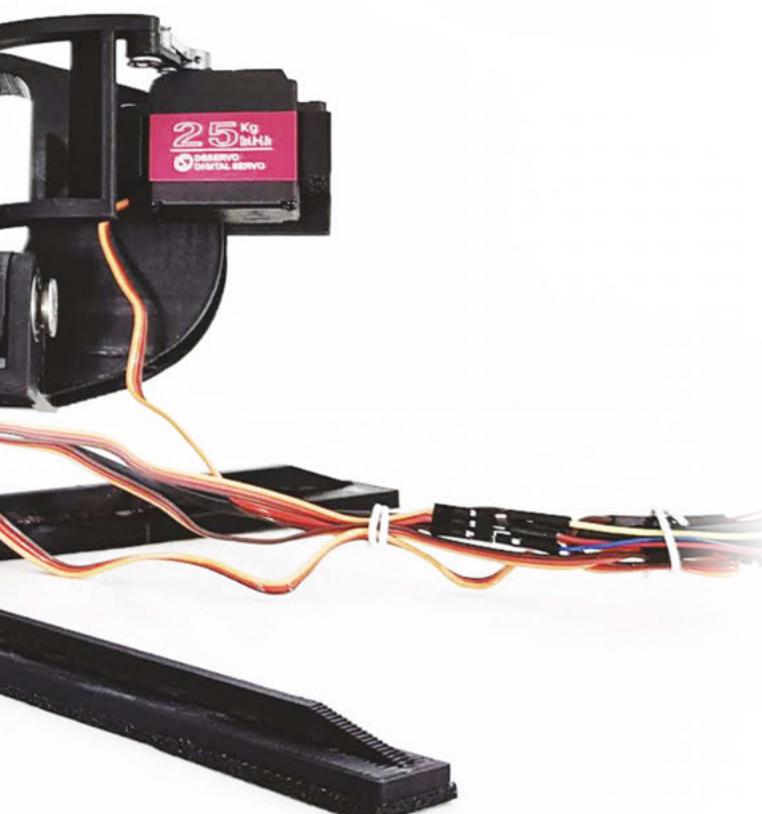
Someone has grafted a pair of these arms on to a quad copter. Nightmare fuel!



# Robot arm

By Federico Ciccarese

 [hsmag.cc/Ms34D0](http://hsmag.cc/Ms34D0)



## Y

oubionic is a project born five years ago. We work every day to evolve humankind by developing sophisticated technologies to greatly improve the intellect and human physiology. We fight to transform the human into transhuman, and fight aging, illness, and death.

Our robotic human arm is the first 3D-printed arm with shape, structure, and movements, obtained from an in-depth study of the human arm. These features make it compatible with remote control uses (through an exoskeleton), or independently controlled with the use of artificial neural networks.

We wanted to develop this so that it could be taken and developed by the greatest number of developers, so the challenge was to use low-cost components without sacrificing the quality of the device. We managed to offer it at an affordable price: \$97 for print files and electronic documentation, \$150 for prints and mechanical and electronic components. □

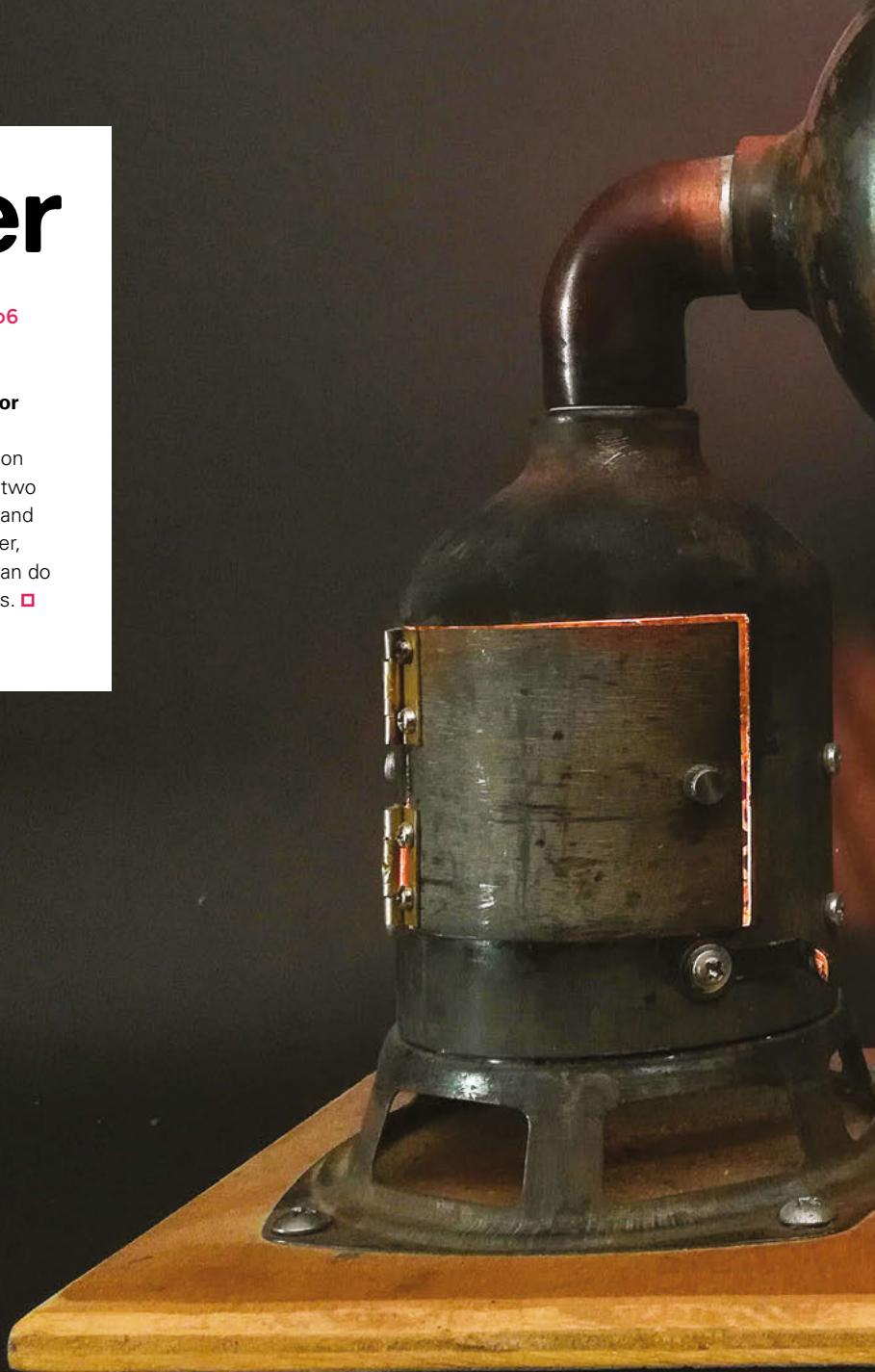
# Mini smoker

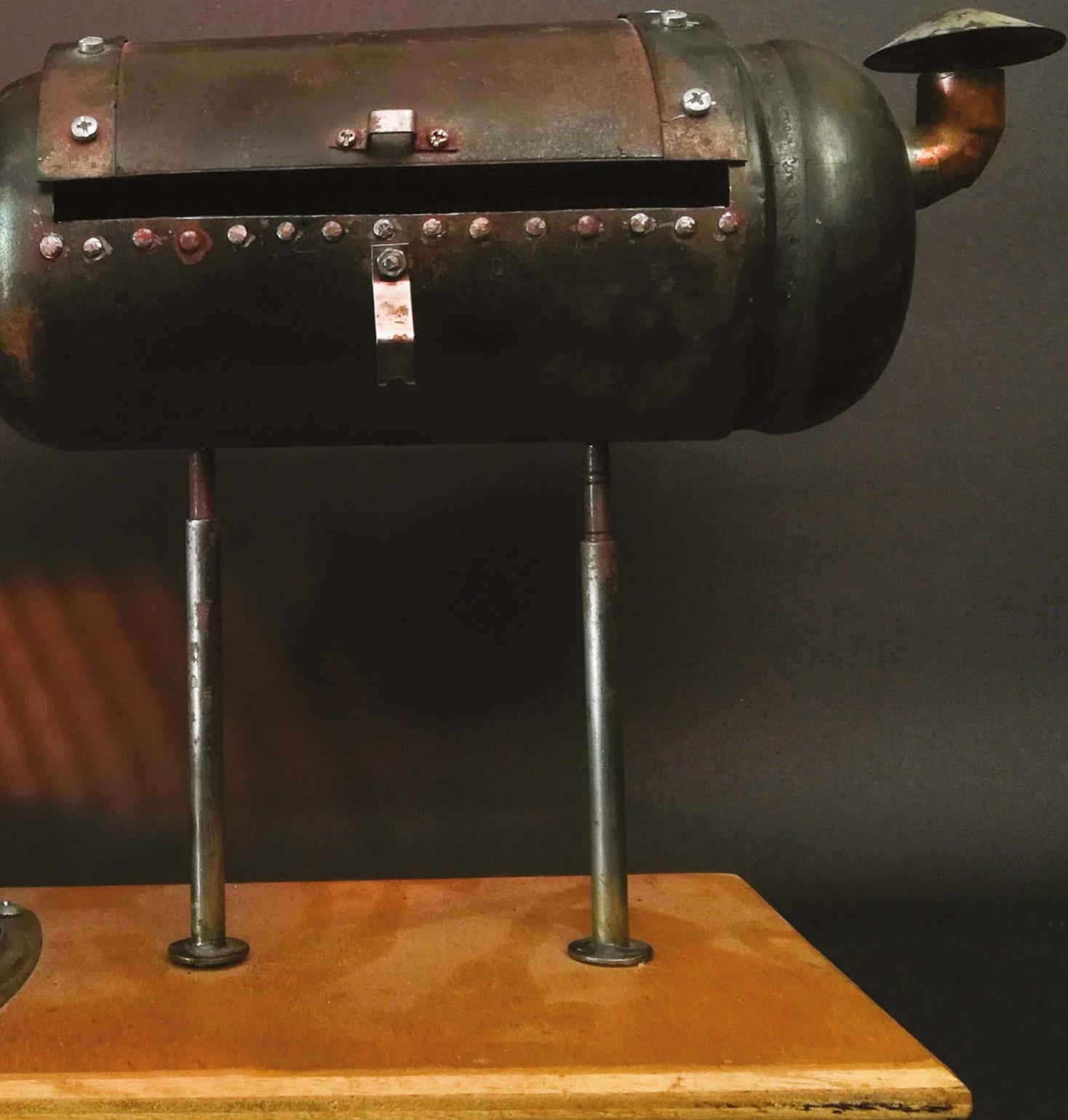
By F\_A\_B\_A\_S

 [hsmag.cc/ySxBo6](http://hsmag.cc/ySxBo6)

This miniature hot smoker is just the thing for tiny briskets, individual ribs, or teeny-tiny lamb shoulders. It was made out of a collection of scrap metal, including a speaker mounting, two fire extinguishers, bits of a broken typewriter, and some welding rods (to make the grill). Its maker, F\_A\_B\_A\_S, reckons, "If I need to smoke two sausages, I can do it". Maybe it's not all that useful, but it's absolutely gorgeous. □

**Right** □  
We heartily endorse a slow-smoked pork shoulder on a cold winter night





# Solenoid boxer engine

By Maker B

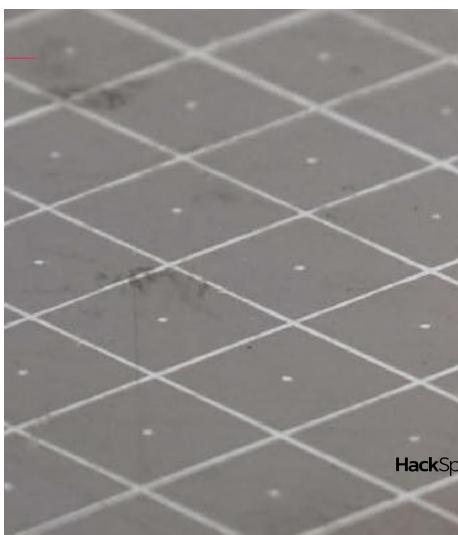
 [hsmag.cc/oK2Wa1](https://hsmag.cc/oK2Wa1)**M**

**y name is Jony [aka Maker B]. I'm a maker and hacker.** I like to build creative things that have never existed before. A lot of the time, I just build things for fun, which I think is one thing that makes me a maker.

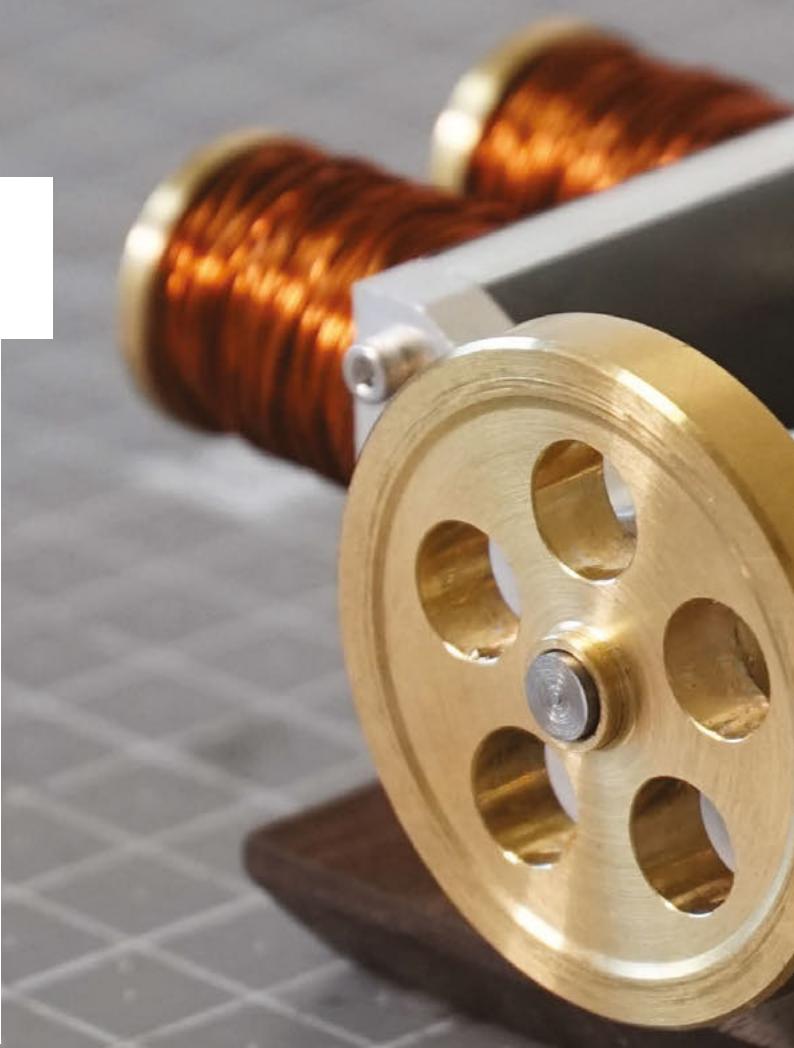
Unlike the internal combustion engine, which uses an air/gasoline explosion to turn a crankshaft, the Solenoid Boxer 4 Engine is an electromagnetic device which pulls the piston into the cylinder, using the electromagnetic force to turn a crankshaft.

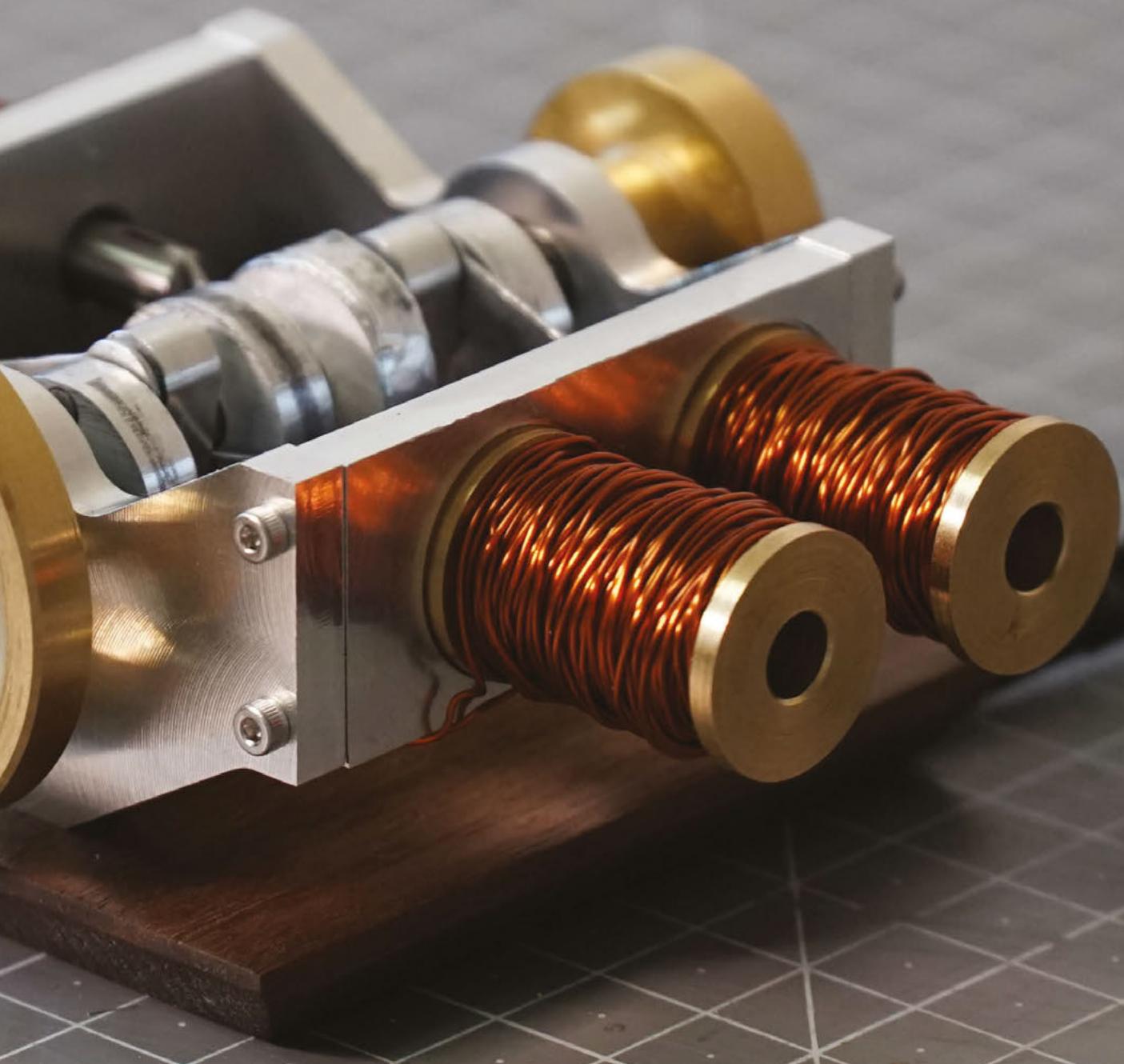
Four microswitches are installed in the base that are pushed down by the camshaft, to actuate electromagnet according to the position of piston in cylinder.

First, I used CAD software to design this engine, and aluminium, brass, and steel are carefully crafted into the various components of the engine using a lathe and milling machine. Lastly, all the parts are assembled with small fasteners and retaining compound. □

**Right** □

Jony milled every element of this beautiful engine himself to create an incredibly soothing 20-minute video





Objet 3d'art

REGULAR

# Objet 3d'art

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





We've seen 3D-printed buildings before, but the leap forward here is that this one meets local building codes for a residential building – that means it's a massive step up from a proof of concept, and is something that can actually be lived in.

The 3D-printed part of this 350-square foot home took two days to print, and cost around \$10,000. That's fast and cheap, compared with traditional methods. And it needs to be, because the aim is to take 3D printing →



technology to the developing world, to help improve living standards for the estimated one billion people without access to adequate housing. The project is a joint venture between New Story, a non-profit focused on improving housing, and ICON, a firm with expertise in large-scale 3D printing.

The house was printed in ICON's Vulcan II printer, which uses a proprietary concrete blend called Lavacrete. The maximum print height is 8.5 feet, and width is 28 feet – and it needs 4–6 people to operate it. If you feel like having a go yourself, they'll be on sale from 2020. □

 [iconbuild.com](http://iconbuild.com)



#### Left ♦

The first houses built in the developing world using this technology are due to break ground next year in El Salvador

#### Below ♦

We're used to thinking of print layers in terms of microns, but the standard print bead of the Vulcan II is one inch tall, by two inches wide



# Meet The Maker: Brian Lough

Tindie, makers, and the loveliness of sharing



**I**f you're running a business, a good first step is figuring out what people might want to buy. That's what most people will tell you, anyway. For most makers though, the process starts with fixing an itch of your own.

That's what led Brian Lough to put his first creation up on Tindie a little over a year ago. Since then he's added more gadgets to his stable, scaled up, and shared knowledge with makers all over the place. We chatted with him to find out more about the world of open-source electronics.

"I was always interested in the idea of making a PCB, but I put it off for a while. And then I saw a couple of other makers, like Unexpected Maker showed it a few times on his channel – I thought that it looked like something I could do. I made it a goal a few years ago to make a PCB and see how it goes."

"Similar to software or whatever, when I'm learning a new language I prefer to have a project in mind rather than just go 'OK, I'm going to learn Python because I want to learn Python'. It would be more, I'm going to do something on the Raspberry Pi because that uses Python'.

"If there's a practical thing that's going to come out at the end of it, I'm more encouraged to keep at it and keep learning. If it's a useless project or has no end goal, I struggle with motivation."

"I had this minor bugbear for years...I had OctoPrint set up on a Raspberry Pi controlling my 3D printer. So I left my Raspberry Pi on all the time; I didn't want to be booting it up and down every time I wanted to

print something. But I was turning the printer off in between prints, and the Raspberry Pi is connected to the printer via USB. I had, and still do have, a cheap Chinese printer...it takes the power from the Raspberry Pi USB and powers the screen board and stuff. So even though the printer was off, the screen was staying on. It's quite a bright LCD screen, so it was quite frustrating."

"This is a common problem; loads of people have it. What some people do is they cut their USB cable; they peel back the shield, and cut the 5V wire inside the cable."

## THE FIRST PROJECT

"I was thinking, 'Wouldn't it be nice if there were a solution for this that didn't require you to cut open a cable?' This would be a nice first PCB design because it's super-simple: there are two components, all I have to do is connect three of the four wires between those two components, and that would be it. I had a practical use case, so I said OK, I'll make that."

"[PCB fabricating service] JLCPCB had this thing where you could panelise your board for free, so once it fit within 10 by 10cm, you could have rows and columns of the same PCB design. I think I ended up ordering about 200 PCBs for what I call the Power BLough-R. I got two hundred of these Power BLough-Rs and thought this is an absolute lifetime supply of these; I will never need to order any of these again. I bought enough parts for ten of them, and thought, this will do me for months, even if I decide to ↗



Above □  
Making nice things  
for christenings, bar  
mitzvahs, and weddings



**Above** Brian's take on the classic seven-segment display

sell them. That ended up being a lot more popular than I thought!

"I like to design things that solve problems that I have, because I feel like if I have problems with it, then surely other people have problems with it too. A lot of people come to me with some problem in a far-off field saying that there would be good money to be made in that, but I find that really hard to develop anything for, because I don't experience the problem myself, so I can't have empathy with other people's problems; I don't fully understand the issues they're having, and I would have to conduct

**II If I'm solving a problem I have, I understand what the crux of the issue is and how to make it better**

a lot of interviews and things like that. But if I'm solving a problem I'm having myself, I understand immediately what the crux of the issue is and how to make it better. If you solve the problem in a way that makes it significantly better for me, maybe it'll make it significantly better for another person.

"I have a full-time job, a 40-hour a week job in software development. On top of that, I can easily put in eight hours, ten hours a week making hardware. Sometimes you'd have a really busy week, sometimes a quiet week. When I started out, I used

to pack pretty much on demand; I would go get the pack and put all the parts in it, but I found that was really inefficient from a time point of view.

"If you bought something off me and I had to get down all the boxes, put one kit together and then put everything away, it was quite inefficient. Oftentimes on a Saturday, my wife and I would just bag up kits ahead of time.

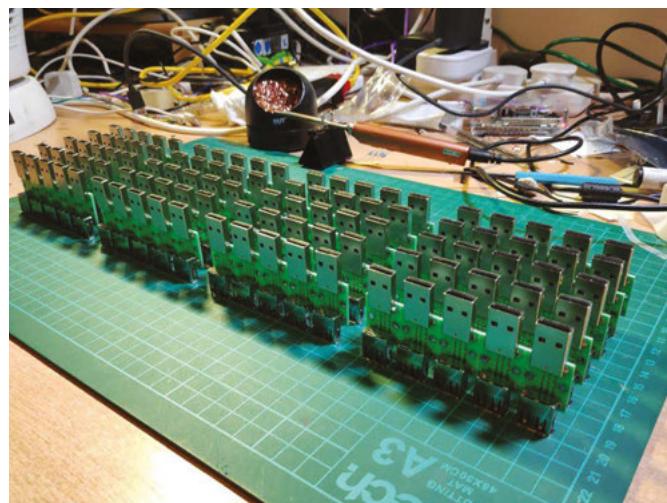
"I've tried really hard to reduce the amount of time it takes me to pack orders to an absolute minimum. I was writing the address by hand, and I have terrible handwriting, so that's a big problem. If I write badly, then it doesn't get to you!

"I've optimised now though; where it was taking me a couple of minutes to print out a label, it now takes me seconds. If you've made an order with me, I could have it processed and ready to go out in two minutes now.

"It takes the pressure off you too – I found that whatever was on my plate, when someone is giving you money for something, it automatically becomes top of the list, whatever else you're doing. Context switching is a bit of a problem too – five evenings a week, you've packed one thing, and maybe the process of packing only took you five minutes, but the cleaning up afterwards and all that stuff... it's just so inefficient at times.

### MAKING FOR MAKERS

"Sometimes it can be really busy. The matrix shields recently I've been selling a lot of. They're the display that normally would make up large displays in a soccer stadium or whatever. You can buy individual panels of them, and you can control them with Arduinos.



**Right** The Power Blough-R is even in a retail shop in the USA



"They're really nice displays. They're not particularly difficult to connect an Arduino to, or an ESP32, but the matrix shield makes it a lot easier, because you just drop the shield into one of the ports, use the ribbon cable that comes with the display to connect to the other one – that looks after power because it has a barrel jack on it.

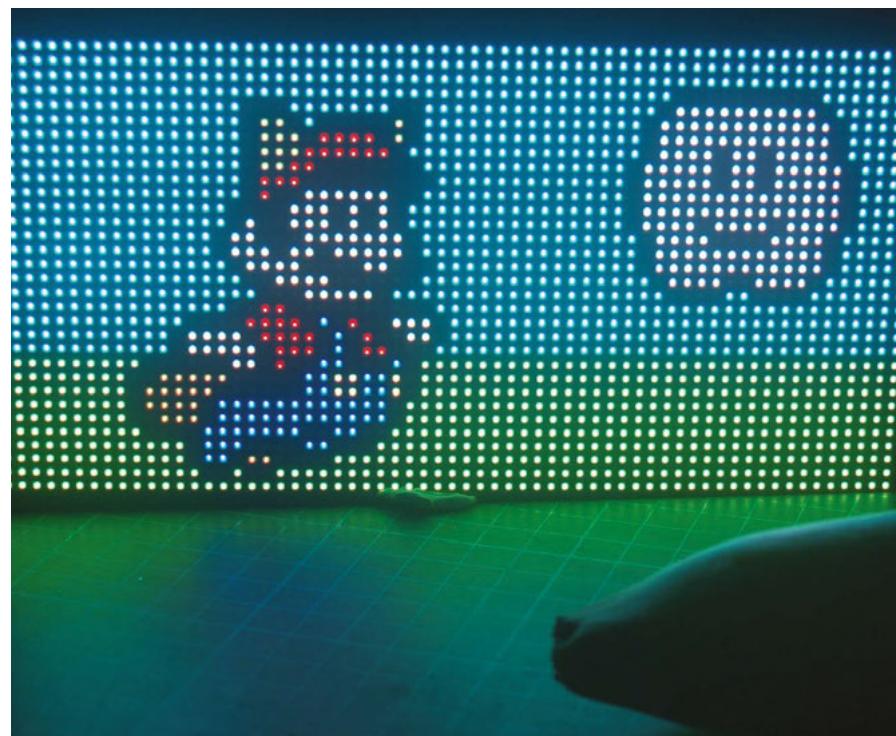
"It tidies things up, makes it less prone to error, it's a bit neater as well. They've sold really well over the summer. There are a couple of people in the States on Twitter who have been playing around with these pixel purses: Les Pounder took one apart in the magazine, Emily Velasco is one of the two people I was talking about, and Geek Mom Projects is the other one. When people ask Emily what's controlling her project, she tells people she's using my board, and links to it. That has given me a boost.

"I'm happy enough for it to be a side project. At the moment it funds the other stuff I do; it's nice to not have to worry about the money you're spending on electronics for projects.

"Tindie's great – I think because it's targeted at makers. I think, in general, makers are a pretty good community and pretty friendly. As I mentioned with Emily, she seems to be happy to tell people about it any time – people go 'Hey, what are you using to make it run?' She could just say 'Oh, it's an ESP32', but she does go out of her way to link to the board and things like that. People, if they get the board, seem happy to talk about it on Twitter. If they develop code for it, they always seem to be happy to share it back, and let me use it to show off the board's features. Some of the coolest things that come out

of it are not written by me, but by other people. It's very nice. I haven't had any negative experiences in selling to anybody at the moment. A couple of times things have gone missing in the post, but people have always been happy to take a refund, or for me to send it again. I haven't had any negative issues. Let's hope that continues for the next year as well." □

**Above** Brian's builds are electronically simple, but they have real-world uses



# Fixing wizard

Share and share alike (your skills)



**Lucy Rogers**

 @DrLucyRogers

Lucy is a maker, an engineer, and a problem-solver. She is adept at bringing ideas to life. She is one of the cheerleaders for the maker industry, and is Maker-in-Chief for the Guild of Makers: [guildofmakers.org](http://guildofmakers.org)

**A**re you the friend that everyone brings their broken things to for repair? Are you the tech 'wizard' who has to work out what they have done to break their phone/computer/television and then fix it? I get a buzz out of fixing things. It's not a natural talent of mine though – but I do have a lot of tenacity and make great use of the internet – so eventually things usually get fixed. I like the accumulation of knowledge I get from it – it gives me greater confidence to fix things in the future.

However, sometimes, it feels like I get taken for granted.

When it's a fair trade of time, it's fine. For example, if in return for my making or fixing skills, a meal is cooked for me, clothing is mended, the dog is walked, or I get lifts to places – these all make me feel my time and effort is valued and appreciated.

But there are only so many "thank yous" I can take before I feel like I'm enabling lazy behaviour, rather than helping someone out. Instead of helping, I am encouraging them to rely on me. I let people think, "Why should I even try to fix this when Lucy enjoys fixing things".

If challenged, this laziness is obviously denied – people say "Oh, but you're so much better at it than me", or "But you find this stuff easy". I'm only better at it because I have done it more often!

What isn't said, but what I can now hear is, "I really can't be bothered to think about or do this".

A friend told me a story recently – her brother (in his forties) got huge kudos for having bought their mother a birthday present from a high street clothing store

**Our joy in fixing, mending, or making can easily be tarnished by the reaction of others**

– complete with receipt. The positive comments he got for doing this "on his own" – without help from his wife or sister – were considerable. My friend has been buying presents for her mother from

her father since her twenties. And not once was it commented upon that this was wonderful. In fact, it only made her father more likely to ask her to do other chores he didn't want to do. I hear it's the same with nappy changing in some households. And putting up shelves, or checking tyre pressures.

Our joy in fixing, mending, or making can easily be tarnished by the reaction of others. I am sure I have been guilty of not appreciating the efforts of others in the past. Maybe it's time for some honest discussions with our friends and families. □

# Two years young

So long, and thanks for all the fish



**Bunnie Huang**

@bunniestudios

Andrew ‘Bunnie’ Huang is a hacker by night, entrepreneur by day, and writer by procrastination. He’s a co-founder of Chibitronics, troublemaker-at-large for the MIT Media Lab, and a mentor for HAX in Shenzhen.

**S**ince HackSpace magazine launched about two years ago, a lot has changed. We’re now on to Raspberry Pi 4. It’s an exciting development that continues the trend of narrowing the gap between what’s found in bleeding edge mobile phones and entry-level maker hardware. Meanwhile, chip foundries have managed to finally bridge the EUV (Extreme Ultraviolet) lithography chasm, promising to unlock a flurry of improvements in performance and transistor density. We’re also finally getting a sneak peek at what’s beyond Moore’s Law: researchers at MIT have managed to fabricate a functional RISC-V microprocessor out of carbon nanotubes, while researchers at Google have laid claim to the mantle of quantum supremacy, albeit on a very specific problem.

A lot has also changed in the world outside of technology. At the time of writing, the UK hangs on the edge of a hard Brexit. The US president is facing an impeachment inquiry. The #metoo movement continues to unseat patriarchs. Hong Kong is filled with unrest.

The stark juxtaposition of the progress in technology, against the turmoil in politics, reminds us that there may be a larger role in society that technologists

can play. However, it’s worth remembering that all technology is fundamentally dual-use: controlled fire cooks food; unchecked fire burns down villages. Smartphones have brought us closer to each other; but they also expose us to greater surveillance. Drones aid exploration of land, sea, and space; but also deliver bombs. AI helps us access and process more information; but also helps spread more disinformation.

Fundamentally, I’m a technology optimist. I believe that a utopian *Star Trek* future, where technology has eliminated poverty, making space exploration the primary mission of the human species, is a possibility. However, in order for that world to be realised, the primary utility of fantastic technologies like the replicator needs to be for making ‘Tea, Earl Grey, Hot’, and somehow not for making weapons.

**We can build anything if we put our hearts and minds to it, but the trick is knowing what to build**

There’s a lot going on in the world, and I need time to reflect, grow, and invent. As such, this is my last column for HackSpace magazine. We can build anything if we put our hearts and minds to it, but the trick is knowing what to build. So, instead of writing, I’ll be taking the time to explore and connect. Meanwhile, I look forward to watching this community continue to grow and flourish. Happy hacking! □

# 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](http://hsmag.cc/hello)

### ELECTRICK FLAPJACK

The guitars made by Michael Dales at Makespace Cambridge look fantastic. I started out the same as Michael, taking the electronics and neck of an old guitar and adding it to a body I'd made myself. It was scratching my own itch because I wanted a Flying V, but I found that the Gibson/Epiphone models in the shops are really thin and flimsy. So I made my own V-shaped body out of a bit of oak. The thing weighs a ton!

If I ever get around to making a neck (unlikely given how hard it looks), I'll use his system for laser-etching the fretboard markings. Thanks for sharing!

**Jamie Rider**

West Mids

**Ben says:** Give a man a fish, and you feed him for a day. Give a man a ready-made way of calculating fret distances for a given scale length of guitar, and you've done the world a favour. We're amazed that Michael is so happy to help other people with their projects – but that's makers for you.



### THE TELLY BOX

Top Tip: get on the BBC iPlayer and look for *The Big Life Fix*. It's a bunch of makers, making things to help real people, and it's excellent. That is all!

**Dave Smith**

Swindon

## DARKNESS FALLS ACROSS THE LAND

Cheers for the Halloween stuff last issue! As far as I'm concerned, it's a poor man's Bonfire Night, but the kids love it and they pester me every year to help them make scary stuff. It's like Christmas; it gets earlier and earlier. This year they started in September, so the magazine came at the right time. I'm thinking something with hydraulics and fake blood...

**Daniel Greeves**

London

**Ben says:** The science on ghosts and ghouls isn't settled yet, but whether or not you believe in things that go bump in the night, Halloween is a brilliant excuse to make something daft just for the sake of it. Just make sure the kids share their sweets with you when they get back from trick-or-treating.



## BRAZE YOURSELF

I had no idea brazing was that easy [as demonstrated in issue 23 by Andrew Lewis]. In fact, scratch that, I'd never heard of it. I can solder, but I always thought I'd never have the space/budget/fire-resistant trousers to try welding, so I've never had a go at sticking bits of metal together. Thanks for showing us non-welders how easy it can be!

**Dietmar**

Hamburg

**Ben says:** When I first tried welding, I was rubbish at it, but it felt amazing. The power to join bits of metal is a completely different feeling to my normal making. Thanks for the feedback on this from everyone who's written in; we want to get as much variety in the magazine as possible, so it's good to know what's struck a chord.

# CROWDFUNDING NOW

## Surf window

The Internet of Beaches and Reefs

From \$299 | [kck.st/30gBTnR](https://kck.st/30gBTnR) | Delivery: June 2020

**S**creens have become the default way of displaying data. They're cheap (depending on size), easy to use, widely available, and... pretty boring. In our view, they're unpleasant to look at as well. Perhaps we at HackSpace magazine towers are just a bit too old and crusty, but we really like displays that are a little more inventive. The Surf Window is a great example of this. It uses motorised plywood to create a display that is, by itself, interesting to look at, but that also provides useful data about the conditions at the local surf break.

Of course, the downside of bespoke displays is that they're single-purpose. This display only shows information about surf conditions. In our opinion, that's a small price to pay for an object that's an interesting curio in its own right. The actual price is not so small, at £299 (for the early bird). That pays for what is obviously quite a lot of love and attention to detail in this build.

Regardless of whether you're thinking of buying this, we'd recommend taking a look at the Kickstarter page. The video takes you through all the information that's shown on the display, and this may also give you some inspiration if you're thinking of building a display for other data. For surfers, this one is a great way of keeping an eye on your local break when you're not close enough to see it. For non-surfers, it's a great example of a data-driven curio to inspire mantelpieces around the world. Let's make the 'Internet of useful, beautiful Things'. □

It uses motorised plywood to create a display that provides useful data about surf conditions



---

## 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.



SURF WINDOW

# Space of the month: STEAMhouse



## STEAMhouse

- [steamhouse.org.uk](http://steamhouse.org.uk)
- [STEAMhouseUK](https://www.facebook.com/STEAMhouseUK)
- [@STEAMhouseUK](https://twitter.com/@STEAMhouseUK)

**S**TEAMhouse differed from most spaces we've been to. The usual paradigm is that everyone's welcome, for a small fee, finances are tight, and there's a range of ages and seriousness to the makers there. This is a different offering entirely. It's part of Birmingham City University, it's open to businesses (this includes sole traders and people who are just starting out and who need a leg up), and there's a focus on product development. This is a place for people who want to get things done.

"You have to be a member to use STEAMhouse", Business Development Manager Sophia Tarr tells us. "To be eligible to be a member, you have to be a company or have a Unique Tax Reference. The application isn't difficult; the most important things we need to know are what it is you're trying to do; what product idea you want to work on. We take the time to go over your idea with you, and see what we can offer you. We don't like to say no!"

“We take the time to go over your idea with you, and see what we can offer you”

"You don't have to have a business plan, because a lot of the time, especially with the business route, they're obsessed with getting a business plan, and actually they haven't even got their concept together. A good business plan has to be a live document, as well. Some people do one; it kills them. There's something called a concept overview that people do instead of a business plan. It has a lot of the same information, but is much less detailed. If you go for massive amounts of funding, you will need a business plan, because [anyone willing to put money in] will want to see that you've thought about it." →



Right ♦  
"You get to work with a technician who has expertise in your area - I think that's what makes us unique as a makerspace or innovation space"



## Space of the month

### REGULAR

#### Right ♦

STEAMhouse doesn't have two members doing the same thing, which is really exciting – there are furniture makers, a luthier, electronic music makers, artists, and all sorts

#### Below ♦

Everyone has to do a one-hour induction, regardless of previous experience





## 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](mailto:hackspace@raspberrypi.org) with an outline of what makes your hackspace special, and we'll take it from there.



"It's such a curse that people think you've got to do one straight away when you don't even know what you're making yet. We wouldn't put that pressure on you."

STEAMhouse employs a team of technicians to help its members in the area they're working on – the four specialisms are metal, wood, print, and digital design. It feels like a formalised version of the makerspace phenomenon where there's often someone on hand to help out, with the exception that the experts here keep regular hours, and you won't feel like you're pestering them or stopping them from getting their own work done.

## TEARDOWN

Like the Royal Marines, the STEAMhouse experts want to take your idea to bits and rebuild it stronger: "We have two dedicated teardown spaces," Sophia tells us. "Some of the companies don't want to do the teardown, but they always come out smiling. A lot of the designers go through the teardown process, and also get 3D models out of it to help them refine the design, so it's a useful process." This is something we'd not seen before: a formal recognition that breaking something is a key part of making it better. We talk about failure being iterative [and it is!], but if you can take a concept to bits in the presence of an expert, and let them guide you through likely failure points or ways you can make the manufacture cheaper, you might save yourself months or years of trial and error.

The makerspace itself is huge and full of goodies – there's a woodworking area with band-saws, a steamer for bending wood for furniture, a huge CNC machine, many, many metalworking tools including a welding station, an area for print and textiles, plus a load of computers with all the 3D design software you'll ever need.

So what are the fees? "STEAMhouse is fully funded, so you're not charged for anything. It's a combination of European funding, Arts Council England, and Birmingham City University; you just need to demonstrate that you've done twelve hours working within STEAMhouse to become a member. That's not twelve hours a week; that's twelve hours full stop. And if you have a meeting or any inductions here, it counts towards those hours."

If you're interested in making tables and chairs and you have no experience of doing that, STEAMhouse isn't the right place for you. But, if you've got a design idea or a prototype, and you're local to Birmingham, this is a fabulous resource. □

**Below** STEAMhouse had 30 grants available for its members for Phase 1, worth £2500, one-third of which is earmarked for intellectual property advice; the remaining two-thirds are for prototyping materials



# Wuthering Bytes Festival Day 2019

Geeking out in Yorkshire

# W

**Wuthering Bytes is an amazing event that takes place over a week in the picturesque and vibrant Hebden Bridge in Yorkshire each year.** This year was the seventh Wuthering

Bytes, and we were lucky enough to attend the opening Festival Day and spend a little time there that weekend. Wuthering Bytes is a collection of events with an opening Festival Day on the Friday featuring a plethora of talks, and then OSHCamp takes over the weekend with a day of talks followed by a day of workshops. Something is happening each day of the week, including more in-depth workshops and an open day at Hebden Bridge's makerspace Bridge Rectifier. There have been some amazing activities over the years, from igniting a large rocket motor in the town to flying high-altitude balloons.

This year's Festival Day featured a great range of talks, ranging from Dr Heather Williams on nuclear

**Below** This fantastic badge for all Festival Day attendees was a lovely welcome to the event



medicine and how PET scanners work, through Michael Dales's approach to making electric guitars; space and satellite talks from Ben Cartwright and Jo Hinchliffe; Badgeline by Jenny List; Muriel Howorth and atomic gardening by Sarah Angliss. Drew Fustini of OSHPark gave a great presentation on the current state of play of single-board computers that are capable of running Linux. It's fair to say the Festival Day was fascinating from start to finish.

**There was a real sense of community, with lots of areas of maker and hacker culture represented**

The MC for the day was Dr Laura James, who kept everything running to time and well managed, and the venue was excellent with everyone well fed and watered. There was a real sense of community, with lots of areas of maker and hacker culture represented. In terms of both audience and content, it felt like one of the more diverse technology events we'd attended.

**Below** Electronic design engineer, programmer, and contributing editor to Hackaday Jenny List gave a great talk about Badgeline and how we can make them useful beyond their event



**Above ♦**

Drew Fustini from OSHPark gave an excellent talk on his quest to research every Linux-capable single-board computer

The Festival Day finished with drinks, nibbles, and music in the bar, while the early evening talk on Tesla coils was set up in the main room. Derek Woodroffe (Extreme Electronics), whom we featured in issue 16, delivered this fantastic final talk of the day which not only looked at the technical aspects of Tesla coil construction but also its history and Tesla's work. Culminating in an audible rendition of Kate Bush's 'Wuthering Heights' played by two larger Tesla coils – a memorable finale!

Saturday marked the start of the OSHCamp weekend, and attendees piled in to hear the talks. The talks were focussed and technical, but all speakers went to great lengths to make their talks as accessible as possible. Many of Saturday's speakers were also scheduled to run workshops on Sunday, and were therefore laying out some theoretical



groundwork so that attendees on Sunday had some theory knowledge ready to apply. It was an excellent day, with subjects ranging from Ken Boak's talk on the TTL Gigatron computer through to the architectures of RISC-V chips. The Wuthering Bytes festival continued over the following week.

Thanks to the organisers, speakers, hosts and the sponsors for putting on a great festival. Wuthering Bytes are keen to hear from you if you have an idea for something you would like to run at next year's events – get in touch with them via the festival website: [wutheringbytes.com](http://wutheringbytes.com) □

**Above ♦**

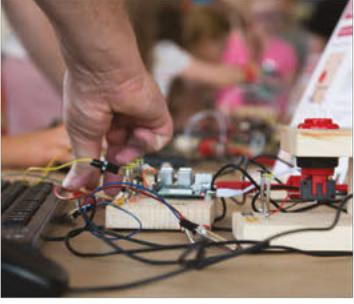
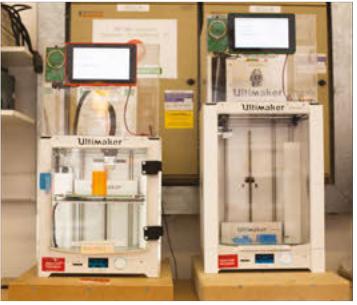
Spencer Owen, creator of the RC2014 – a retro computer kit built around the Z80 microprocessor – was a sponsor of this year's OSHCamp weekend events. Each attendee got a free RC2014 Micro kit to build

**Above ♦**

Derek Woodroffe, of Extreme Electronics, finished off the Wuthering Bytes Festival Day with a spectacular talk both about and featuring Tesla coils!

**Left ♦**

Wuthering Bytes takes place in the small town of Hebden Bridge, which is a fabulously welcoming town with plenty of beauty spots



# Build a Makerspace for Young People

Join our **free online training course on makerspace design** to get expert advice for setting up a makerspace in your school or community.

Sign up today: [rpf.io/makerspace](https://rpf.io/makerspace)



Raspberry Pi

The Raspberry Pi Foundation. UK registered charity 1129409

#RPiLearn

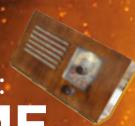
# LENS

HACK | MAKE | BUILD | CREATE

Uncover the technology that's powering the future

PG  
**56**

## HOW I MADE: **WW2 TIME MACHINE**



How a refurbished radio and a Raspberry Pi provide a portal to the past

PG  
**62**

## IN THE WORKSHOP: **TAILOR-MADE LAPTOP**

A dual-screen ruggedised Raspberry Pi-powered machine for doing real work.

PG  
**66**



## INTERVIEW: **EBEN UPTON**

Wales is the new China, 4 is the new 3, and doing the right thing is still doing the right thing

PG  
**36**



PG  
**74**

## IMPROVISER'S TOOLBOX: **BINDER CLIPS**

Let your imagination run free with affordable, bendy bits of metal



# BREWING

BEER • CIDER • MEAD • KOMBUCHA

MAKE DELICIOUS DRINKS  
OUT OF HONEY, APPLES,  
LEAVES, OR BARLEY

# B

**rewing alcohol is an ancient art.**

There's evidence from Israel of 13,000-year-old beer, and it's possible that the use of alcohol predates modern humans – fallen fruit can contain a significant percentage of overripe fruits from palm trees (studies have found overripe fruits from palm trees can average 4.5% ABV), and this could have been part of the diet of our ancestors.

Over the millennia, we've developed new and interesting ways of creating alcohol. We say interesting because it's not all about creating alcohol, it's about the process of fermenting with yeast to create new and interesting flavours.

Alcohol can be a part of this, but it doesn't have to be. Take a look at the section on kombucha (page 46) for a look at fermented drinks that don't intoxicate. We're going to look at four drinks that we think highlight the different approaches to fermenting. →

BEN  
ere!  
woz

CIDER



# W

**e start our fermentation journey with mead – one of the oldest alcoholic drinks.** We'll start with it because it's an easy place to start; the ingredients and processes are all easy to understand.

The resulting drink is pleasing and can be tweaked to suit different tastes. Let's first look at the very basics of alcoholic fermentation. There are two things you need to create alcohol: yeast and sugar. There are many forms of both that work. You'll find yeasts labelled ale yeast, cider yeast, wine yeast, and many more in brewing shops. These are actually the same species: *Saccharomyces cerevisiae*. The different strains produce different flavours, but all work in the same basic conditions. You won't generally find specialist mead yeast, so you'll have to improvise a little. For 'clean' flavours like you get in mead, we use cider or champagne yeast.

The second thing you'll need is a form of sugar. In mead, this comes from honey, but there's nothing particularly special about honey (other than the fact that it tastes nice) – most forms of sugar will work. There

are a few fermentable sugars like lactose, but you're unlikely to have trouble with these unless you're doing something particularly unusual.

#### The process for basic alcohol fermentation is:

- Prepare your liquid
- Add the yeast and allow it to colonise the liquid
- Remove any oxygen
- Wait
- Drink

There are a few things you need to keep in mind at each stage. In step one, you're creating a liquid with a large sugar content. This sugar content affects the final drink in two ways: its sweetness and its alcohol content. Yeast will keep on consuming sugar and producing alcohol until one of two conditions is met – either it runs out of sugar, in which case you have a dry drink, or the alcohol content exceeds the level yeast can survive (usually around 14–16% but it depends on the strain of yeast). This means that with this process, you can't create a weak, sweet drink. You can create a weak, dry drink or a strong, sweet drink (we'll look at ways of getting around this when we look at cider).

At step two, you add yeast and allow it to colonise the liquid. Although yeast needs an oxygen-free environment to create alcohol, it grows much better in the presence of oxygen, so this step is usually done in a container that allows air in.

Steps three and four are when the fermentation happens. Yeast only produces alcohol in an anaerobic



environment, so we need a way of removing any oxygen. In vigorous ferments, we can just leave the container open, and enough carbon dioxide is produced to stop too much oxygen getting in. However, in less vigorous ferments, we need to seal the brewing container. As the liquid ferments, yeast produces carbon dioxide, and we need a way to let this out. The usual way of letting gases escape without letting air in is via an S-shaped 'airlock'. This is made in such a way that it contains a small amount of water that lets gases bubble out, but none get in. There is a second reason for adding an airlock – if oxygen gets in, it allows acetic acid bacteria to convert the alcohol into acetic acid, which turns your lovely mead into vinegar.

**Above ↑**  
There's a wide range of honeys available, and all should work

## HONEY

Honey varies hugely in price and flavour. We suggest starting with cheap honey – the yeast doesn't care. Once you've mastered the brew, you can try more expensive honey if you wish – or try some other ways to adapt the drink.

#### GET BREWING

That's enough of the theory, let's get down to the business of making mead.

You don't need a lot of equipment to make mead. At the very least, you'll need a container in which to ferment the mead and a means of stopping air getting in it. With stronger drinks like wine and mead, this is typically a glass demijohn and an airlock, but you can use more hack-y solutions. When this author first started fermenting, he used two-litre soda bottles with balloons →



M E A D

**Left ←**  
Most brews start with dried yeast granules, but it's also possible to brew with wild yeast from the air

MEAD

## BOTTLE BOMBS

Yeast will convert sugar into alcohol and carbon dioxide as long as it can, and it can survive at high pressures. If you bottle your drink while the yeast is still working, it will build up pressure inside the bottle. This can result in a pleasant fizziness if controlled, or it can result in too much pressure building up and the bottle exploding. Make sure your ferment has stopped before bottling, either by using a hydrometer (the reading should be static and at the expected level given how much alcohol should be produced), or by giving it plenty of time to finish before bottling. If you're unsure, keep the drink chilled (yeast is inactive below 14°C) and drink it!

In the next section, we'll look at adding a little fizziness to our drinks.

**Right ↗**  
An airlock lets carbon dioxide escape, but doesn't let oxygen in

stretched over the necks. If you put a few pinpricks in the balloons, these will open up when the gas pressure inside is greater than outside and let carbon dioxide out, but then close up to stop any oxygen getting in. It's not perfect, but it can work if you want to try out brewing before committing to purchasing equipment. For larger quantities, you can get larger fermentation vessels that also take airlocks.

It's also useful to have

a funnel to get the liquid into your brewing container especially if it has a small neck.

In step one, we need to produce our liquid. This is simply honey and water. We made a gallon of mead as this fits nicely in a standard demijohn, but you can adjust the amounts depending on your brewing containers. Our preferred mix is 1.6 kg of honey per 4.5 litres of total liquid (this quantity fits nicely in a one-gallon demijohn). This will ferment out to a



Follow the instructions on the packet, but typically you'll need around one teaspoon per gallon.

We've never had any problem using chlorinated tap water, but if your water is particularly heavily chlorinated, you might want to take steps to dechlorinate it (such as boiling and leaving to cool) before adding.

Make sure that the liquid has cooled to room temperature (or at least below 30°C), then add the yeast. Yeast usually comes in 5g packets, which can make up to five gallons.

There's no harm in adding too much, so we usually split one packet between two or three demijohns. Pour your yeast for the brew into a glass of lukewarm water with a pinch of sugar added, and wait for it to start to froth a little and smell like baking bread. This may take up to

half an hour. Once it's showing signs of life, pour this liquid into your brewing container. Give the brewing container a good shake or stir and cover it with a cloth.

### SETTLE DOWN

After a day or so, the liquid should have gone cloudy and started bubbling. At this point, put the airlock on and leave it to ferment. It may ferment very vigorously for the first few days before settling down to a more mundane pace.

## MORE THAN 2KG WILL PROBABLY BE TOO SWEET

strong, slightly sweet mead. 1.4 kg of honey will give a dryer mead, and anything up to about 2kg will give progressively sweeter meads (more than 2kg will probably be too sweet for even the most sweet-toothed brewers). The easiest way of doing this is to mix the honey with about two litres of warm water in a bowl or pot, then pour this into the brewing container before topping up with cold water.

This contains all the sugar that the yeast needs, but, like us, yeast needs vitamins to survive. The easiest way of adding these is with yeast nutrient.



## CLEANLINESS

To give your ferments the best chance of success, it's a good idea to keep everything sterilised using either baby bottle sterilisers or specialist home-brew sterilisers. Make sure you fully rinse off the sterilising liquid to avoid it flavouring the final drink, and follow the instructions for your sterilisers.

Also, pay attention to your own hygiene – keep your hands and fingernails clean.

Honey contains two sugars: glucose and fructose. The glucose will ferment very quickly, followed by the fructose at a more sedate pace – it may take a month or two to fully ferment, depending on temperature.

Once the bubbling's stopped, your mead should be ready to bottle. If you're using a hydrometer, then you should see the reading stay stationary for a week or two. There are loads of options for bottling – the key thing is that it's food-safe and airtight. You can reuse beer bottles (hand-operated cappers are cheap and widely available) or wine bottles (corking devices are easy to use), or you can purchase home-brew bottles with swing tops. Whatever you use, make sure the bottles are clean, and follow the instructions for sealing the bottles if using caps or corks.

You can drink your mead straight away, or let it age to soften the flavours. After about a year it should be at its peak. ➔



## HYDROMETER

You can brew perfectly well without monitoring anything, but if you want to keep an eye on your brew, a hydrometer is the most basic piece of measuring equipment. It tells you the amount of sugar in your liquid. This is particularly useful as you can calculate the amount of alcohol in your drink by seeing how this changes, using the formula:

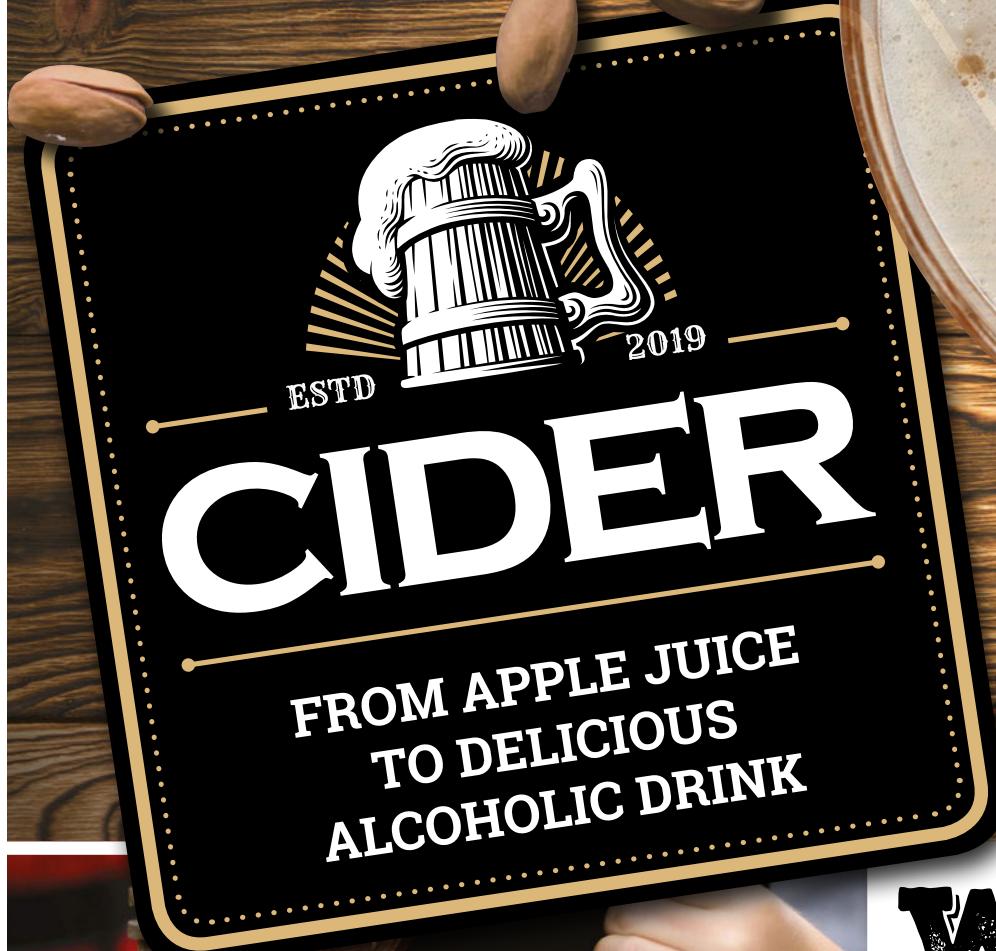
$$\text{ABV}(\%) = (\text{Initial Gravity} - \text{Final Gravity}) \times 131.25$$

You can also make sure that all the sugar has been metabolised before bottling, to avoid exploding bottles.

Hydrometers are basically graduated sticks that only just float. Pour a bit of liquid off into a measuring cylinder that's big enough for your hydrometer, then drop the hydrometer in. You read the hydrometer at the point it breaks through the surface of the liquid (level with the surface, not the 'ramp' up to the edge of the hydrometer). For accurate readings, make sure the liquid is close to 20°C, and free of any carbonation (pour the liquid between a few containers to get rid of carbonation if necessary). Unless you sterilise your measuring equipment, it's safest not to pour this liquid back into the fermenting container – we prefer to only measure occasionally and drink the liquid to get a sense of how the flavours are developing.

**Above ↗**  
You can use a hydrometer to measure the amount of sugar left in your drink (shown here on finished cider)

**Left ↙**  
A demijohn (known as a carboy in America) is a fermentation vessel designed to take an airlock – they're traditionally glass, but plastic ones are available



**Above ↑**  
Pressing apples is a fun way of starting cider, but we'll start with the more available apple juice



APPLES!

# W

ith mead, we created a sweet liquid and added yeast. We'll use the same basic processes with cider, but there are a few things we need to do differently.

We'll begin by assuming that you don't have access to an orchard of cider apples, a scrapper, and a press, but if you do, take a look at 'Starting with apples' (overleaf). Fans of traditional cider had better have a sit down before reading this because we're about to get modern.

There are many types of apple, and not all of them make good cider. There are a few things that affect how your final cider will turn out:

- **Tannins** – These affect the 'dryness' of the final cider. Apples without much tannin, if fermented out of all their sugar, will end up watery rather than dry.
- **Acid** – Apple juice can be surprisingly acidic – usually between pH 3 and pH 4. Again, this contributes to the 'dryness' of the drink.

T  
urnins

## SAFETY

There are persistent rumours that home-brewing is a dangerous hobby. This is almost entirely people getting confused between the risks of distilling alcohol (i.e. making spirits), which can be dangerous and is illegal in many countries, and brewing (i.e. making low-strength drinks – below about 20%), which is legal in many countries (but check your local regulations) and very safe.

By far the most dangerous thing about home-brewing is the alcohol – make sure you drink responsibly. As long as you pay attention to hygiene, and don't drink something if your nose or taste buds tell you not to, you shouldn't run into problems.

- **Sugar content** – Natural apple juice varies a bit in sugar content, and will usually ferment out to between six and eight percent alcohol.
- **Flavour** – This is more-or-less what you expect – apples with a good apple-y flavour often make better cider, but the flavour is heavily dependent on the sugars, so dry ciders can taste less apple-y than apple juice, hence you want apples with a strong flavour.

There are many different traditions of making cider. This article is being written in Bristol, which is in the heart of the 'West Country', a traditional cider-making region of the UK where specific varieties of cider apple are used. There are hundreds of varieties, and it was common for each village – often each farm – to have their own variety of apple. These cider apples are very high in tannin and acid. If you ever accidentally eat one, it'll turn your face inside out.

## TEMPERATURE

The warmer your liquid is, the faster it will ferment. This isn't necessarily a good thing, as fermenting too fast can introduce some strange and unwanted flavours into your drink. Under about 16 °C, yeast usually stops fermenting. It's not a problem if it does this occasionally as it will begin fermenting once it warms up again, but you probably don't want to leave it too long.

In general, you probably want to try to keep your ferment below about 25 °C.

Different fermenting temperatures will result in different flavours in the final drink, and you can get very serious with temperature-controlled apparatus. Makers often use old fridges as the base of temperature-controlled spaces for brewing, and devices such as the BrewPi ([brewpi.com](http://brewpi.com)) make it easy to build your own DIY setup. While this can be a fun and interesting angle to perfect your brews, it's absolutely not necessary to go to this level of precision to create delicious drinks.

In other cider-growing regions, it's more common to use multi-purpose apples. A mix of high-acid cooking apples (such as Bramley) and eating apples is a common way of creating a juice that tastes good after fermenting (though it lacks the tannin kick of a West Country cider). In Northern France, eating apples are used, but a process known as keeving is used to prevent them fermenting all the way to dry, and they get much of their flavour and mouthfeel from sugar in the final product.

As we've assumed you don't have an orchard of apple trees, and buying apples commercially is a very expensive way of making cider, we'll have to turn to →



**Left ↪**  
Your brew will initially foam brown. This will soon die back to a much smaller white foam, but leave a residue on the fermenting vessel



**Above ↑**  
You can give body to your cider by adding powdered tannin – about one teaspoon per 4.5l of apple juice

## RERACKING

As any drink ferments, you'll see sediment collect on the bottom of the brewing container. This is known as the lees, and it's dead yeast. If the drink sits too long, it can impart a slight flavour on the drink. To reduce this, many longer-fermented drinks are 're-racked' or poured into a new fermenting container leaving the sludge behind. This is usually done once the ferment has slowed down and almost finished to allow the long, slow final bit to take place without the risk of imparting off flavours.

On drinks with strong flavours (like mead and cider), it's not very noticeable. So if you only have one fermentation vessel, or if you forget to re-rack it, it's not a big problem.

in tannin and low on acid. If you add yeast and ferment it, then you'll end up with a very disappointing drink – something like slightly apple-y water with a shot of vodka poured in (but worse). We need to convert this apple juice into something more akin to cider apple juice before starting, and there are two ingredients that we can use:

the only source of liquid apple that's commonly available – apple juice.

Yep, the stuff you get at a supermarket (we hope you traditionalists took our advice to sit down before reading this).

There are a wide variety of types of apple juices on offer, and we've had reasonable success with all the ones we've tried. It's a great area to experiment in, but the basic 'from concentrate' stuff is a good starting point.

This apple juice is low

## SWEET CIDER

We've talked quite a bit about fermenting to dry, but many people prefer their cider with a little sweetness. There are a few options here. The simplest way is to ferment to dry, then add a little apple juice to it as you drink it, and that's the way we'd recommend you drink this cider – even if you like a fairly dry drink, a little juice really adds more sparkle to the flavour. It doesn't have to be apple juice that you add – a little cordial can also add a little sweetness. Blackcurrant is the most famous option here, but we've been particularly enjoying our home-brew with ginger or elderflower cordial recently.

A second option is to add a non-fermentable sugar to the cider such as lactose, or an artificial sweetener.

The traditional way of making sweet cider is called keeving, and it's a strange process that removes some of the nutrients from the apple juice so that the yeast dies of malnutrition before it has fully fermented the sugar. It can produce excellent cider, but it's a difficult process to perfect.

- **Grape tannin** – This is a powder that you can add to your juice to give it more dryness in the final cider.
- **Malic acid** – This is the acid that's naturally present in apples.

Shop-bought apple juice usually has about 11 grams of sugar per 100 ml (see your packet for the actual details). This will ferment out to around

## DON'T USE OLD WINE BOTTLES

6.5% alcohol by volume. You can add more sugar if you like (we've had success in the past by adding honey to take it up to a wine-strength drink), or water it down for a lower percentage.

In theory, you shouldn't need yeast nutrient for cider, as apples should contain the full range of

# STARTING WITH APPLES

If you've got access to a large number of apples, then that's a great starting point.

The first thing you'll need to do with your apples is to convert them into juice, which is a two-stage process. Firstly you need to scratch them, which is basically the process of breaking them up into small pieces. Most small-scale scratchers are hand-cranked machines that take the form of two spiked wheels rotating against each other. Put apples in, turn a handle, and out comes apple pulp.

This apple pulp needs to be pressed to extract the juice. There are two common types of press: basket presses and cheese presses. In basket presses, you load the pulp into what looks like a barrel with gaps between the planks, then a screw press at the top

squeezes down on it to extract the juice. In cheese presses, the apple pulp is loaded into sacks, and these sacks are loaded into the press in a pile (with planks of wood between the presses to stabilise the pile). This pile is then pressed, again using a screw-thread press.

You can improvise your way of doing this if you want, but be careful as the forces needed to extract juice from the pulp are very large and if anything goes wrong, it can go badly wrong. A less risky option is to take your apples to a communal press. These travel around the country in autumn, and you can turn up with your apples and leave with bottles full of your own apple juice to either drink now or ferment for later. Search for local 'apple days' to find one near you. National Trust properties are common locations.



vitamins and minerals that yeast needs. However, we usually add a little just to be safe.

As with mead, we make our cider in 4.5 litre demijohns, but other containers will work – scale up or down the quantities as needed.

Add 4.5 litres of apple juice, one teaspoon of grape tannin, and one teaspoon of malic acid (you can adjust these up or down slightly, but we recommend these levels for your first batch). Once that's all mixed up, pitch the yeast in the same manner as with mead, and leave to ferment.

Once the bubbling has stopped, your cider is ready to bottle. If you like still cider, you can bottle it as we did with the mead (just syphon it into bottles and protect it from oxygen). However, we can also make fizzy cider. To do this, add a half a level teaspoon of sugar per 500ml to a bottle before capping. This will be fermented by the yeast and produce enough carbon dioxide to make a fizzy drink. Make sure that you're using bottles designed to take pressure, such as old beer bottles (definitely don't use old wine bottles as these may explode). After a few days, your cider should be fizzy and ready to drink. ↵

**Above ↵**  
Malic acid is available as a supplement from health food shops

**Left ↵**  
Don't add too much sugar when bottling. We can speak from experience and say that too much sugar can lead to cider hitting the ceiling when you open it



## FLAVOURED CIDER

You don't have to stick with just apple juice – you can put in whatever else you want. We've had success adding one bottle of another fruit juice to three of apple. A personal favourite of the author is one bottle of mango juice to three of apple. The resulting drink doesn't taste of mango; in fact, it seems to taste more of apple than the version made with apple juice.

Bear in mind that other fruit juices don't necessarily have the same sugar content as apple juice. This isn't necessarily good or bad, it's just different.



# S

**O** far, we've focused on alcoholic drinks. However, not everyone wants alcoholic drinks, and there's a great range of fermented non- or minimally alcoholic drinks available.

Let's take a look at kombucha. This is a form of fermented tea – the process for making it is very simple. You need to start with sweet tea. The exact amounts of tea and sugar you start with are up to you. We'd recommend starting with something that's about the right strength for sweetish tea that is OK to drink on its own. You then need to wait for it to cool.

The starting point for the live part of this ferment is a 'scoby' (symbiotic culture of bacteria and yeast) which is a jelly-like disc, and some kombucha from a previous batch. You can buy these online, or other kombucha brewers are often happy to give them away.

Add the scoby and kombucha to your sweet tea (kombucha is traditionally made with black tea, but you can experiment with others). Make sure that you add at least 10% of the total volume of

**Right →**  
Secure a clean cloth over the opening to prevent flies from getting into your kombucha



## LACTIC FERMENTS

There's another category of alcohol-free ferments – those done by lactic acid bacteria including water kefir and ginger beer. The basic process is fairly similar to here (inoculate a sweet liquid with bacteria and wait for it to get an acidic tang), but the ferment here is straight from sugar to acid without going via alcohol. This isn't necessarily better or worse, but gives a different flavour that some people will prefer and some won't.

There are loads of different ways of gaining the bacteria for these ferments – water kefir grains and ginger beer plants can be purchased online, or you can harvest them from a more common source such as the whey on natural yoghurt or the skin on vegetables (such as root ginger). You can get recipes from fermentation supply shops; or, if you want to explore this area further, we'd strongly recommend the book *The Art of Fermentation* by Sandor Katz.

You may find that your scoby gets thicker and thicker with each batch. This isn't a problem, but it might start getting a little inconvenient. You can peel layers off the scoby and either discard them or give them to friends to start their own kombucha batches.

In general, there's not much that can go wrong with kombucha, but if you notice anything looking like mould (furry rather than slimy like the scoby), then it's best to be safe and discard the lot and begin again with a fresh scoby. ↗

**Below ↓**  
The scoby is a slimy disk that will grow to cover the entire surface of your kombucha

## ALCOHOL FREE?

Here in the UK, a drink can legally be sold as alcohol-free if it's under 0.5% ABV. That may satisfy the law, but some people may prefer a different definition. It's annoyingly difficult to know exactly how much alcohol a drink has – the traditional method of using a hydrometer just tells us how much sugar there is in a drink, from which we can infer how much alcohol yeast could have produced, but this method falls flat when bacterial ferments are used.

Any fermented drink can contain alcohol (as can ripe or overripe fruit), even if you've not added yeast as it could gain wild yeast from the air. The same can be said for any sweet drink that's been out of the fridge for a day or so.

The drinks we've looked at here shouldn't contain any significant amount of alcohol, but we can't guarantee that they'll be completely alcohol-free.



STOUT



**Right →**  
Powdered malt extract ready  
to be added to  
your beer



beer is arguably the most complex of the alcoholic drinks we're looking at. As with the others, it involves a sugary liquid that has yeast introduced and left to ferment, but the origin of the sugary liquid is a bit convoluted. Let's take a look at the full process (but even most professional breweries don't do the full process).

The starting point of beer is usually barley, though a few other grains such as wheat are sometimes used. However, none of these grains has a significant sugar content, and therein lies the difficulty of beer. The grains do contain starches, but yeast can't digest starches. It turns out that the plant also needs sugars in order to grow, so if you plant a grain (grains are a type of seed), the grain will release enzymes that convert the starches to sugars that the growing plant can use for energy before it has leaves to photosynthesise. We then need to stimulate the grain to release these enzymes, but then stop it fully germinating as we don't want it to use up the sugar. This process is known as malting. This involves soaking the grain in water, then drying, and roasting the grain. The amount the grain is roasted has a big impact on the flavour – unsurprisingly, dark roasted malt makes dark beer while lightly roasted malt makes light beer. It's certainly possible to do this yourself, but only a few very determined home brewers do. You can buy pre-malted grains in a range of different roasts.

### MASH IT UP

Once you have your malt, you need to 'mash' it. In the malt, you still don't have sugars, but you have starches and enzymes that can convert the starches into sugars. In order to allow the conversion to happen, you need to soak the grains in warm water. The temperature of the water is critical here. Cooler water allows the enzymes to produce simpler sugars, and these sugars can be completely digested by the yeast (in a later stage) – this results in very crisp beers. Warmer water allows the production of more complex sugars that can't be digested by the yeast, and these sugars will therefore be present in the final beer. These sugars aren't particularly sweet, but do add to the richness and mouthfeel of the final beer.

After mashing comes sparging, where you extract the brewing liquid (or wort) from the grains. This is a bit more complex than it may first appear, as you



want to extract the sugars from the malt without too many of the tannins. There are a few processes you can use here, from the simple 'fill and drain' to more complex sprinkling systems.

This is the third point at which you can enter the brewing process. If you don't want to start with pure barley or malted barley, you can start with malt extract. This comes either as a liquid or a powder. In either case, it contains the sugars from the malted barley and can be mixed with water to create your wort. Most home-brew kits start at this point, and you can also buy malt extract by itself.

Now you have your wort, it's time to boil it with hops. There are a lot of different types of hops that all have different flavours, so the type and quantity of hops you add will have a big effect on the final drink.

## YOU CAN ADD MORE HOPS HERE

The boiling allows the hops to introduce their flavour, removes some off-flavours that can come from the malt, and sterilises the liquid.

Pew, that's quite a process, and this gives us our sugary, flavourful liquid that we can ferment. From this point, the process is broadly similar to our other ferments. We add a yeast – with beer the choice is perhaps a little more important than with some other ferments as there's a wide range of sugars, and different strains of yeast digest different sugars. You can also add more hops here – this is known as



dry hopping, and these hops impart more scent and less flavour than hops added during the boil. With the yeast and hops added, you hold it at a temperature around 20°C, and wait. Once the ferment has finished, you can prime it and bottle it as you would with cider to create a fizzy drink.

By far the easiest way of getting started is with a beer kit, which should include everything you need to get started and instructions for how to use it. One thing to look for is whether or not you need to add sugar – kits where you do need to add it tend to be cheaper but may not have the same flavour as kits where all the sugar comes from malt extract.

Once you've run through the process with a kit, you can start experimenting, whether that's designing your own beers by selecting the right hops and malt combinations, or by taking control of more of the process by starting with malted grains (or if you're really keen, unmalted barley). ↗

Above ↑  
Hops create much of  
the flavour and aroma  
of beer

Below ↴  
A selection of different  
malted grains

## WATER

The one ingredient that we haven't talked about is water. Although this is mainly H<sub>2</sub>O, there are also various quantities of different minerals – and in domestic water, chlorine. The particular make-up of the water can affect the brewing process and the final beer, with different water types producing better results for different beers. Burton upon Trent is a town famous for its brewing water, and the water of Dublin and London are also said to influence the brew.

Fortunately, you don't need to drive around the country with buckets of water in your car – there's a range of water treatment products that you can add to your water to create a make-up more conducive to a particular style of beer.





**Right ↗**  
Bristol water is famously unpleasant, so it requires quite a bit of treatment before brewing can begin

We luv home br

**I**f you've immersed yourself in home-brew and want to take your hobby to the next level, what does it take to turn your hobby into a viable business? We talk to Michael Wiper from Bristol-based Wiper and True to find out.

**HackSpace** Can you tell us how you got started brewing?

**Michael Wiper** I got started by making cider as well [as Ben Everard conducting the interview]. A few friends got together and started making cider every year as a bit of a tradition. I got really into making things that way. Also, as a massive beer lover, that got me started thinking about making beer, so I started home-brewing. And got straight into it really quickly – started reading too much on the internet.

**HS** Did you start because you were interested in the process, or because you wanted beer styles that you didn't have access to?

**MW** I was interested in the process. It was much more about the process than anything – I didn't have any ambition with it. I really enjoy being creative. And I really enjoyed the social aspect of cider-making. It was so much about community gathering and going picking together, pressing together, and everyone drinking cider together, and that's what got me into that, and I started making beer with friends.

**HS** How did you end up brewing professionally?

**MW** Over a couple of years, the beers started to get better, and that's when I started making [beer styles] that I had limited access to. Like a lot of people, I was quite influenced by American brewing and American hops, and I started making things that were quite fruity

and soft, and quite pale and clean. [They] didn't look or smell anything like the kind of beer offering that was around at the time.

I was thinking about different career options, and I started writing a document about 'if we were going to start a brewery, how would we do it?', and listed a load of tactics: how we'd brand it, what sort of markets we'd want to approach, that sort of thing. I never really stopped answering those questions.

At the same time, with my business partner Al True, we started making beers together, and you've got the whole day to stand there talking – if we were going to do this commercially, what would we do?, and we never really stopped. Where could we start this process? Maybe we could find some local breweries to help us out. Amazingly, some people said yes, and we took our recipes and our malts and hops along to some local breweries and made our own beers there.

#### **HS** How did the process of brewing in someone else's brewery go?

**MW** In general, it was a day working together. Largely it had to be led by whoever's there – the main brewer – and leaving them to be the guardian of fermentation with instructions on what we wanted done. I'd be going and checking on it all the time.

As we built relationships with the breweries, we built these amazing setups where we essentially had the keys to their breweries. We'd let them know when we'd be in, and we had our own tanks and they'd just let us brew. We'd have all our stuff delivered to them. They were completely trusting – they'd say 'knock yourself out' and they'd go and do something else for the day while we used their kit.

#### **HS** The first time you went in to use a brewery – was that a commercial run?

**MW** Yes it was. The first run was over in Essex, in a place called Dominion Brewery Company. It was really hard to find people who'd let us use their kit – because it's a mad thing to do. I met this guy on an organic hop conference, and he was like 'yeah, come and have a go'. He was so charitable and open.

Then I started pestering a guy in Bristol, and went and hung out with him. We had some other places



lined up, but they'd dropped out and he felt sorry for me so he let me use his kit. We brewed three batches and got them branded up and sold them at the Christmas market. We didn't have much of a plan beyond that – we didn't have any more beer booked in.

# THERE ARE NO EXAMS YOU HAVE TO PASS

But they were all commercial brews – I was absolutely petrified. They were all 800 litre batches, and I'd only made 50 litre batches before that. The amount of time I spent looking at recipes and trying to tweak recipes ... it was very daunting.

#### **HS** Was the legal side hard?

**MW** No, that's not to say it shouldn't have been. There was very little discussion about any legal things with it.

There are very few barriers to entry – in the UK at least. It's great – if you want to start up you can. You have to follow food safety rules and industry practices, but there are no exams you have to pass or anything. In Germany, you can't start brewing unless you're a master brewer, but there's no rule about that in the UK. Maybe there should be, but there isn't.

A lot of the HMRC side of things and food compliance, we were coming under the umbrella of where we were brewing, so we'd take on the ➤

**Above ↑**  
Michael explained the importance of temperature control in mashing the malt



**Above** ↑  
Despite its size, brewery equipment isn't very different from what home brewers use – here's an airlock protecting the beer from oxygen

**Below** ↴  
Alcohol content is critical for professional brewers as it affects how much tax they pay, but it's still calculated using hydrometers

was so encouraging, so positive. So it was 'right, we should really go for it, and now's the time'. We should have bought a brewery more quickly, but we had to find more and more places as property deals take a long time to get going.

We ended up with three really key relationships with constant tank space: Cheddar Ales down in Cheddar, The Cotswold Brewing Company which is an amazing larger brewing place in the Cotswold countryside, and a place in Wales that isn't around any more, unfortunately, but it was called the Celt Experience Brewery. We would have constant beers in their tanks.

#### HS On the commercial side of things, was it hard to build a demand?

**MW** Not at that time – we were really fortunate. I think it would be now. We were lucky in the timing of it all. One of the reasons we hadn't had the confidence to jump in and spend hundreds of thousands of pounds on equipment and renting a building was we didn't know what the reaction would be – whether people would want a new brewery in Bristol. But actually, as

practices of where we were in at the time.

#### HS How long were you borrowing breweries?

**MW** Two years. We ended up brewing in 15 different breweries before settling here [St Werburghs in Bristol].

#### HS Were you doing it full-time?

**MW** Yeah – after that Christmas market it became full-time very quickly. The response

soon as we started, landlords and shops got behind us straight away and said, "We'll take what you can give us, and we're really excited about a new brewery in town – it's great, that's really good for us." We had an incredible response. At the end of 2012, the excitement around at the time was really palpable.

#### HS Are there more breweries around now?

**MW** Yes. I think we were the fourth or fifth. Now there's 15 or something. We were making something at that time that was very different and stood out. It was the right time, right place – a lot of people's palettes were sparked by this sort of beer. That's now a much more common thing.

#### HS How does the process of creating a new Wiper and True beer go?

**MW** To start with, we set it up so that every batch was different and we had no core range. There were two reasons behind this – one was, our philosophy behind it was to make how we want to drink. Certainly at the time, if we went out to a bar, we would try a load of different beers; even if there was one I really liked, I'd still try another one to try and learn as much as possible. If a new brewery came out, it was exciting because it meant access to new styles of beer with vast amounts to explore.

We wanted to brew like that – the idea that there's no such thing as a perfect beer, there's just lots of amazing variations on a formula. On a practical level – this was a total coincidence – it would have been very



MEAD

difficult to make identical beer in different breweries at the scale we were operating at. We [didn't] have advanced water processing facilities. Big brewers can do this really well. They can make [for example] Heineken around the world, and it all tastes the same, but if we try to make a pale ale in a small brewery with limited equipment and hardly any measuring tools, it would have been very difficult. It played into it very well, but it was driven by the desire to make something different each time.

We had loads of ideas rather than 'we need to lead with this'. That was actually a founding principle of the company – we wanted all the branding around that hierarchy. We don't want people to look at the name of the beer. It's that they put their trust into Wiper and True as a brewery, not that they like 'Citra and Rye' by Wiper and True. We made it so – in the design – the name is almost irrelevant. It's there if you're interested, but it's not the focal point.

A lot of breweries at the time were leading with their flagship beers, and you might not even know who the brewery is for [e.g.] Doom Bar – you've probably heard of the beer, but do you know who the brewery is? We wanted to flip that on its head. That's evolved, now we can make more consistent batches, and we've got our own place. We've changed in

## WE'VE HAD TO LEARN THE HARD WAY

the market and how we drink, but that was a really important first part of it. It was also something people said we should never do. People said 'you've got to have a consistent offering for your customers' when we had advice from the industry. It actually ended up working too well. We'd release our stock list on a Monday, and we'd have two new beers on, and we'd release a second stock list on a Wednesday, and it had no new beers on, and people were like 'we'll wait until next Monday'.

**HS** Going back to brewing, is there anything you wished you knew when you started?



**MW** How to make beer! I'm only half-joking. Coming up from no industry experience, we've had to learn the hard way, and we've done things differently, like that thing about not having a core range. Another thing we were doing is we don't use any finings in our beer, so it was a little hazy. Again, it was something we were told by the industry, that pubs would reject it and people wouldn't go for it at all, but actually, we've had a really positive experience from it once we told the

story about why. And we didn't want to put fish guts in our beer. People got behind us, and we never had an issue with it. We had maybe one or two pubs say no to our beer, but demand was outstripping supply for a long time. Until we got set up with our own facilities.

It did give us our own take on things at the same time;

it's such a process-driven, scientific set of procedures that we work to, that would have massively helped if we'd had master brewing degrees. Now we've employed a master brewer!

**HS** Is there any advice you'd like to give to someone home-brewing for the first time?

**MW** Have fun! Play around as much as possible and make mistakes. We started off trying to do things like roast malt in the oven and burning it and making a horrible beer using the wrong yeast. It's the best way to learn – just keep on making mistakes. □

Above ↑  
Wiper and True cans  
ready for filling – the beer  
is called 'Light Pale Ale',  
but you might not notice



# SUBSCRIBE TODAY FROM ONLY £5



## SAVE UP TO 35%

Subscribe today and get:

- ▶ **FREE delivery**  
Get it fast and for FREE
- ▶ **Exclusive offers**  
Great gifts, offers, and discounts
- ▶ **Great savings**  
Save up to 35% compared to stores

Subscribe online: [hsmag.cc/subscribe](http://hsmag.cc/subscribe)

# SUBSCRIBE TODAY

**Subscribe for 12 months**

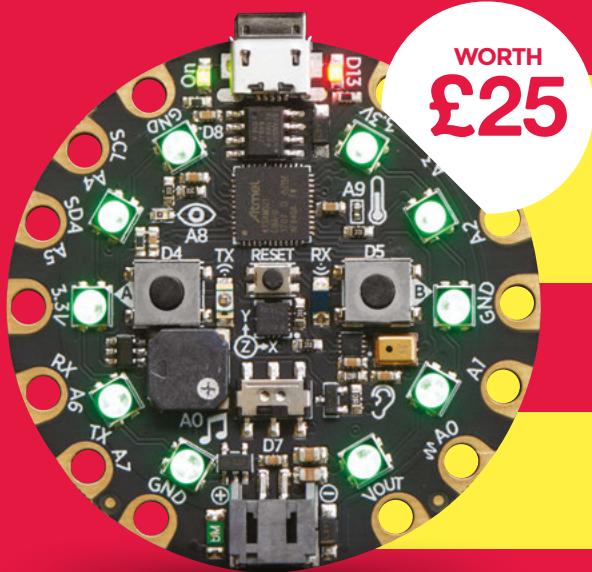
**£55** (UK)    **£90** (USA)

**£80** (EU)    **£95** (Rest of World)

Free Raspberry Pi 3A+ with 12-month upfront subscription only  
(no Raspberry Pi 3A+ with rolling monthly subscription)

**Rolling monthly subscription**

- ▶ **Low monthly cost** (from £5)
- ▶ **Cancel at any time**
- ▶ **Free delivery to your door**
- ▶ **Available worldwide**



# FREE!

Adafruit Circuit  
Playground Express

**With your 12-month print subscription**

This is a limited offer. Offer subject to change or withdrawal at any time.

# SUBSCRIBE on app stores

From **£2.29**



Buy now: [hsmag.cc/subscribe](http://hsmag.cc/subscribe)



# How I Made WW2 RADIO BROADCAST TIME MACHINE

Bringing history to life with a Raspberry Pi

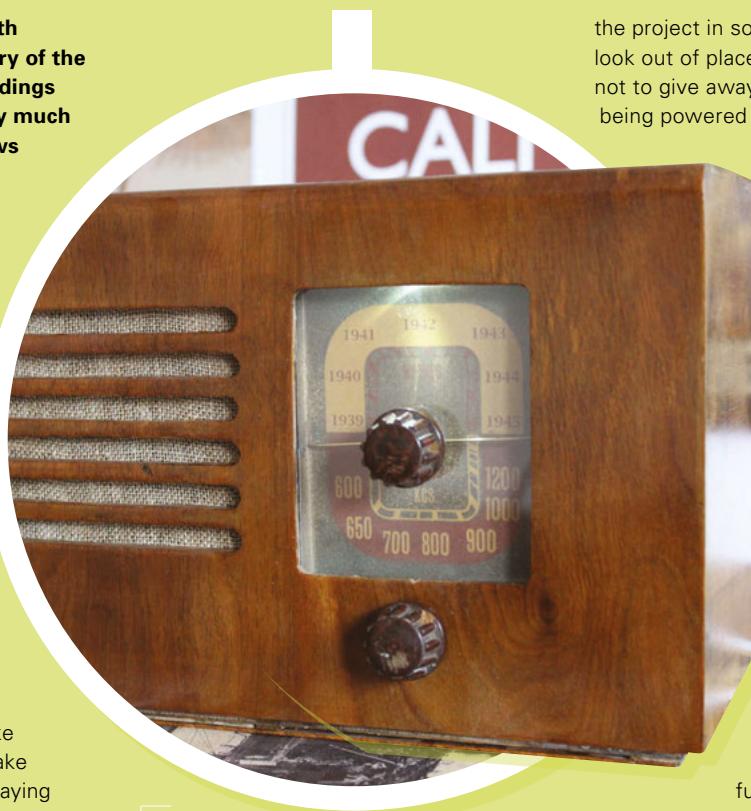
By Adam Clark

**W**ith the 50th anniversary of the D-Day landings being very much in the news this year, my interest was piqued about all things related to that era. So it wasn't long before I found myself on the Internet Archive ([archive.org](http://archive.org)) listening to some of the amazing recordings of radio broadcasts from that time. As good as they were, it felt as if something was missing by listening to them on a modern laptop, so I wanted something to play them back on that was more evocative of that time, and would perhaps capture the feeling of listening to them on a radio set. I also wanted to make the collection portable and to make the interface for selecting and playing the tracks as easy as possible – this wasn't going to be screen-based! Another important consideration was to house

the project in something that would not look out of place in the living room, and not to give away the fact that it was being powered by modern tech. So I

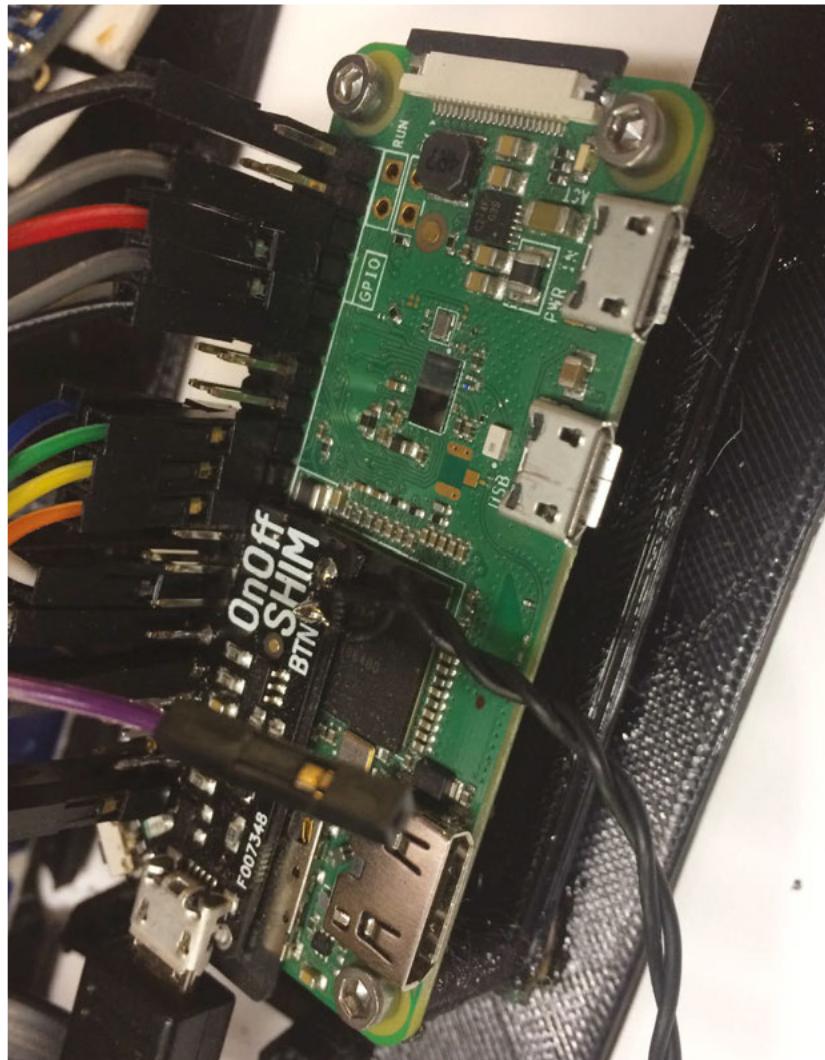
came up with the idea of using an original radio as the project case, and to use as many of the original knobs and dials as possible. I also had the idea to repurpose the frequency dial to select individual years of the war and to play broadcasts from whichever year was selected. Of course, the Raspberry Pi was immediately the first option to run all this, and ideally, I wanted to use a Raspberry Pi Zero to keep the costs down and perhaps to allow expansion in the future outside of being a standalone playback device.

Right off the bat, I knew that I would have a couple of obstacles to overcome as the



Above ◀  
No screens here – the interface is as original as possible

**Right** The Raspberry Pi mounted and connected up



Raspberry Pi Zero doesn't have an easy way to play audio out, and I also wanted to have analogue inputs for the controls. So the first thing was to get some audio playing to see if this was possible.

### AUDIO PLAYBACK

The first obstacle was to find a satisfactory way to play back audio. In the past, I have had some success using PWM pins, but this needs a low-pass filter as well as an amplifier, and the quality of audio was never as good as I'd hoped for. The other alternative is to use one of the many HATs available, but these come at a price as they are normally aimed at more serious quality of audio. I wanted to keep the cost down, so these were excluded as an option. The other option was to use a mono I2S 3W amplifier breakout board – MAX98357A from Adafruit – which is extremely simple to use. As the BBC didn't start broadcasting stereo commercially until the late 1950s, this was also very apt for the radio (which only has one speaker).

Connecting up this board is very easy – it just requires three GPIO pins, power, and the speaker. For this, I just soldered some female jumper leads to the breakout board and connected them to the header pins of the Raspberry Pi Zero. There are detailed instructions on the Adafruit website for this which basically entails running their install script.

```
curl -sS https://raw.githubusercontent.com/adafruit/Raspberry-Pi-Installer-Scripts/master/i2samp.sh | bash
```

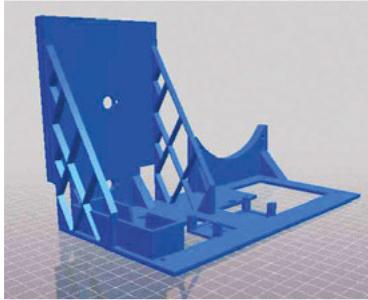
Once the install scripts and mpg123 player are installed with a speaker connected, the Raspberry Pi Zero immediately started playing some very nice quality audio through the on-board 3W amplifier – and it is certainly loud enough to emulate a radio. ↗



**Left** The case after years of abuse

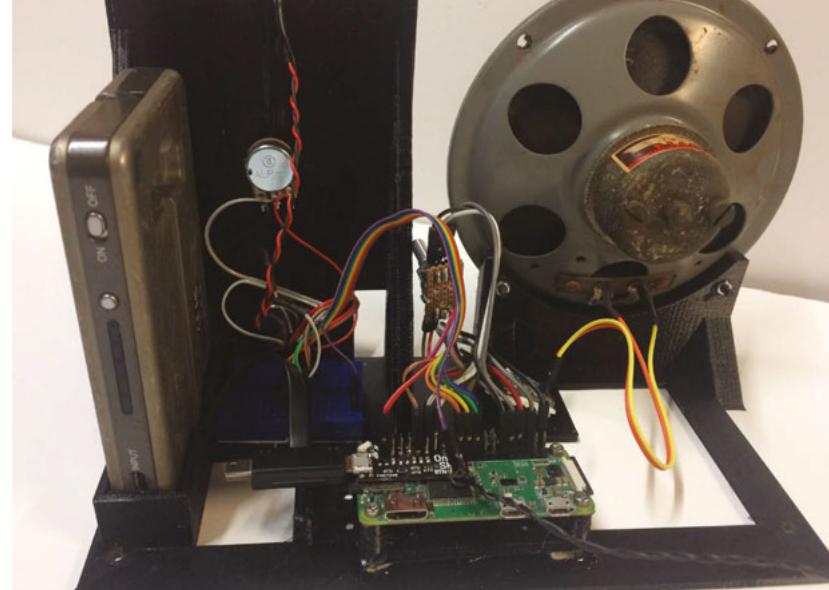
# How I Made: WW2 radio broadcast time machine

## FEATURE



Above ⌘  
3D printing let me hold everything in the right place

Right ⌘  
The innards connected up and ready to play



I'd now got a nice playback device that would easily play the MP3 files downloaded from [archive.org](#) and so the next task was to find a suitable second-hand radio set.

### PREPARING THE CASE

After a lot of searching on auction sites, I eventually found a radio that was going to be suitable: wasn't too large, was constructed from wood, and looked old enough to convince the casual observer. I had to settle for something that actually came from the early 1950s, but it drew on design influences from earlier years and wasn't too large as a lot of the real period ones tended to be (and it was only £15). This is a fun project, so a bit of leeway was fine by me in this respect. When the radio arrived, my first thought as a tinkerer was perhaps I should get the valves running, but a quick piece of research turned up that I'd probably have to replace all the resistors and capacitors and all the old wiring and then hope that the valves still worked. Then discovering that the design used a live chassis running at 240V soon convinced me that I should get back on track and replace everything. With a few bolts and screws removed, I soon had an empty case.

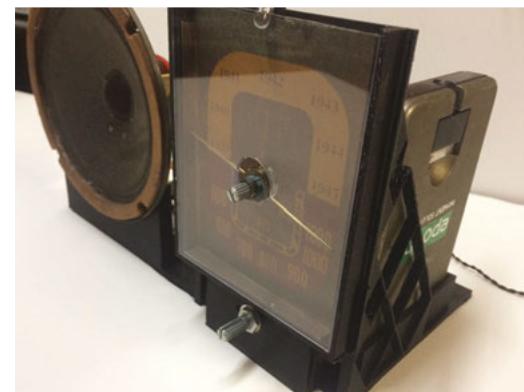
I then stripped out all the interior components and set about restoring the case and dial glass, seeing what I could use by way of the volume and power controls. Sadly, there didn't seem to be any way to hook into the old controls, so I needed to

design a new chassis to mount all the components, which I did in Tinkercad, an online 3D CAD package. The design was then downloaded and printed on my 3D printer. It took a couple of iterations, and during this phase, I wondered if I could use the original speaker. It turned out to be absolutely great, and the audio took on a new quality and brought even more authenticity to the project.

The case itself was pretty worn and faded, and the varnish had cracked, so I decided to strip it back. The surface was actually veneer, but you can still sand this. After a few applications of Nitromors to remove the varnish, it was sanded to remove the scratches and finished off with fine sanding.

The wood around the speaker grille was pretty cracked and had started to delaminate. I carefully removed the speaker grille cloth, and fixed these with a few dabs of wood glue, then used some Tamiya brown paint to colour the edges of the wood to blend it back in with the rest of the case. I was going to buy replacement cloth, but it's fairly pricey – I had discovered a trick of soaking the cloth overnight in neat washing-up liquid and cold water, and it managed to lift the years of grime out and give it a new lease of life.

At this point, I should have just varnished or used Danish oil on the case, but bitten by the restoration bug I thought I would



Above ⌘  
The original dial brought the right aesthetic to the build

have a go at French polishing. This gave me a huge amount of respect for anyone that can do this properly. It's messy, time-consuming, and a lot of work. I ended up having to do several coats, and with all the polishing involved, this was probably one of the most time-consuming tasks, plus I ended up with some pretty stained fingers as a result.

The rest of the case was pretty easy to clean, and the brass dial pointer polished up nice and shiny with some Silvo polish. The cloth was glued back in place,

and the next step was to sort out the dial and glass.

### FREQUENCY, VOLUME, GLASS, AND KNOBS

Unfortunately, the original glass was cracked, so a replacement part was cut from some Makrolon sheet, also known as Lexan. I prefer this to acrylic as it's much easier to cut and far less likely to crack when drilling it. It's used as machine guards as well and can even be bent if necessary. With the dial, I scanned it into the PC and then in PaintShop I replaced the existing frequency scale with a range of years running

from 1939 to 1945, as the aim was for anyone using the radio to just dial the year they wanted to listen to. The program will then read the value of the potentiometer, and randomly select a file to play from that year.

It was also around about now that I had to come up with some means of having the volume control the sound and an interface for the frequency dial. Again there are always several options to consider, and I originally toyed with using a couple of rotary encoders and using one of these with the built-in push button as the power switch, but eventually decided to just use some potentiometers. Now I just had to come up with an easy way to read the analogue value of the pots and get that into the program. There are quite a few good analogue-to-digital boards and HATs available, but with simplicity in mind, I chose to use an MCP3002 chip as it was only about £2. This is a two-channel analogue-to-digital converter (ADC) and outputs the data as a 10-bit value onto the SPI bus. This sounds easy when you say it, but it proved to be one of the trickier technical tasks as none of the code around for the four-channel

MCP3008 seemed to work for the MCP3002, nor did many of the examples that were around for the MCP3002 – I think I went through about a dozen examples. At long last, I did find some code examples that worked, and with a bit of modification, I had a simple way of reading the values from the two potentiometers. You can download the original code by Stéphane Guerreau from GitHub ([hsmag.cc/zWyrhX](https://github.com/zWyrhX)). To use

**The program will then read the value of the potentiometer, and randomly select a file to play from that year**

this on your Raspberry Pi, you'll also need to run up raspi-config and switch on the SPI interface. Then it is simply a case of hooking up the MCP3002 and connecting the pots between the 3v3 line and ground and reading the voltage level from the wiper of the pots. When coding this, I just opted for some simple if-then statements in cap- Python to determine where the dial was pointing, and just tweaked the values in the code until I got each year to be picked out.

### POWER SUPPLY AND CONTROL

One of the challenges when using a Raspberry Pi in headless mode is that it

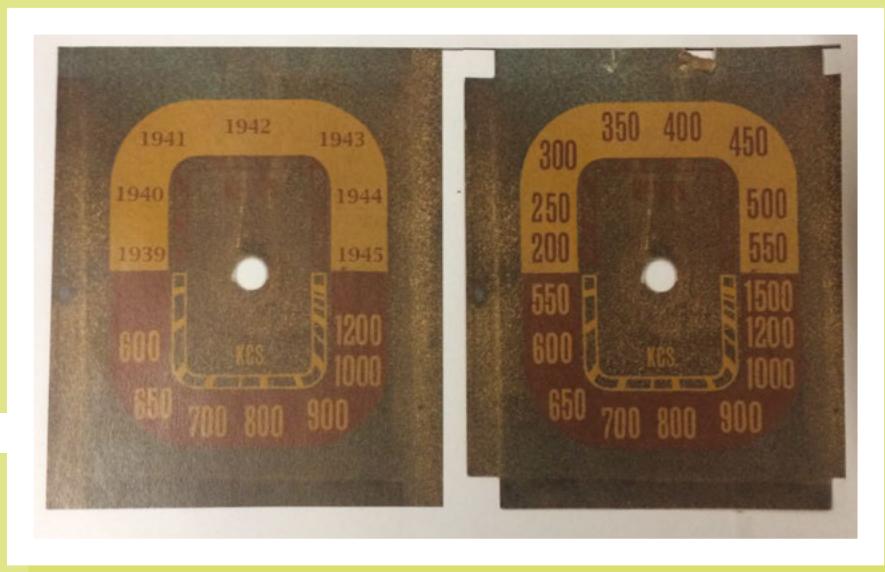
likes to be shut down in an orderly fashion rather than just having the power cut. There are lots of examples that show how you can hook up a push button to a GPIO pin and initiate a shutdown script, but to get the Raspberry Pi to power back up you need to physically reset the power. To overcome this piece of the puzzle, I use a Pimoroni OnOff SHIM which cleverly lets you press a button to start up, and then press and hold it for a second to start a shutdown. It's costly in comparison to the price of a Raspberry Pi Zero, but I've not found a more convenient option. The power itself is supplied by using an old power bank

that I had which is ample enough to power the radio long enough to be shown off, and can be powered by USB connector if longer-term use is required.

To illuminate the dial, I connected a small LED in series with a 270R resistor to the 3v3 rail so that it would come on as soon as the Raspberry Pi received power, and this lets you easily see when it's on without waiting for the Raspberry Pi to start up.

### DOWNLOADING THE FILES

I'm just using the MP3s from [archive.org](http://archive.org) as you can find these sorted by year. I chose mainly the news broadcasts and →



Right ◆

The new dial (left) and the original (right)

# How I Made: WW2 radio broadcast time machine

## FEATURE

placed these into separate year-named subdirectories on the Raspberry Pi. There are several hundred broadcasts for each year – the amount and range is quite astounding.

[archive.org/details/1939RadioNews](http://archive.org/details/1939RadioNews)  
[archive.org/details/1940RadioNews](http://archive.org/details/1940RadioNews)  
[archive.org/details/1941RadioNews](http://archive.org/details/1941RadioNews)  
[archive.org/details/1942RadioNews](http://archive.org/details/1942RadioNews)  
[archive.org/details/1943RadioNews](http://archive.org/details/1943RadioNews)  
[archive.org/details/1944RadioNews](http://archive.org/details/1944RadioNews)  
[archive.org/details/1945RadioNews](http://archive.org/details/1945RadioNews)

Depending on the space you might have on your SD card, you can also add these:

[archive.org/details/WWII\\_News\\_1939](http://archive.org/details/WWII_News_1939)  
[archive.org/details/WWII\\_News\\_1940](http://archive.org/details/WWII_News_1940)  
[archive.org/details/WWII\\_News\\_1941](http://archive.org/details/WWII_News_1941)  
[archive.org/details/WWII\\_News\\_1942](http://archive.org/details/WWII_News_1942)  
[archive.org/details/WWII\\_News\\_1943](http://archive.org/details/WWII_News_1943)  
[archive.org/details/WWII\\_News\\_1944](http://archive.org/details/WWII_News_1944)  
[archive.org/details/WWII\\_News\\_1945](http://archive.org/details/WWII_News_1945)

## THE SOFTWARE

```
#!/usr/bin/env python
# WW2 Radio - software to read MCP3002 ADC
# and convert to volume and year adjustment
# Ouput via i2S amplifier 20/10/2018 -
Ajax Jones

# Code fragments supplied from https://
learn.adafruit.com/adafruit-max98357-i2s-
class-d-mono-amp/raspberry-pi-usage
# MCP 3002 Python https://github.com/
CaptainStouf/Adafruit-rasp Pi-python/blob/
master/Adafruit_MCP3002/MCP3002.py

import RPi.GPIO as GPIO, time, os
from os import listdir
import subprocess
from time import sleep
import random
GPIO.setmode(GPIO.BCM)

# read the SPI data from the MCP3002 chip,
2 possible adc's (0 and 1)
def readadc(adcnum, clockpin, mosipin,
misopin, cspin):
    if ((adcnum > 1) or (adcnum < 0)):
        return -1
    GPIO.output(cspin, True)

    GPIO.output(clockpin, False) # start
clock low
    GPIO.output(cspin, False) # bring
CS low

    commandout = adcnum << 1;
    commandout |= 0x0D # start
bit + single-ended bit + MSBF bit
    commandout <= 4 # we
only need to send 4 bits here

    for i in range(4):
        if (commandout & 0x80):
            GPIO.output(mosipin, True)
        else:
            GPIO.output(mosipin, False)
        commandout <= 1
        GPIO.output(clockpin, True)
        GPIO.output(clockpin, False)

    adcout = 0

    # read in one null bit and 10 ADC bits
for i in range(11):
    GPIO.output(clockpin, True)
    GPIO.output(clockpin, False)
    adcout <= 1
    if (GPIO.input(misopin)):
        adcout |= 0x1
    GPIO.output(cspin, True)

    adcout /= 2 # first bit is
'null' so drop it
    return adcout

# Use these pinouts for the raspberry pi
zero
SPICLK = 11
SPIMOSI = 10
SPIMISO = 9
SPICS = 8

# set up the SPI interface pins
GPIO.setup(SPIMOSI, GPIO.OUT)
GPIO.setup(SPIMISO, GPIO.IN)
GPIO.setup(SPICLK, GPIO.OUT)
GPIO.setup(SPICS, GPIO.OUT)

# Note that bitbanging SPI is incredibly
slow on the Pi as its not
# a RTOS - reading the ADC takes about 30
```

```
ms (~30 samples per second)
# which is awful for a microcontroller but
better-than-nothing for Linux

# list year , this retrieves a list of
files from the specified directory and
returns the list
def list_year(radio_year):
    war_dir = '/home/pi/radio/WWII_
News_'+radio_year
    mp3_files = [ f for f in
listdir(war_dir) if f[-4:] == '.mp3' ]
    if not (len(mp3_files) > 0):
        print "No mp3 files
found!"
    return mp3_files

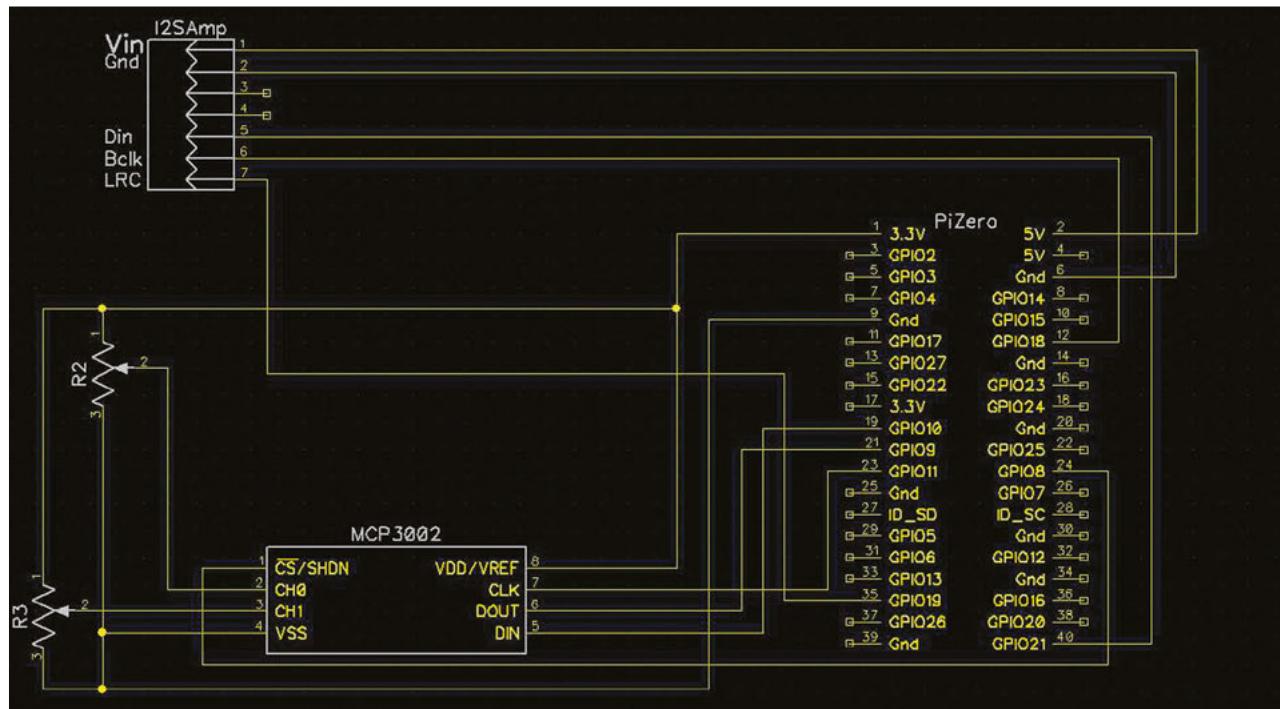
print "--WW2 Radio -----
-----
last_read = 0 # store the last position
of the volume pot
last_year = 0 # store the last position
of the frequency pot
tolerance = 5 # allow a small tolerance
so slight movement of the pots doesnt
cause a change

while True:
    trim_pot_changed = False
    year_pot_changed = False

    for adcnum in range(2):
        ret = readadc(adcnum,
SPICLK, SPIMOSI, SPIMISO, SPICS)
        if (adcnum == 0): # read
the pot for the year selector to see it
has moved
            year_adjust = abs(ret - last_
year)
            if ( year_adjust > tolerance+10):
                year_pot_changed = True

            if (year_pot_changed): # Values
can be decided after its built
                subprocess.call(['killall', 'mpg123'])
#kill any MP3 running

            sleep(0.1);
            if ret <=50:
                war_year="1939"
                elif (ret >50 and ret <150):
```



```

war_year="1940"
    elif (ret >=150 and ret <250):

war_year="1941"
    elif (ret >=250 and ret <350):

war_year="1942"
    elif (ret >=350 and ret <450):

war_year="1943"
    elif (ret >=450 and ret <550):

war_year="1944"
    elif (ret >=550):

war_year="1945"

    # save the value of the pot for the
    # next time around the loop
    last_year = ret
    print ("Playing from "),
    print (war_year),
    print (" number of files="),
    war_dir = '/home/pi/radio/WWII_
    News_'+war_year+'/'
    play_list = list_year(war_year)
    num_of_files = len(play_list)
    print num_of_files
    play_file = random.randint(1,num_
```

```

of_files)  # randomly select one of the
files to play
    war_mp3 = war_dir + play_list[play_
file]

subprocess.Popen(['mpg123', war_mp3])  # 
Use mpg123 as the player for the audio
    sleep (0.1);  # provide a slight
pause before continuing

    if (adcnum == 1):  # read the
volume pot
        pot_adjust = abs(ret - last_read)
        if ( pot_adjust > tolerance):
            trim_pot_changed = True

        if ( trim_pot_changed ):
            set_volume = ret / 10.24
# convert 10bit adc0 (0-1024) pot value
into a 0-100 volume level
            set_volume = round(set_
volume)# round out decimal value
            set_volume = int(set_volume)
# cast volume as integer

            # Use the value from the pot to
send to the amixer prog
            print 'Volume = {volume}%' 
.format(volume = set_volume)
            set_vol_cmd = 'sudo amixer
```

**Above** The wiring for the radio isn't too complicated

```

cset numid=1 -- {volume}% > /dev/null'
.format(volume = set_volume)

os.system(set_vol_cmd)  # set volume

    # save the potentiometer reading
for the next loop
    last_read = ret

    # Pause after volume change so not
too many changes are sent
    time.sleep(0.5)
```

## BOOTING THE SOFTWARE ON LOAD

There are many ways to run a command on the Raspberry Pi on boot up, but I find the easiest method is to place a script as a reboot option in crontab.

```
sudo crontab -e
```

Now just add this line:

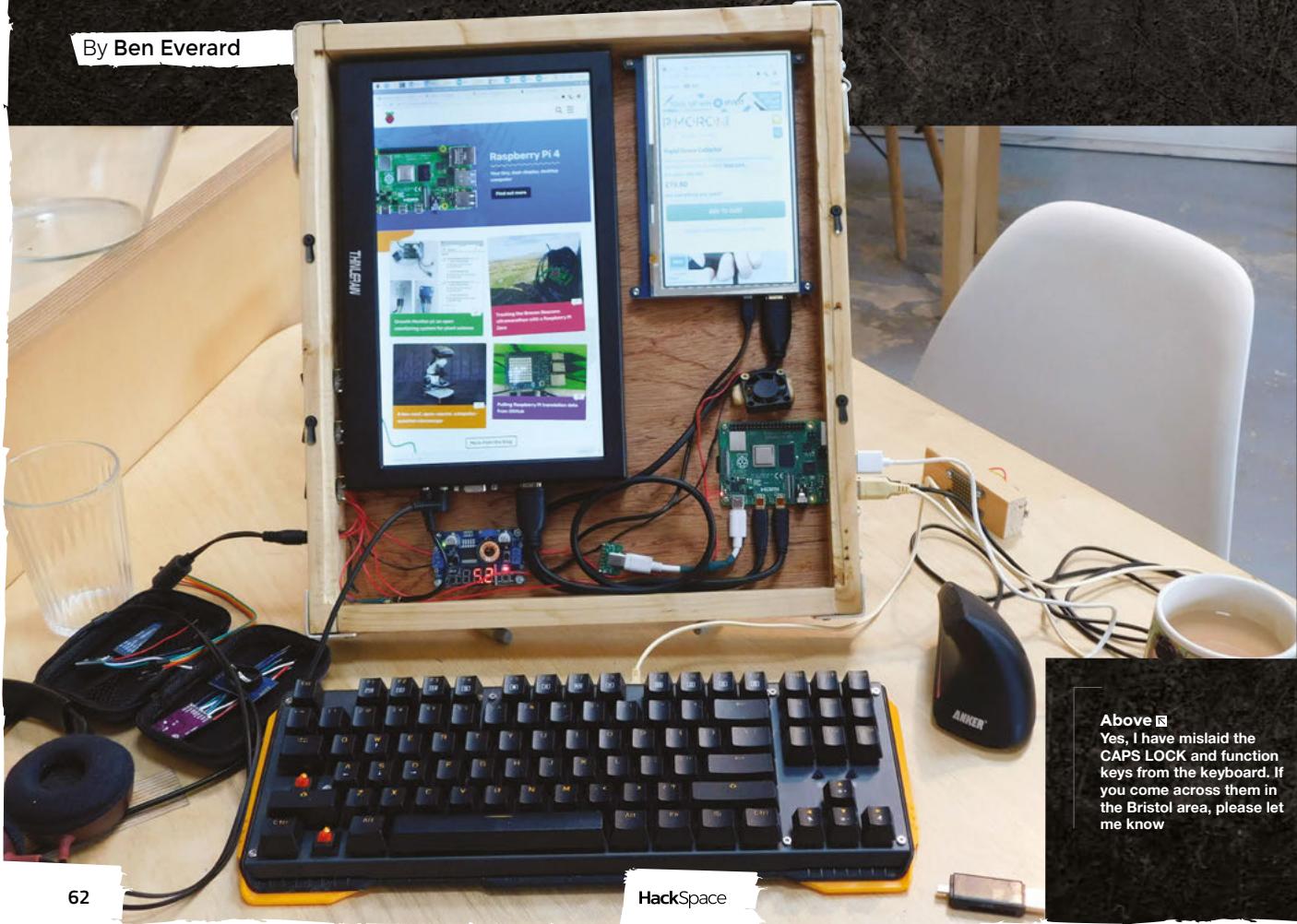
```
@reboot python /home/pi/volume/year.py &
```

The next time you reboot, the Audio control program will run, and you should hear your first broadcast. □

# IN THE WORKSHOP: A portable computer

Taking control of our computer setup

By Ben Everard



Above  
Yes, I have mislaid the CAPS LOCK and function keys from the keyboard. If you come across them in the Bristol area, please let me know

# W

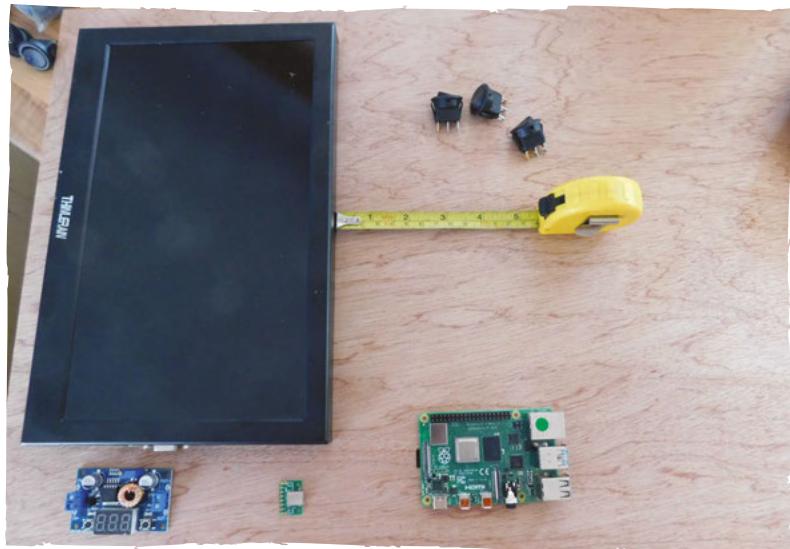
**hen Raspberry Pi 4 came out, we were pleasantly surprised by how the more powerful processor and enhanced memory allowed it to be a serious**

**contender for a desktop computer.** However, what if you don't have a permanent desk? What if you want a more portable option? There are plenty of designs around for laptops built using Raspberry Pi computers, but I've never been that keen on the laptop form factor. Joining the screen and keyboard together always makes me feel like I'm either slumped over the screen or the keyboard is too high. I set out to build a portable computer that fitted my way of working rather than simply copying the laptop design that's been making our backs and fingers hurt for the past decade.

I headed into the HackSpace magazine workshop to see what I could come up with.

## A few things I wanted to consider from a design point of view:

- **MATERIAL** Computer designers have decided that either brushed aluminium or black plastic are the options for computers, but ever since I saw the Novena Heirloom laptop, I've wanted one made in wood. This natural material isn't necessarily perfectly suited to computer construction, but it's aesthetically pleasing and in occasionally stressful work environments, wood is a calming material. What's more, it's easy to work with common tools.
- **SCREEN SETUP** Unsurprisingly, I spend a lot of my time reading or writing. Landscape screens aren't brilliant choices for this, so I



wanted a portrait screen. Since Raspberry Pi 4 has two HDMI ports, I decided to have two portrait HDMI screens. This lets me have one to display the thing we're doing, and one to have the document to write about the thing we're doing.

- **NO IN-BUILT KEYBOARD OR MOUSE** Unlike a laptop, I decided I wanted to work with external input devices to create a more comfortable working setup.
- **EXPOSED WIRING** There's not a good reason for this – we just like the aesthetic (but it does make it easier to hack an upgrade in the future). →

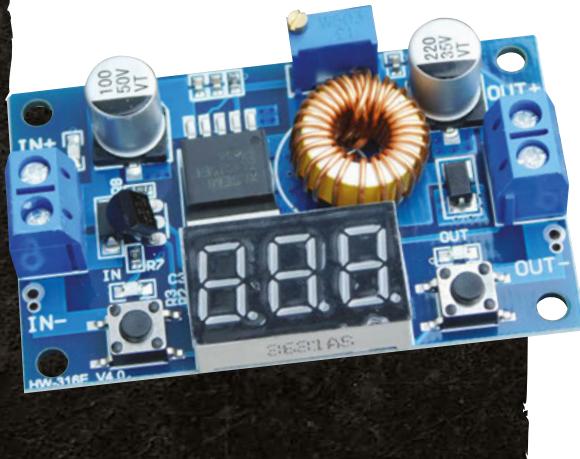
**Above** Deciding where to put the parts on the plywood backing

**Below** You can get smaller voltage converters than this, but we like the look of the large coil and seven-segment display

## Raspberry Pi 4 as a PC

After using Raspberry Pi 4 as a main computer for some time now, we can confidently say that it's up to the task – at least our tasks. For basic programming, making, word processing, web browsing, and similar office tasks, it's not noticeably slower than our previous machine. Of course, if you hammer the processor or use apps that eat RAM for breakfast, your mileage may vary.

Having two screens may not be considered a necessity, especially on a portable machine, but it does give you the flexibility to think about what you want your machine to display. Even if you don't want a full-sized second display, what about a small screen for notifications? Being able to run a terminal in a small second screen is something we've found consistently useful, and even a small screen can be useful for that.





**A few things we wanted to consider from a technical point of view:**

- **COOLING** Raspberry Pi can run a little hot, so I wanted a way of keeping it cool while still enabling the complete board to be accessible for working with the GPIO.
- **POWER** Raspberry Pi needs 5V, but most screens need 12V. I wanted my computer to have just a single power in. Having this on a 12V DC means I can use an external battery pack in the future.

**Above** We used a spade drill bit and a Dremel with a sanding attachment to carve out the space for our Raspberry Pi

**Below** We had to cut quite a lot of cables up to make them fit. Fortunately, most have sensibly coloured inners to help you understand what does what

## Mistakes, niggles, and future improvements

I made one key design mistake with this machine. I made the chassis to fit the screens, and not to fit in my bag. It just fits in my regular rucksack, but it's a tight squeeze and limits what else I can carry. I attached loops for a shoulder strap and a hand-carry handle so I can carry it without the backpack, but in the future I'd make more effort to see if we could transport it easily before committing to the build.

Another point that I'm not hugely happy about is that it's difficult to remove the microSD card (it requires loosening some bolts). This isn't a huge problem at the moment, but it would be nice to have the flexibility to easily switch cards. Once USB booting becomes available, I'll probably switch to an external drive, so this isn't much of a concern.

I did cheap-out on the screens a bit (partly because I wasn't sure if this machine would work as a daily driver). The resolution is OK, but the colours are a bit poor on both of them. It's not bad enough for me to feel the need to upgrade them now, but if I ever have another project that needs an HDMI screen, I'll probably take that opportunity to donate these and upgrade.



# We intended it to be a prototype

There's no great secret to this build. I used two different HDMI screens (one 12 inches and one 7 inches) and mounted them on 3 mm plywood. This gives enough space to mount my Raspberry Pi below the 7-inch screen. This plywood backing is surrounded by a 2x1 inch pine wall that's just high enough to expand beyond the screens. There's a slight recess in this pine surround that a plywood front cover slots into to protect the screens during transport. The joints on the wood are particularly unimpressive being butt joints with gaps in. The corners are secured by protectors which I fabricated from 3 mm aluminium sheet (OK, fabricated is a bit of a grand word – we cut, bent, and drilled them from 3 mm aluminium sheet).

I made this machine quickly as we intended it to be a prototype. I fully expected that the setup would prove too unusual to be useful and planned to disassemble it and make a different form factor after I'd learned what worked and what didn't. However, so far, I'm happy with this setup and don't have any plans to redesign it soon.

Power comes in via a 5.1 mm jack. This goes to both the monitors and a buck converter which steps it down to 5V for Raspberry Pi and fan (the converter has a display showing the current voltage because I like the look of seven-segment displays). Power is controlled by three rocker switches (because I like rocker switches rather than soft switches), allowing you to turn Raspberry Pi, fan, and screens on and off separately.

We've had to cut USB and power cables and shorten them to make them fit nicely in the case.

The only unusual part of the build was the cooling for Raspberry Pi. Since I wanted to leave the body of my Raspberry Pi free, that meant that I had to have a fan directing air over the CPU from the side.

## Upgrades

There's a small amount of space under the right-hand screen that I've wondered about putting another display device into. Not a regular display, but something like an LED matrix or strip that can be used to show the device temperature, notifications, or some other data. I've contemplated going full steampunk and putting a Nixie tube there, but there's really no justification for that.

At the moment, I've decided that I prefer to leave the space as bare wood unless I come up with something that would be particularly useful to show.

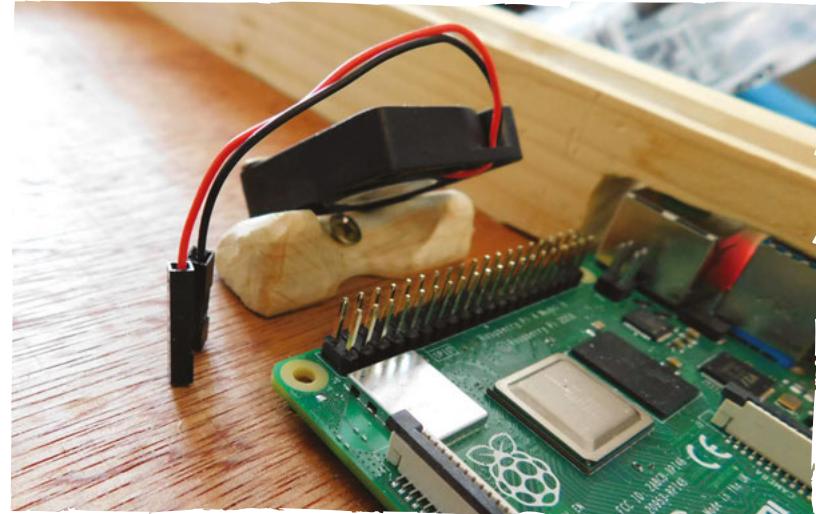
After jiggling the fan into various positions, I decided to mount it at 45 degrees just to the side of the board. I needed a mount for this – 3D printing would have worked well, but I'd been working through the *Power Carving Manual* reviewed in issue 23, so put these skills to the test and whittled a bit of wood to the right shape. Although power carving is usually used to produce artistic objects, it's also a good

# So far, it has proved sturdy and reliable

choice for fabrication when you need a bit of a 'try-and-see' approach, as it lets you make very quick adjustments.

Overall, my only disappointment with the making of this computer is the HDMI cables. I decided not to cut and splice them to the correct length as the high-speed nature of the HDMI signal makes this unreliable. Instead, I got the shortest cables I could and jammed them in.

In use, I'm really happy with my new computer. So far, it has proved sturdy and reliable, and our design decisions have been vindicated by the way it works for me. Having two portrait screens may seem odd, but at least for technology journalists it's a great option. The 7-inch screen may seem little, but these days most websites have a mobile-friendly

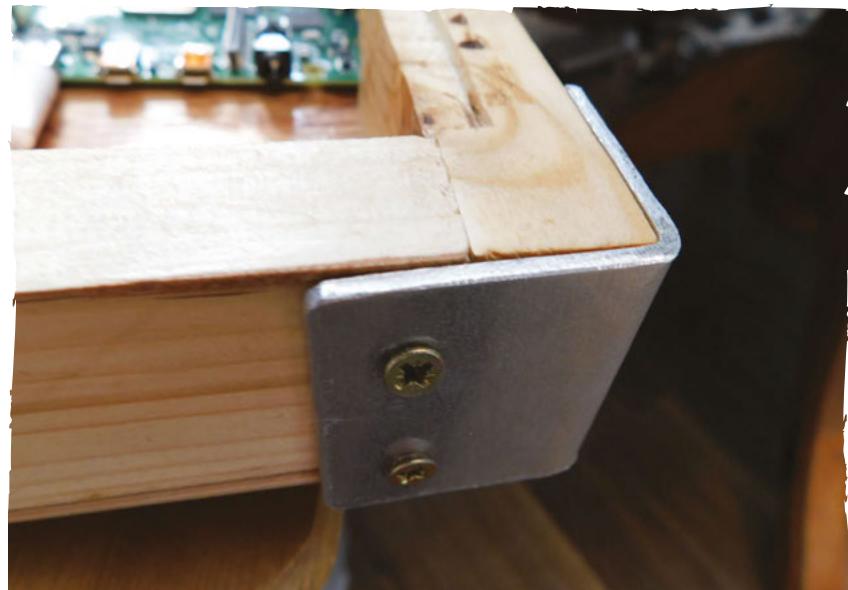


version that renders well in this size, and it's also big enough for a terminal window or Arduino IDE. A few programs struggle to work in this form factor (we're looking at you Mu).

We live in a world where – for many of us – computers are an indispensable tool that we spend most of our working lives using, yet the options for creating ones that are personal and genuinely fit our way of working are slim. We don't have to accept that. We can build the machines that we want to use: build our own tools. This is a machine designed for my needs – yours may be different, but you understand them better than anyone. If you find off-the-shelf machines don't work well for you, head to the workshop and make something that does. □

**Above** We control the fan via a switch rather than automatically for two reasons: so we can run silently when we want, and so all the GPIO pins are available for HATs and other expansions

**Below** Our corners are not the best joints, but the metal surrounds ensure they are strong and protected from bumps (oh, and we like the look of them)



HackSpace magazine meets...

# Eben Upton

Maverick tech genius, playboy philanthropist...

**S**ince launching in 2012, Raspberry Pi has become indisputably the most popular single-board computer in terms of sales.

It's taken a lot of the fear factor away for students and teachers of programming, it's spawned several companies selling gear to support it, and its exposed GPIO pins have enabled millions of makers to link their creations to the internet, automate them, or just make them smarter. It's a useful bit of kit.

We had the opportunity to chew the fat with the inventor of Raspberry Pi, Eben Upton, about what the team has been doing since the launch of Raspberry Pi 4, the amazing things that people are doing with them, and why globalisation, like football, is coming home. ➤

**Right** ■  
Raspberry Pi 4:  
proudly made  
in Wales







**Above ↗**

During the course of our chat we arrived at the philosophy of KEGS – keep everything great still

**HACKSPACE** So, Raspberry Pi then: do you think it will ever take off?

**EBEN UPTON** I reckon so: we'd sold 28 million units as of the end of September 2019. That's a lot of units! That's twice as many as the Commodore 64 ever sold.

**HS** Are they still made here, in the UK?

**EU** Raspberry Pi from 3+ onwards are only built in Pencoed in Wales. We've always built large numbers in Wales, but the 4 and 3+ we haven't built anywhere other than Wales. With the exception of a small number of legacy products, they're all built in the UK.

**HS** And is that down to some sense of patriotism that they're all made here?

**EU** It's really not. We build them in Wales because it's cheaper and the quality's higher than we'd get if we built them anywhere else. I think there's an obsolete belief that if you are building anything electronic, the best, cheapest place to do it is China. I just don't think that's true.

I'm sure 20 years ago this was true; but, even when we started in 2012, it was already the case that China had become an expensive place to manufacture a load of product. Chinese manufacturing is emptying out into adjacent countries. People are shutting down factories in China and opening up factories in Cambodia and Vietnam and Indonesia.

I think it's still the case that if you're building a smartphone, if you're building something that inevitably has a lot of manual assembly, then you kind of have to go somewhere low-cost, because you have to have some person-minutes involved in each object. Although you could argue that the margins on those products are often rather better, so you could afford those person-minutes in Wales.

It's actually cheaper at the factory gate for us to build in Wales. The factory gate

is in Europe, so you're not paying for shipping from China to get the product to your customers.

**HS** And it must be good to be close to the factory...

**EU** There's a kind of iteration; as you make a product, you learn what the good things and the bad things about the design are, and then you can change the things either in a point release of that product or in a subsequent product, in order to make it more manufacturable or higher quality, and it's easier to do that learning if your production line is four hours away in a car, and the people there speak your language, rather than if the production line is on the other side of the planet.

People have an obsolete view of how cheap China is; China's actually quite an expensive place to manufacture now. And people under-price the benefits you get from being in close proximity

“  
People have an  
obsolete view of  
how cheap China is;  
**China's actually quite  
an expensive place to  
manufacture now**

to the manufacturing when you're designing products.

Ironically, that second one is the lesson from China; it's the lesson from Shenzhen. Why does interesting technology come from Shenzhen? It comes out of Shenzhen because you have a bunch of interesting people designing products who are right next to the people who make it.

There is still loads of exciting innovation coming out of China. But, increasingly, I expect it'll be from Chinese companies innovating in China, and British companies innovating in Britain, and American companies innovating in America.

**HS** Right, so the globalisation trend almost going into reverse?

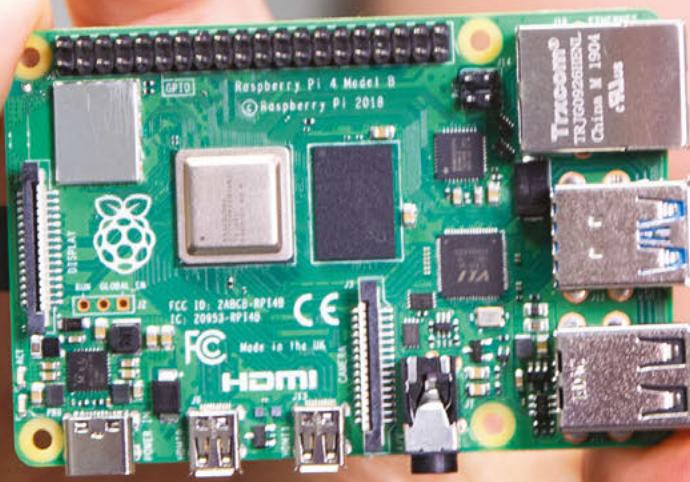
**EU** Yeah, and that's a good thing, right? Do you only want to create the design jobs in your country? Or do you want to create the manufacturing jobs as well? I'm always a bit nervous talking about this, because it sounds kind of like economic nationalism. But it isn't really, because I think it applies to all countries. If you only create one sort of job in your country... And this is the same in China: China realises that it cannot just go on being a manufacturing country for stuff that's designed in California. That's not healthy.

And I suspect it's not healthy the other way round either, that we focus on designing the stuff and see manufacturing as this grubby thing that you can offshore to the cheapest possible country on any given day – then you have unemployment and you have to have high tax rates for your designers, and give benefits to the people who could otherwise be making your stuff. That doesn't feel healthy.

**HS** That's what a lot of readers are doing, albeit on a very small scale: making things for themselves rather than buying them in from somewhere else. Innovating on a micro, individual scale.

**EU** And that's what's exciting about being a part of this, is that it is a bunch of people figuring out how to be a little bit more self-reliant. When the status quo is 'shut up and buy this thing', that's a boring status quo. This thing has happened in the last ten to twenty years of people starting to push back a bit against that, against this assumption that your job in life is to consume.

You look at the trajectory Wales had, where you've got historically a very, very successful industrial economy, then industry moved on and left, and some bits of Wales are quite deprived. But then there was this next wave in the 1970s of foreign direct investment. Why is there →



**Above** ▶  
“We’re really pleased.  
People underestimate  
how scary it is,  
launching a product”

a massive Sony factory in Pencoed? It's because Sony, at the time, looked around for a place to make these bulky items, CRT televisions, near to their market, and discovered that land was cheap and they could employ lots of skilled people.

LCD televisions take over, and one of the things about LCD screens is that they're very portable; you can manufacture them further away and fit more of them in a lorry, and so Wales lost out again. It's like waves, but each of these waves leaves a residue of capability. Wales was a sensible place to manufacture televisions because it was a sensible place to dig coal out of the ground. Even when you're not digging coal out of the ground, the industrial heritage of the place makes it a good place for industry. There are a lot fewer factories in Wales now than there were in the 1980s, but they left behind a wave of capability and that's what we're tapping into now.

**HS** You've obviously made quite a few Raspberry Pis; what have you made with a Raspberry Pi?

**EU** I've made very little with a Raspberry Pi. The tragedy is that, for all the fun you're having, I'm the guy sacrificing my fun time in order to help make it happen!

I don't have a lot of time to do this stuff. I use Raspberry Pis generally as Unix boxes when I need another Unix box. I have a router at home that has a bunch of Raspberry Pis hanging off the back of it, running bits of software that I needed – network monitoring stuff mostly.

The other thing is that I'm a software guy, not a hardware guy. Although we make Raspberry Pis and I've been involved with bits of the hardware design, the hardware design I've been involved with is chip-level design rather than bigger hardware design. I can solder stuff together, but I'm not a solder-stuff-together-and-build-robots kind of guy.

I really want to do a Pi Wars robot. I go to Pi Wars, and I either attend or judge

every year. You know those wheels that have the sideways rollers on them, and you run the robot in two directions by running the wheels in different ways? Tom Owen did one of those. It was a triangular robot with a wheel at each vertex, and the thing was insanely manoeuvrable. I don't think it won anything, but I saw it driving around and just thought it was incredible.

Formula Pi, that the PiBorg guys do, Kim and Claire, that stuff is really appealing. I used to do a lot of Lego Technic when I was a kid, and a lot of what I find appealing now goes back to that. The thing about Technic is that you build the kit once, then after a couple of days you rip it apart and start building your own stuff. I have a two-year-old daughter, so I see that as an opportunity.

The tragedy is that, for all the fun you're having, I'm the guy sacrificing my fun time in order to help make it happen!

"Hey, we're playing! I'm spending quality time with my daughter!"

**HS** What can you tell us about the new [redacted] that's coming out?

**EU** I'm not sure I can tell you anything. It's an unannounced product, and we don't talk about unannounced products.

**HS** How has Raspberry Pi 4 been received? That was a huge jump in capability.

**EU** Really well. We've made about a million and a half, getting on for two million now. What's nice is that we've been able to get them in stock really quickly, far earlier than previous Raspberry Pi products. We've also had a few surprises:

we knew the 4GB one would be the popular one, but we didn't quite appreciate how popular. We had to do a bit of fancy footwork in July to turn down 2GB manufacture and turn up 1GB manufacture. In descending order of popularity, it goes: 4GB, 1GB, 2GB.

It's like the venti latte: people don't buy grande lattes, they buy tall lattes and venti lattes. The grande latte is there because it would look weird if you didn't have anything between regular-sized coffee and coffee that's twice the size of your stomach. People don't buy them much.

We did a lot of software work on the thermals, to take energy out of the design. I think on day one there were a lot of people who thought: 'This is a bit warm'. But you've got day-one software. I think a lot of people don't appreciate how much power

is a software thing these days, rather than a hardware thing. Chips have a lot of mitigations in them, a lot of things you can do, knobs that you can adjust to take power out; but turning these knobs creates risks. The safe thing to do is to run with all the power mitigations turned off, because you know that will work. It will also get warm. Over time you can apply software mitigations to the platform. Every time you turn one on, you take the risk that you're going to break something.

USB is a great example. We shipped with high-energy USB firmware and then we got some low-energy USB firmware from our supplier, which enabled power mitigation in the PCI Express link between the main chip and the USB hub, which was great. It took 10% of the power out of the system at a stroke, but nerfed the performance of a subset of USB 3 mass storage devices.

So, you go back to your vendor and say "here are some mass storage devices; can you please make sure it works with these". They then give you another version, so what we have now is a USB firmware which is both low energy and which doesn't lose any USB performance.

But all that takes time – you can't do all of these things on day one. On day one,

all you're concerned with is making sure the thing works. Over time, I guess we've made three significant adjustments that reduce energy in the device, and together they take out well over half a watt, which is around 20% of the idle power consumption, and we're not done yet. We're probably knocking on the door of taking about a watt out of the loaded power of the device. You want to take power out of the idle device because you want it to be cool when it's sitting doing nothing, and then that also means that you have a lot of headroom for what we call sprint performance. Things like your mobile phone and your laptop are designed to idle and then sprint for a certain amount of time. Your mobile phone doesn't have a fan, and it's designed to sit there at a low temperature and then you have a certain amount of let's go full tilt, and eventually, it will get too warm and then slow down.

That's important because people like idle devices to be cool; they associate heat with poor performance, so people like it to be cool when it's not doing anything. And because it creates a thermal buffer that you can then use when you push the device hard, you have more time because there's more of a gap between the idle temperature and the limit temperature.

So idle is important for those reasons. Load is important because it reduces the rate at which you go toward that temperature. Both of them contribute to user experience in different ways.

We've probably taken north of half a watt out of idle power and getting on for one watt out of loaded power. That's quite satisfying, and that's three months of software engineering. There's a lot more that can be done; we don't know yet what that's going to yield in terms of power consumption. So I'm pretty happy with that.

By and large, software has been good actually. We're not done – it'll be a long time before we're done with software on this platform – but it's very, very stable. We've changed a lot more from 3 to 4 than ever did before, from 1 to 2 or from 2 to 3. And I had this nightmare that we'd take a



**Above** Eben's been working on some classic gaming stuff – stay tuned if you loved Sensible Soccer!

big step backwards in terms of the stability.

### HS And has that happened?

**EU** RetroPie doesn't work yet. That's been a thing that people have been sad about, and I'm hoping that we'll get that fixed soon. But really, it's been down to that kind of level: one or two third-party pieces of software where we weren't able to get bits out to the developers before launch.

Every launch, we try to do more with third parties, and every launch we wish we'd done more with third parties. So, we'll try to do more next time.

It was always the dream of Raspberry Pi to build a PC, except a PC with GPIO pins. Gordon Hollingworth, our Director of Engineering, he's always had a current-generation Raspberry Pi on his kitchen counter, running with a screen and keyboard. He now doesn't take his laptop out of the bag when he goes home,

because there's no point: he can use a Raspberry Pi to check his mail, surf the web, write a bit of software.

There was a lot of fuss about this USB C thing that was a bit dispiriting. You can't use your MacBook charger to power your Raspberry Pi – you cannot use your \$100 charger to power your \$35 Raspberry Pi. So, I'm sad about that. But it was reported with a sort of glee almost in some segments of the press, which was a bit dispiriting. But, by and large, actual users were a lot more supportive.

Normally, when you read a story in the press, the comments are ghastly; the interesting thing is that reading the comments to these stories, which were written by actual human beings, was the right thing to do to cheer yourself up. That was good. Raspberry Pi people are nice people. They understand that we're doing our best. If you do the right thing, then the community will do the right thing by you, and it's lovely to be part of a community like that. □



Above ♦  
You can try out  
hardware at the  
Raspberry Pi Store

# BINDER CLIPS

Complete your builds at a pretty good clip



**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.

P

erhaps we've all spent a bit too much time idling in the office.

How else would you explain the popularity of office stationery with the maker community? This month we're looking at the binder clip, which

with its distinctive prism-like shape is often used as a sturdier alternative to the paper clip. The clips come in all shapes and sizes, typically between 0.5 to 5 centimetres (0.2 to 2 inches), and are also preferred over the stapler as they can hold paper together without punching holes in them.

Binder clips were invented by Louis E. Baltzley in 1910. Until then, if you had to bind a stack of papers, you had to punch holes into them to pass a thread in order to sew the papers together. As you can imagine, this made it rather inconvenient to remove a sheet of paper from the stack. Louis came up with the binder's clip to help his father, a writer and an inventor himself, with his manuscripts, and he received a patent for the invention in 1915. Initially the clips were exclusively produced by Louis's company before he licensed the design to other manufacturers.

Not surprisingly, the highly functional and efficient original design has undergone very slight changes in the 100 years since its invention. A binder clip's body

is usually in the shape of a triangular prism that's made of spring steel, with attached metal wire loops that are used as handles for opening and closing the body. Tension along the base of the triangle compels the two sides to close, while the loops prevent the sharp steel edges from cutting into the paper. There are slots in each loop that are cut in order to allow the handles to be folded down once the clip has been attached.

Not only do these clips have a good grip and are rust-resistant, but their design makes them a lot more

**"NOT SURPRISINGLY, THE HIGHLY FUNCTIONAL AND EFFICIENT ORIGINAL DESIGN HAS UNDERGONE VERY SLIGHT CHANGES IN THE 100 YEARS SINCE ITS INVENTION"**

useful than just holding paper together. Although they are popularly used as alternatives to the paper clip, their design makes them useful for a variety of different purposes. For instance, with one of their handles up, you can use the clip to hang papers from a hook. Even as items of stationery, in addition to grouping paper together, they are very commonly used as bookmarks, money clips, and holding objects in place. If anyone could use the clips for such varied purposes, imagine how useful they would be in the hands of our creative makers.

# MATHEMATICAL SCULPTURES

**L**e'ts be honest; we've all tried clipping a bunch of binder clips together in a **Lego-esque fashion**. Zach Abel has gone a little too far. A mathematics lecturer at MIT's Computer Science and Artificial Intelligence Lab, Zach loves to "reveal hidden geometric beauty in office supplies and other modest materials." One of his most popular designs is sculpted from 132 binder clips. Zach warns that replicating the build isn't easy but is highly rewarding, especially if you are a maths geek. In addition to the clips, you'll need a pair of needlenose pliers and some time to understand the geometry of the construction. Zach does a nice job of explaining the maths behind the build, and details

**"IN ADDITION TO THE CLIPS, YOU'LL NEED A PAIR OF NEEDLENOSE PLIERS AND SOME TIME TO UNDERSTAND THE GEOMETRY OF THE CONSTRUCTION"**

Project Maker  
**ZACH ABEL**

Project Link  
[hsmag.cc/QjgoGP](http://hsmag.cc/QjgoGP)

each step of the process. You'll have to first remove the handles from the clips and wrap them around the body. The rest of the build involves connecting the pieces in a particular fashion, and then arranging them into grids of 4x4 clips. The complete build has six of these grids, built with a total of 96 clips. Once all the grids have been connected, the leftover clips are used to fill the edges. There are eight corners, and each requires handles from three clips woven in a particular fashion to close them off. □



**Left ↪**  
Stop by Zach's gallery to admire the other structures he's sculpted from binder clips and other office supplies

# LIGHT TENT



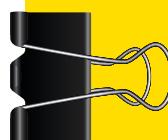
One of the essential elements for tabletop photography (besides a good prime lens) is a light tent. Instead of shelling out money for one, you can create one yourself with some white paper and binder clips (and save the money for the lens). Nathan Moroney is a Principal Scientist at HP

**"KUDOS TO NATHAN FOR COMPLEMENTING THE TEXTUAL DESCRIPTION WITH VISUAL REPRESENTATIONS OF THE FOLDS"**

**Project Maker**

**NATHAN MORONEY**

**Project Link**  
[hsmag.cc/dvObIV](http://hsmag.cc/dvObIV)



Labs and details the build on his personal blog. The process requires three A3-size sheets of medium thickness, and four binder clips. Read through his blog to fold the sheets of paper to create the three sides of the light tent. Two are mirror copies of each other and are used as the sides, while the third makes up the back and the bottom. The binder clips help connect the three folded pieces of paper. Kudos to Nathan for complementing the textual description with visual representations of the folds. You can customise the tent as per your needs, such as substituting the white sheets of paper with coloured ones. Nathan suggests adding more binder clips to add more stability to the contraption. He uses the light tent for shoots with indirect office lighting or reflected sunlight. It's a wonderful hack that comes in handy when you're away from your studio: "It takes me about a minute to make one from scratch." □

**Left ↪**

If you need to shoot larger objects, Nathan suggests using railboard or rolls of paper, cut as per your requirements

# PHONE CAR MOUNT

Project Maker  
**TAYLOR PEET**

Project Link  
[hsmag.cc/FbDJuj](http://hsmag.cc/FbDJuj)

**Right ↘**  
Rotate and reposition  
your clip to change the  
orientation of your phone  
from landscape to portrait



**C**ar phone mounts aren't really expensive, but the joy of using a hack is priceless, especially when you are a college student like Taylor Peet. She used a large binder clip, a couple of rubber bands and two 6" long lengths of paracord. The first and most crucial step is to size the clip to your phone. This involves disassembling the clips and bending the wires with pliers to about 20 degrees. To make sure these wires don't scratch the phone's screen, follow Taylor's instructions to wrap them with the paracord before reattaching the clips. The final step involves wrapping the rubber bands around the wire holders to provide the reverse tension to hold the phone in place. If there is some slack, Taylor suggests looping the rubber band over your fingers or using a smaller one. She says one of the best things about the binder clip mount is how easy it is to reconfigure. □



# PEN AND PHOTO HOLDER

Project Maker  
**SONJA**

Project Link  
[hsmag.cc/fQbWHm](http://hsmag.cc/fQbWHm)

**Right ↘**  
Place pens and pencils  
in the space between  
the clips and photos,  
postcards, or notes  
between the wire loops



**H**ere's a trick to save you some real estate on your desk. Sonja uses eight binder clips and four rubber bands to create a pen and photo stand that takes a minute to put together. Pull the wire loops such that they rest on the clip. Then lay them on their sides arranged in the shape of a circle: "The shape will look more like a flower, and may not be a perfect circle, but get as close to it as you can." Now take two rubber bands and stretch them over one side of the clip. Flip the binder clips, and place rubber bands on the other side as well. Sonja suggests stretching the rubber bands larger than the circumference of the clips, and then dropping them over the clips in one smooth action in order to maintain the flower-like shape of the stand. □



# 3 ISSUES from £5

on a quarterly subscription



Visit: [hsmag.cc/345](http://hsmag.cc/345)

# FORGE

## HACK | MAKE | BUILD | CREATE

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

PG  
**88**

### ANTENNA OPTIMISATION

Design and build your own  
radio receiver

PG  
**94**

### WEATHER FORECASTING

Avoid the rain the 21st century way

PG  
**98**

### SUPER GLUE

Stick things that stay stuck



PG  
**100**

### WORKSHOP TURNTABLE

Precision spinning for  
precision engineering

PG  
**80**

### SCHOOL OF MAKING

Start your journey to craftsmanship  
with these essential skills

**80** LED matrix

**82** Arbor press



PG  
**104**

### FM RADIO

Grab music from the airwaves  
with a microcontroller

PG  
**106**

### 3D-PRINTED JEWELLERY

Create multiple colours of body bling  
with a single extruder

# LED matrix modules in Arduino and CircuitPython

Add 64 pixels of output using either popular language



**Ben Everard**

[@ben\\_everard](#)

Ben loves cutting stuff, any stuff. There's no longer a shelf to store these tools on (it's now two shelves), and the door's in danger.

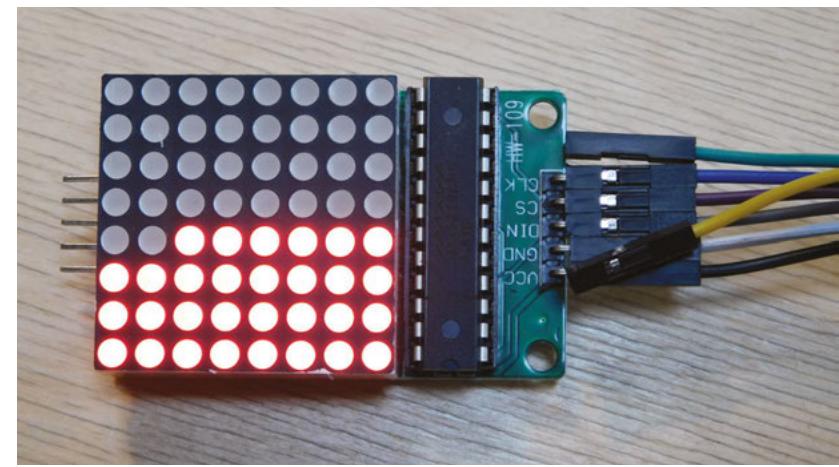
**T**here are, broadly speaking, two ways of hooking up an **LED matrix**. One is to use LEDs with in-built controllers that handle communication over one or two wires (such as NeoPixels), and the other is to multiplex individual LEDs – this is wiring them in a grid in such a way that you can turn individual LEDs on or off by turning connecting voltages to the column and row wires. Here, we're going to look at the MAX7219 chip, which is a very popular way of controlling these multiplexed LED matrices.

We're going to use a very common module that combines an 8x8 LED matrix and a single MAX7219 controller. You'll find identical modules in many hobbyist suppliers and direct-from-China websites. While they come in a variety of colours, they're typically monochrome. You can get multicolour LED matrices, and it is possible to control them in this way. It's complicated by the fact that the multicolour LEDs typically share either a cathode or an anode.

Once you've got your matrix module, you need to connect everything up. There are three communication pins on the module: Data In (DIN), Chip Select (CS), and Clock (CLK). If you've worked with low-level comms protocols before, you might suspect that this is an SPI interface, and you'd be right. DIN corresponds to Master Out Slave In (MOSI). Some SPI devices also have a Master In Slave Out (MISO) connection, but there's none on this board as no data goes from the LED matrix back to the microcontroller.

The module also needs power (3.3V) and a ground connection. With that all wired up, we're ready for our software. First, make sure you've got the latest

**Above** The same basic module comes in a few different form factors, and they should all be quite easy to hook up, but make sure you've got one with the MAX7219 chip, not just the matrix



version of CircuitPython installed on your device (head to [circuitpython.org](#) for details).

Let's take a look at the CircuitPython code to display the words 'HackSpace magazine' scrolling across the matrix:

```
from adafruit_max7219 import matrices
import board
import bitbangio
import digitalio
import time

clk = board.D12
din = board.D13
cs = digitalio.DigitalInOut(board.D11)

spi = bitbangio.SPI(clk, MOSI=din)
display = matrices.Matrix8x8(spi, cs)

while True:
    display.brightness(1)
    display.clear_all()
    s = 'HackSpace magazine'
```

## SHOWING NUMBERS

The MAX7219 chip isn't actually designed to run LED matrices. If you take a look at the datasheet, you'll see that it's intended to be used with seven-segment displays. However, it turns out that the needs of seven-segment displays and LED matrices are actually pretty similar. Despite their name, seven-segment displays often have eight LEDs (one is the decimal point), and this lines up quite nicely with a single line on an 8x8 matrix.

```
for c in range(len(s)*8):
    display.fill(0)
    display.text(s,-c,0)
    display.show()
    time.sleep(0.25)
```

As you can see, we've created an SPI connection using the bitbangio module. This allows us to use any pins, not just those with hardware support (though you can switch this to use the hardware SPI port and the busio module if you'd rather).

We use the `matrices` class in the MAX7219 module – there's also a `bcdigits` class for displaying binary coded decimal on seven-segment displays using the same chip (see box above).

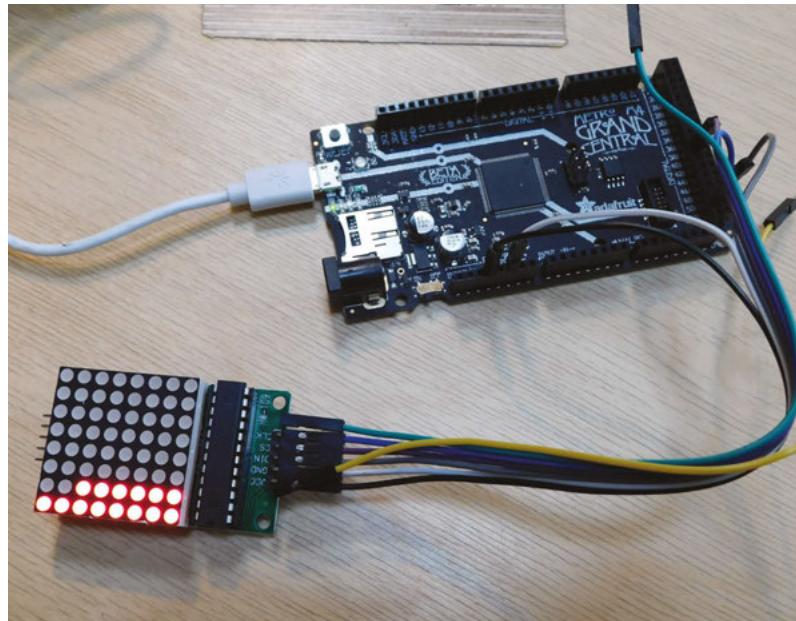
**With these matrices, you can add all manner of graphical interest to your projects**

The `text` method takes three arguments – the string to display, the x position, and the y position. By slowly making the x position more and more negative, we scroll the text across the display.

If you'd rather do more free-form drawings, you can also set individual pixels using the `display.pixel(x, y)` method.

### ITALIAN JOB

Let's now switch our attention to the Arduino programming environment. Unlike in CircuitPython, most libraries for the MAX7219 require you to use hardware SPI connections for the Data and Clock inputs. You'll have to refer to the documentation for your device to find out which pins these are. On our test board (the Adafruit Grand Central M4), MOSI (which corresponds to DIN) is on pin 51, and SCLK (which corresponds to CLK) is on pin 52. CS can be whichever pin you want it to be (we used 40).



There are a few libraries you can use to get these matrices working, but we found the `LEDControl` library worked well. With everything connected and this library installed, we loaded the demo sketch (`LCDDemoMatrix`), and changed the setup line to:

```
Lc=LedControl(51,52,40,1);
```

Once the code uploaded, the demo sequence ran smoothly.

There are three ways of setting the LEDs using this library:

```
lC.setRow()
lC.setColumn()
lC.setLed()
```

The first two take three parameters – the index of the LED matrix (that's 0 if there's only one), the row or column index (between 0 and 7), and the data to display in a binary string. The final function takes four parameters – the matrix index, the x and y coordinates of the LED, and the Boolean value you want to set.

With these matrices, you can add all manner of graphical interest to your projects. You can get quite a lot in 64 pixels, such as anthropomorphic expressions, bar graphs, or even a game of Pong. □

## CHAINING

MAX7219 chips are designed to be daisy-chained, allowing almost arbitrarily large LED matrices to be created. Most modules are designed with input pins on one side and output pins on the other, so they can be simply connected together.

**Above** The Grand Central is overkill for this project – even a modest microcontroller should have no problems controlling this display

# The arbor press, its uses and modifications

Let's look at this useful and affordable workshop tool and explore some simple modifications to increase its functionality



**Jo Hinchliffe**

@concretedOg

Jo is a contributor to the Libre Space Foundation, and is passionate about all things DIY space. 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, milling machines, and CNC kit!

## YOU'LL NEED

- ❖ Arbor press
- ❖ Drilling and tapping equipment
- ❖ Some small pieces of steel
- ❖ Access to a lathe
- ❖ Access to a 3D printer
- ❖ Eyelet fitting tool
- ❖ Vee block

# A

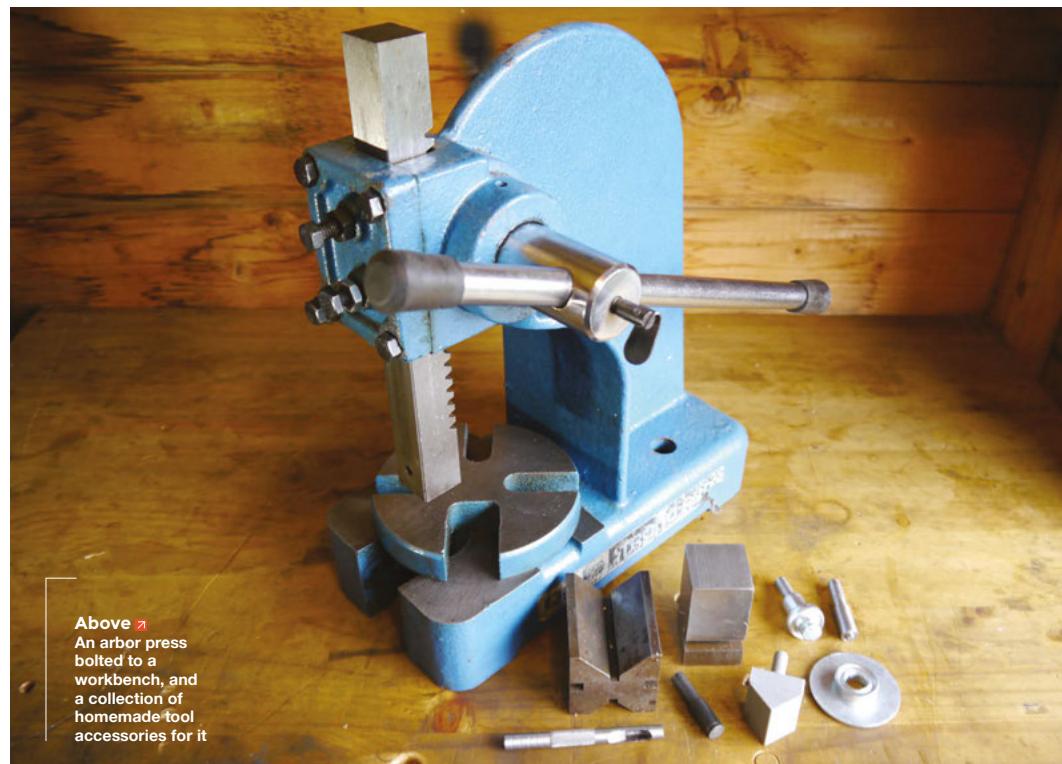
**n arbor press is a really useful workshop item that is reasonably affordable, and many of the large DIY retailers sell them.**

They are available in lots of sizes and pressure ratings, but the common smaller sizes are able to apply either a half tonne or a tonne of pressure. In this article, we will explore some common uses of the arbor press, as well as looking at some less common uses and some modifications.

Arbor presses consist of a solid, heavy cast body that should be bolted down to a bench surface and

have a rotating spindle which, when turned, raises or lowers the ram which can exert a downward pushing force onto an object placed on the work table. The work table is often a rotating cast disc with a flat surface, with different size gaps in it to accommodate various jobs. The rotating table is often removable, and a flat work surface underneath can also be used.

A typical job for an arbor press is to press-fit something into something else with an interference fit; for example, pressing a bearing into a hole that has been created to a tolerance that will hold the bearing once it is pressed in.



**Above ↗**  
An arbor press bolted to a workbench, and a collection of homemade tool accessories for it

We can see in **Figure 1**, the bearing (a 10mm one in this case) is placed onto the hole edge, and the assembly is placed on the work surface. Lowering the spindle results in pushing it onto the bearing and, in turn, pushing the bearing into the workpiece.

When raising and lowering the ram to engage with a piece of work, it's very common for the handle to end up in the wrong place and not have enough travel for the job in hand, or for it to be in an awkward place for the user to exert any pressure. A common modification for this is to remove the ram and modify it by removing a few teeth from it, which means that at the top limit of travel the ram will ratchet on the spindle, allowing the handle to be set to any position relative to the ram and spindle. It should be noted that this will slightly limit the travel length of your arbor press, as the ram will be unable to be fully retracted, but it's definitely a modification that is worth considering. We haven't done this modification as we came up with a slightly different solution that allows for a ratcheting handle from a socket set to be used, as well as a torque wrench.

## LET'S TORQUE

This simple modification was to drill and tap the end of the spindle on the other side from the handle and to insert a bolt. This allows the user to use torque wrenches fitted with the correct-size socket, in this case, a 10mm one. Using the torque wrench as a handle instead of the actual handle means that the user can set the torque wrench to deliver different amounts of force (**Figure 2** overleaf). While it's probable that the translation of

**Using the torque wrench as a handle means that the user can set it to deliver different amounts of force**



## ADJUSTMENTS

The arbor press is quite a simple tool that is relatively easy to assemble and disassemble. The spindle that runs through the body is removed by removing a locking ring on the left-hand side which is clamped in place with a grub screw. The ram can be removed by undoing the four bolts on the corners of the cover. Inside the section where the ram passes through the body, two floating strips of metal can be tightened and loosened against the surface of the ram. These are called gib strips, and they will fall out when you remove the cover and the ram. The gib strips are adjusted by the bolts on the centre line of the front of the ram and the two bolts on the side of the body casting. The ram should move freely up and down with little play from front to back and side to side. Also, the ram shouldn't be so loose that it travels down under the weight of the handle when no pressure is applied. To adjust the gib strip, loosen the locking nut on the adjustment bolt and then finger-tighten the bolts against the gibs. Then try moving the ram to ascertain if you need to adjust more. Usually, you might need to back off each bolt a fraction to get the ram flowing freely while minimising play. Once you have the ram how you want it, use two spanners: one to hold the bolt in the current position and not allow it to move, and the other to tighten the locking nut so that the bolt is set in position and cannot move.

force through the socket, spindle, and ram means that the force at the end of the ram is different to the force dialled in on the torque wrench, it does mean that repeated use at the same torque wrench setting

will deliver the same repeatable force every time. This is useful for numerous things; for example, when inserting PEM nuts, we have found that a particular torque setting is the best combination of getting

the nut in while not distorting the workpiece. Another use is in materials testing. For example, we wanted to explore the different strengths in 3D-printed tubes with varied wall thickness and printed infill; setting up the press with the torque wrench allowed us to see

and measure the amount of deflection in the same-size tubes under the same amount of load (**Figure 3** overleaf). It's worth noting that the addition of the bolt also allows you to use non-ratcheting bars from a socket set, or a long 'breaker bar', with which it would be possible to create a force larger than the press is specified for – useful, but be careful! →

## QUICK TIP

Do ensure that you bolt your arbor press to a sturdy workbench. We have removed the fixings in some of the images to enable us to move the press into more photograph-worthy positions.

**Figure 1** ◆  
A typical use for an arbor press, using the ram to press-fit a bearing into a hole. The hole has been created accurately so that the bearing is an interference fit

## SCHOOL OF MAKING



**Figure 2** ◊  
A simple modification allowing a torque wrench to be used as an alternate handle to deliver a repeatable force through the ram

### MORE SQUEEZING THINGS IN!

Inserting PEM nuts and threaded inserts is another useful task for which an arbor press can be used. PEM nuts are press-fitted into an undersized hole with a small jagged crushable area on the nut that is forced into the hole and forms a tight fit. They are commonly used, but the official insertion tools can be very expensive for the home or hackspace tinkerer. As an example, we needed to insert a PEM nut inside a small aluminium extrusion but, of course, we wanted to avoid bending the extrusion itself. Using a steel block (**Figure 4**), we milled a channel into the block to create a tool that allowed the edge of the 50 mm aluminium extrusion to be placed under the ram and have the PEM nut inserted while allowing the workpiece to ‘float’ and minimise the forces directly applied to the extrusion. The result is a neatly inserted PEM nut with no visible bending of the extrusion (**Figure 5**).

**Figure 3** ◊  
Using the torque wrench allows us to compare the strength and the strain in a 3D-printed part when under a known load. Using the height gauge allows us to measure the deflection of the 3D print



### EYELET AND TOOLS

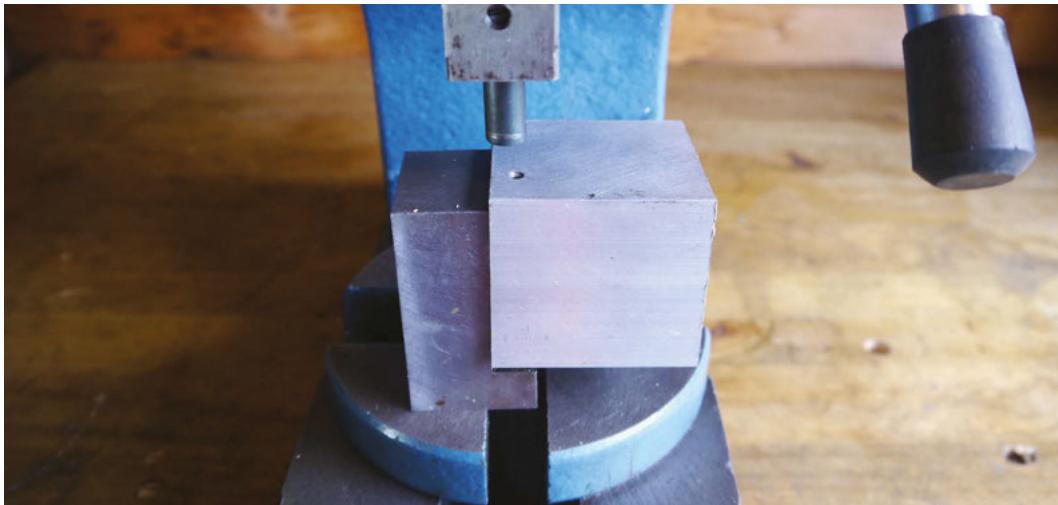


Also modified to fit our 8 mm mounting system are pressing tools to fit eyelets to materials. The larger tool for fitting the 15–20 mm eyelets (pictured) is adapted from a standard tool by shortening the shaft and turning the shaft down to 8 mm to be held in the ram. The smaller tool is for fitting the smaller 9 mm eyelets and has been made from scratch in the lathe by turning down a 10 mm steel rod. Again, using these tools in the arbor press, rather than by hitting them with a hammer, means that the work is more accurate and the pressing load is exerted evenly and simultaneously over all of the eyelets, leading to an accurate, strong eyelet being placed in the material. We have also turned down some cheap hollow punches to allow them to be used in the press for cutting holes in a variety of materials.

### ADAPTED END



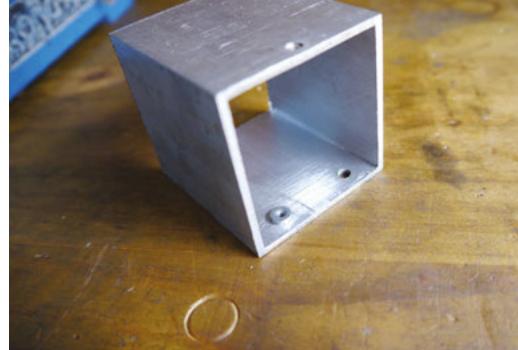
One of the modifications we've made to the arbor press is to remove the ram from the assembly and drill an 8 mm hole into the end of it to allow it to hold different tools at the end of it. It's a bit of a challenge to drill into the end, due to the length of the ram and it is essential to make sure that the hole is parallel and concentric to the spindle. This author's pillar drill and manual milling machine are both too small to do this, and we ended up using a larger lathe to do the job. Having got our hole into the end of the spindle, we drilled and tapped a threaded hole into the side of the spindle to allow an M6 grub screw to be used to hold tools. If you are unsure how to tackle this job, we wrote a tutorial on drilling and tapping in issue 20 ([hsmag.cc/issue20](http://hsmag.cc/issue20)). We look at some of the tools we have made in this article, but the most used basic tool is a piece of hardened and tempered drill rod/silver steel which is used for general pressing.



**Figure 4** ◇  
Inserting PEM nuts into the inside of an extrusion requires a stand to be made that allows the nut to be pressed in while not bending the actual extrusion

## NEW AND OLD TECH

We had seen some examples in the community of people using 3D-printed parts printed with a high amount of infill to make tools to put accurate folds into metal. The proper tool for this is a ‘press brake’, but the arbor press can be made to emulate a press brake with the addition of some of these 3D-printed tools. We 3D-printed a pressing vee tool, which again can be received by the 8mm tool-holding arrangement (**Figure 6**). Printed with 1.2 mm thick walls and a 40% infill in PLA, this tool is plenty hard enough, in combination with a receiving vee block, to put bends into thin sheets of aluminium and even



**QUICK TIP**  
Make sure to wear your safety glasses when pressing things in an arbor press. The high-pressure nature of it means that if something breaks, things can leave the work table at high velocity!

“ The arbor press can be made to emulate a press brake with the addition of some 3D-printed tools ”

thin steel sheets. It’s very useful for also placing 90-degree bends into solid wire etc. The receiving vee block could also be 3D-printed, or just use engineering vee blocks if you have them already. Again, the value of using the arbor press for this is that it is repeatable and should result in similar results each time, making it ideal for short runs of folded items etc.

We had also seen people using 3D printing and some form of press device to emboss shapes into items. As an experiment, we have printed a small rocket shape (of course!) and attached it to a backing plate. Using this and the arbor press, we managed to emboss the image into a notebook which had a card and vinyl cover (**Figure 7**).

Hopefully this tutorial has shown that the arbor press is a valuable tool that, with a little time and imagination, can be used for lots of tasks – and that



some simple additions and modifications can easily broaden the range of tasks. We have lots of jobs left on the list to try with the arbor press: fitting thermal inserts into 3D prints and broaching key ways into metal, for example. The internet is full of useful things that people have done with this affordable and resilient tool. If you have a job or a modification you do using an arbor press, do let us know via either the letters page or social media. □



**Figure 5** ◇  
The steel PEM nut is fitted accurately and securely into the aluminium extrusion

**Figure 6** ◇  
A 3D-printed tool that enables repeatable folds to be pressed into thin metal sheet

**Figure 7** ◇  
Using the press, we managed to emboss the shape from a 3D-printed object into a vinyl covered notebook

2nd  
Edition

FULLY UPDATED FOR RASPBERRY PI 4

THE OFFICIAL  
**Raspberry Pi**  
Beginner's Guide  
How to use your new computer

Fully  
Updated for  
**Raspberry  
Pi 4**

The official Raspberry Pi Beginner's Guide

2nd Edition

by Gareth Halfacree



# THE OFFICIAL Raspberry Pi Beginner's Guide

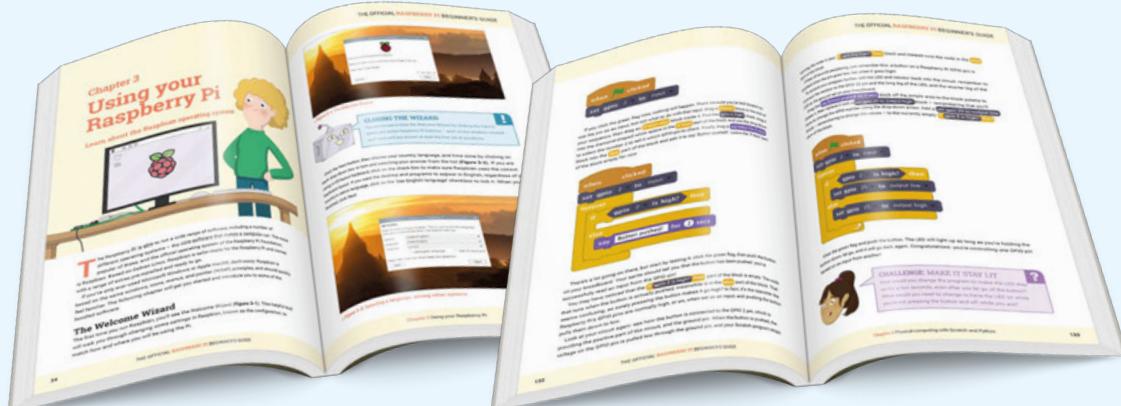
**The only guide you need to  
get started with Raspberry Pi**

## Inside:

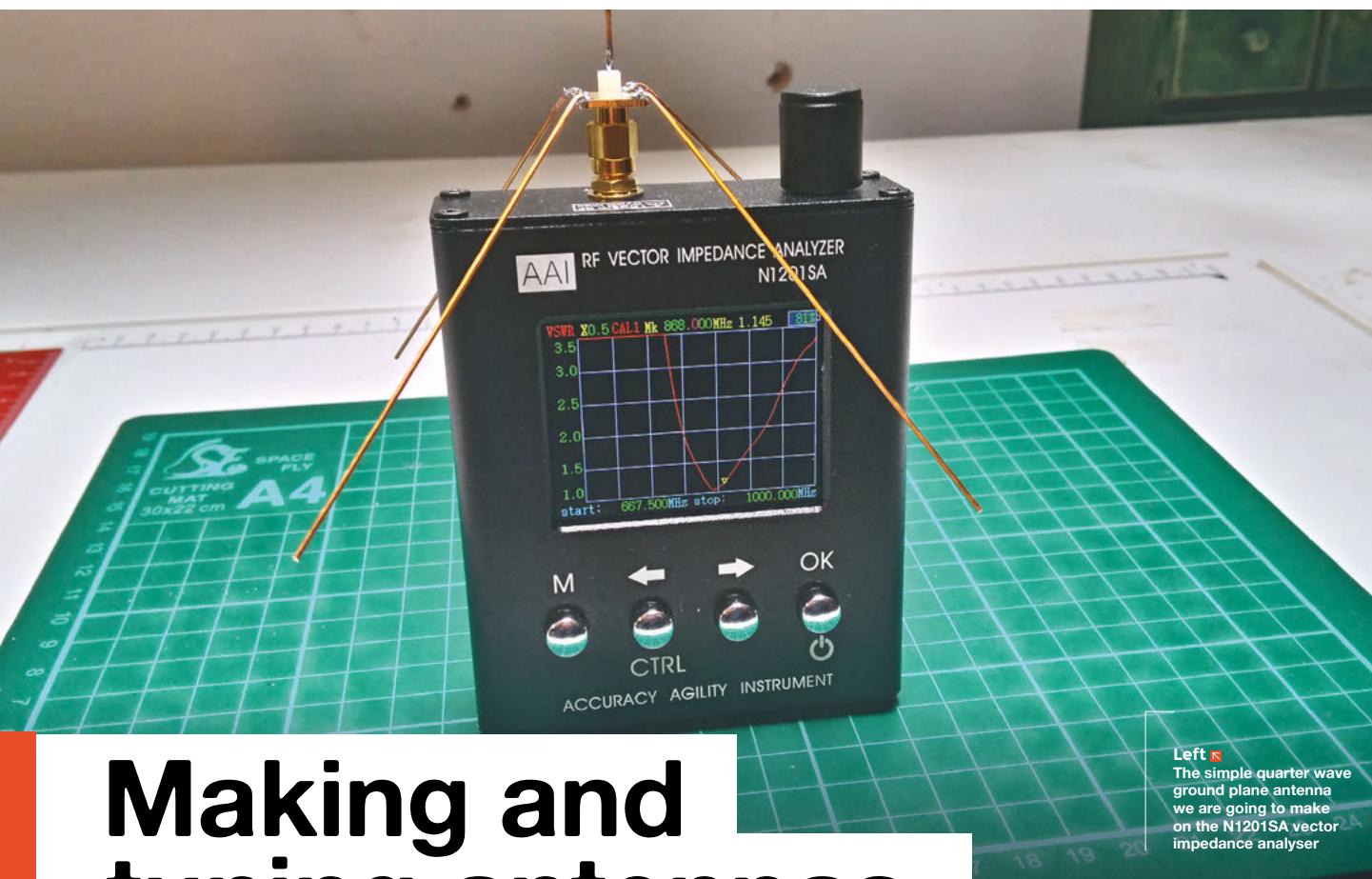
- Learn how to set up your Raspberry Pi, install an operating system, and start using it
- Follow step-by-step guides to code your own animations and games, using both the Scratch and Python languages
- Create amazing projects by connecting electronic components to Raspberry Pi's GPIO pins

**Plus much, much more!**

**£10 with **FREE** worldwide delivery**



**Buy online: [magpi.cc/BGbook](http://magpi.cc/BGbook)**



# Making and tuning antennas

Sending and receiving data the most power-efficient way



**Jo Hinchliffe**

@concreted0g

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

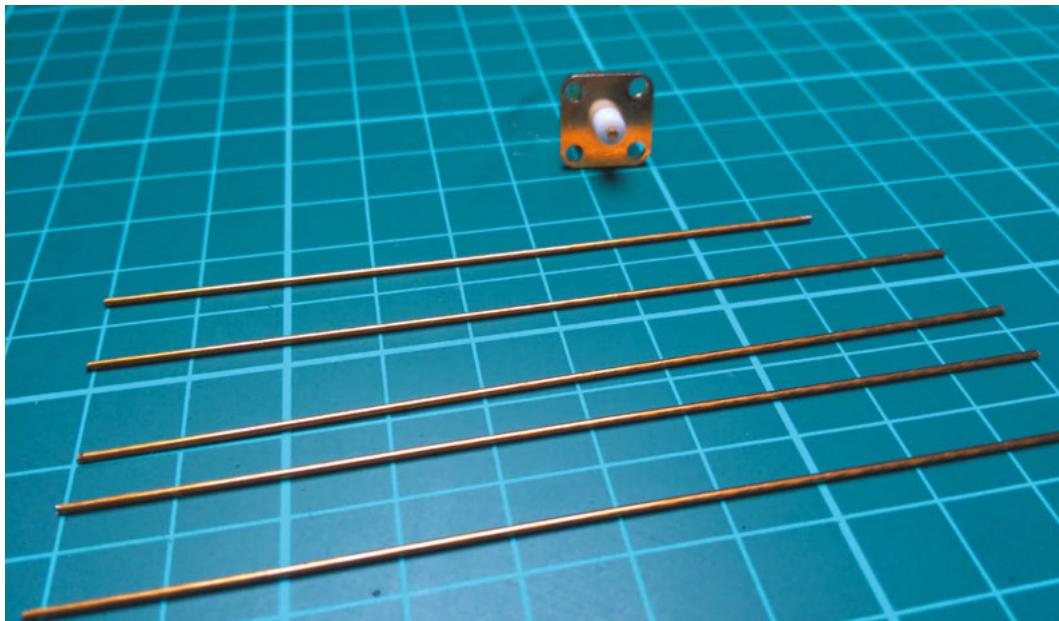
In this tutorial, we are going to make a simple DIY antenna, and we are going to try to maximise its efficiency. We are going to make a type of antenna called a quarter wave ground plane, and we are going to make it suitable for use with a LoRa device operating on the 868MHz frequency. As this frequency will result in quite a small antenna, we are going to attach the antenna elements directly onto an SMA chassis mount socket.

The first thing we do is use an online calculator to work out our design. We used the one on this site: [hsmag.cc/LIVzgj](http://hsmag.cc/LIVzgj). Simply insert the target frequency of 868 into the input box, and click the 'calculate my quarter wave' button. You will see that some dimensions for different parts of the design are given in the other boxes. The quarter wave ground plane design has essentially one vertical element, a piece

of wire in our case, which is the radiating or driven element called a vertical monopole, and numerous radial elements that form the ground plane. These ground plane radial elements can vary in number between three and six, but we are going to use four for our design.

As we can see in **Figure 1**, the dimension for the driven radiating element is 8.2cm, and the radials are 9.2cm. However, as it can be difficult to cut these accurately – including some material for the bit that is soldered on – and then difficult to measure the length once attached, we are going to cut them oversize and then trim them to size whilst measuring the efficiency of the antenna.

We used some enamel-coated copper wire that we had a reel of, but it's fair to say that any solid wire (such as the copper stripped from mains cable) could be used.



**Left ♦**  
The copper wire elements cut to length and the chassis mount SMA socket we are going to use

## QUICK TIP

The N1201SA is a brilliant tool but has some quirks! For example, the knob rotation is slightly counter-intuitive when adjusting frequencies – anti-clockwise raises numbers and clockwise lowers them!

1/4 Wave Ground Plane Antenna Calculator	
Quarter Wave Ground Plane Antenna Calculator	
Frequency	868.0 MHz
Velocity Factor (see text*)	0.95 vf
Give me the results in...	<input type="radio"/> mm (Millimetres) <input type="radio"/> cm (Centimetres) <input type="radio"/> m (Metres) <input type="radio"/> in (Inches) <input type="radio"/> ft (Feet)
<input type="button" value="Calculate My Quarter Wave"/>	
A. Vertical Monopole Radiating Element ( $\lambda/0.25 \times v_f$ )	8.2 cm
B. Radials ( $\lambda/0.28 \times v_f$ )	9.2 cm
Actual wavelength	34.6 cm
<input type="button" value="Clear Form"/>	

**Figure 1 ♦**

Using the online calculator to get the dimensions needed for our antenna design

## A CUT ABOVE

Having straightened a section of wire, we are going to use some side cutters to cut the five pieces we need for the design. Let's cut them oversize, so that we can trim them to length once we have assembled the antenna. We went roughly 8mm over the lengths that we calculated. The wire we used happened to be coated with an epoxy finish, so we sanded one end to reveal the bare copper underneath to allow it to be soldered.

Next, tin those ends with some solder. To assemble the quarter wave ground plane antenna, we held the chassis mount SMA adapter in a small vice and tinned the centre pin, and also a small amount on each corner of the chassis plate. It can be quite hard to solder to the chassis plate, as the SMA connector itself acts as a bit of a heat sink, making it tricky to get the solder flowing. Having tinned all the parts of the

connector we are going to solder, begin by soldering the shorter vertical element onto the centre pin. Next, in turn, solder the radial coming off each corner of the connector chassis mount plate (**Figure 2**, overleaf). We found it was easiest to solder these on and then bend the radials down to the 45-degree slope after attaching them all (**Figure 3**).

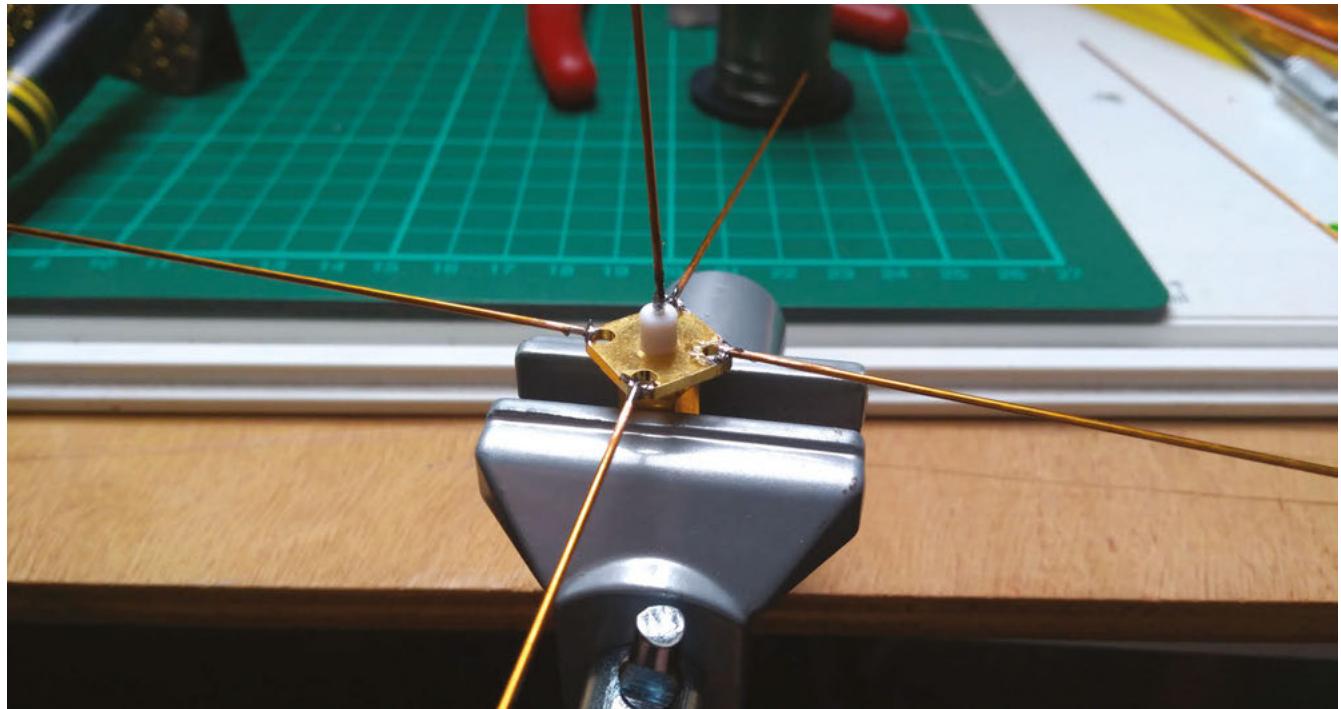
An antenna such as this one could be used on a LoRa node (we covered LoRa in issue 22). In this node, the radio transmitter module and the antenna's job would be to transmit a data payload, radiating the signal out into the air to be picked up by a gateway receiver. LoRa devices are limited to 100mW of power, which is enough but not a huge amount of power in terms of radio transmission. This low power obviously helps in terms of battery life and other factors important for LoRa networks. We need the LoRa device (and usually any low-power radio device) to be able to maximise the use of its small power budget. A well-optimised antenna will send as much of its available power as possible through →

## YOU'LL NEED

- ♦ An SMA chassis mount socket
- ♦ Some copper wire
- ♦ Soldering equipment
- ♦ Some sharp side cutters
- ♦ A budget antenna analyser (N1201SA or NanoVNA)

## STRAIGHTENING WIRE

Often, for antenna building and other projects, we have the need for straight pieces of wire, but wire is often supplied coiled on a small reel. A simple way to straighten a piece of wire is to use a vice and a cordless drill. It does result in the wire surface appearing like a spiral, but in this case, that doesn't matter. Cut a length of wire around 60cm, and fold a small 1cm section over at each end to give a little more surface area for the vice and the drill to grip onto. Clamp one end into a vice and tighten the other end into the drill chuck. Pull the wire taught by pulling the drill away from the vice, and then rotate the drill slowly. The direction of rotation doesn't matter. You should see the wire begin to straighten along its length. Continue until the entire length of wire has straightened. It's a good idea to wear safety glasses for this as, with copper wire, sometimes the wire can snap and go in any direction.



**Figure 2** The centre radiating element and the four ground plane radial elements, all soldered into position

**Figure 3** The completed antenna, with each radial carefully bent downwards by 45 degrees

into the air, maximising the signal strength. A poorly optimised or badly designed antenna will reflect some of the power back into the transmitting device; this can cause damage to the transmitting device, but also will dramatically reduce the capability and range of a system as that power is wasted.

### GOOD VIBRATIONS

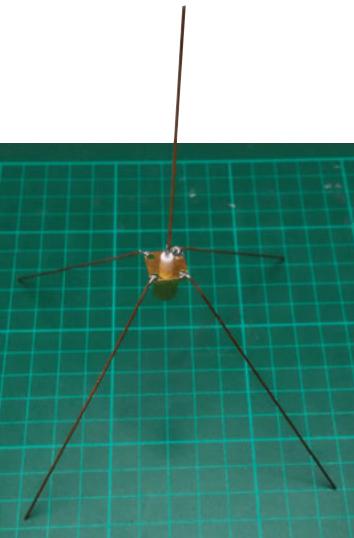
When antennas are tuned to their resonant frequency, we can optimise the ratio of transmitted power versus reflected power, enabling as much of the power to be used to radiate the signal and therefore maximising the transmission range.

The ratio between transmitted power and reflected power is called the standing-wave ratio (SWR). As this is a ratio of voltage, it's also referred to as VSWR (voltage standing-wave ratio), as indeed it is on the N1201SA vector impedance analyser we are going to use. It's widely accepted that a VSWR ratio of less than two is acceptable enough to call

an antenna optimised, and this should be easily achievable with our antenna. It is certainly possible, however, to simply try as best as one can to make the antenna using the design measurements and, if realised accurately, it should perform reasonably.

To begin optimising the antenna, connect it to the N1201SA analyser and long-press the CTRL and

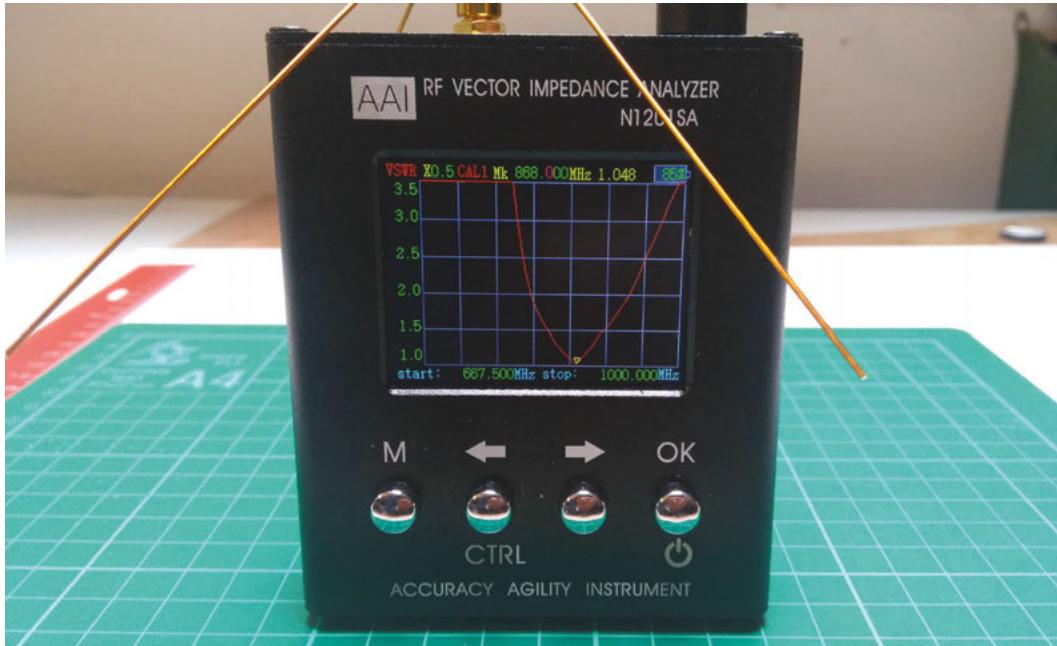
The ratio between transmitted power and reflected power is called the standing-wave ratio (SWR)



### THE THEORY

Adjusting the VSWR is a great way of optimising the antenna; however, the theory behind what we are doing is a broad and complex subject. Impedance matching, or balancing the capacitance and inductance of the antenna, and these underlying theories are worth exploring. A great primer video by Andreas Spiess, which also features the N1201SA and a quarter wave ground plane antenna, can be found here: [hsmag.cc/MgITHK](http://hsmag.cc/MgITHK).

power/OK buttons to turn it on. Press the M button once to get to the screen that looks like **Figure 4**. Next, we need to set the range of frequencies that this screen is going to show us. At the bottom of the screen, we can see the 'start:' and 'stop:' frequencies. Clicking the arrow keys enables us to highlight these numbers, then click OK. We can then select each digit of the frequency number with the arrow keys and use the rotary knob on the top of the unit to change the value. First, adjust the start and stop values to between around 400MHz and 1500MHz – you should see a dip in the line somewhere on the screen, probably not near our desired 868MHz frequency. Next, let's set the yellow cursor to our desired target resonant frequency of 868MHz. Navigate to the frequency at the top of



**Figure 4** ◇  
The reasonably affordable N1201SA antenna analyser with our quarter wave ground plane antenna attached, ready to be made more efficient

the screen and adjust it to 868. You should now see that a small yellow cursor is set to 868MHz. The game now is to try to get the lowest point of the dip to correspond to the yellow cursor. We can see that the y axis scale of this screen is the VSWR, and therefore the y axis reading (the position of the yellow cursor) is the VSWR of our antenna.

To make our adjustments, we are going to carefully take small cuts from the antenna elements to bring them close to the designed dimensions and hopefully reduce the VSWR down to less than two. We started by taking a measurement of the centre monopole element we attached first. It's important that we measure from not just the solder joint but also include any length of the brass pin we soldered. Measuring from the point that the brass pin protrudes from the insulating jacket, we made a small cut to reduce this element towards its designed length of 8.2cm. You should see the resonance (dip) change and the dip move closer to the yellow cursor representing our desired frequency. As the antenna becomes closer to being optimised, you might consider reducing the range of frequencies a little to make the dip look larger and easier to see. We ended up with a start frequency of 600MHz, and a stop frequency of 1000MHz.

Once you have reduced the monopole element to the designed dimension, turn your attention to the radial elements. In turn, make small cuts to remove some material and try to ensure that after each

## AVOID INTERFERENCE

When using the N1201SA, it's important to be in an area that doesn't interfere with the analyser too much. Working in a space that doesn't have any large metal objects close by is a good start. We also found that using a camera or a phone near the N1201SA affected the readings – not easy to avoid when trying to take photographs for an article! In the image, we have the same antenna attached, but local objects are causing interference and changing the output of the N1201SA.

round of cuts, the elements are the same length. For the adjustment of the radials, it is less important that we end up with the exact designed length, as the body of the chassis socket also affects the capacitance and inductance of the design, but we do want to keep each element the same length as the others. Again, aim to get the yellow cursor of the resonant frequency to the lowest point in the VSWR ratio dip. We achieved a VSWR of just under 1.2, which is very satisfactory.

Congratulations, you should now have a reasonably well-optimised antenna that should be fairly capable on the designed frequency. Adjusting the VSWR is a similar task for many antennas, and there are lots of tutorials online about many different types of antenna designs, as well as heaps of resources on the theory of antennas and signal propagation. A great place to start with this complex subject might be to visit the Radio Society of Great Britain site ([rsgb.org](http://rsgb.org)), or check out your local amateur radio group. □

## QUICK TIP

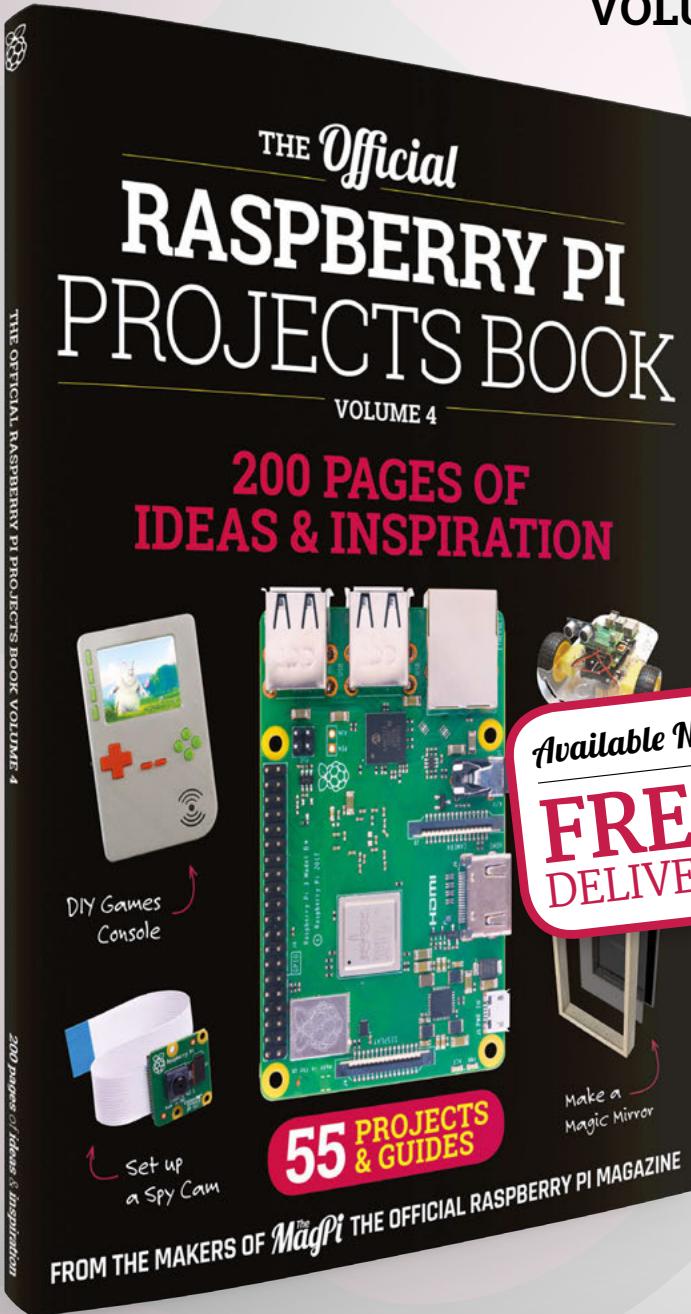
It is pretty difficult to add material back to the element if you go too far! Always cut less than you think you need to remove, and allow the analyser to settle and take a reading before continuing.

£12.99

200 pages of  
Raspberry Pi

# THE *Official* RASPBERRY PI PROJECTS BOOK

VOLUME 4



Amazing hacking  
& making projects

from the creators of

*MagPi* magazine

## Inside:

- How to get started coding on Raspberry Pi
- The most inspirational community projects
- Essential tutorials, guides, and ideas
- Expert reviews and buying advice

[store.rpipress.cc](http://store.rpipress.cc)

plus all good newsagents and:

WHSmith **BARNES&NOBLE**

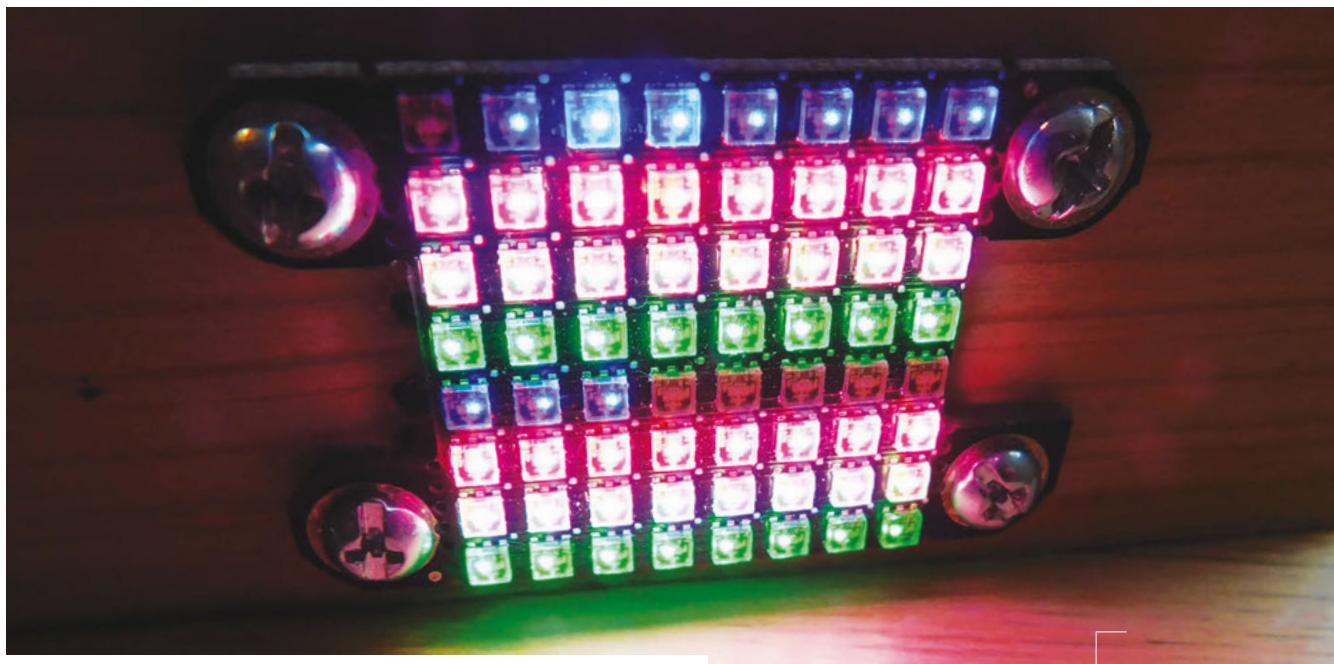


# Wireframe

Join us as we lift the lid  
on video games



Visit [wfmag.cc](http://wfmag.cc) to learn more



**Above** ▶  
The 2020 LEDs are tiny and give pleasing pinpoints of light

# Keep an eye on the weather

Display data from the internet in a concise but meaningful grid of lights



**Ben Everard**

🐦 @ben\_everard

Ben loves cutting stuff, any stuff. There's no longer a shelf to store these tools on (it's now two shelves), and the door's in danger.

**B**arometers are great, aren't they? A quick tap and they tell you if it's going to be stormy, rainy, or fair. The only problem is that they tend to be fairly inaccurate. The reason for this is that they only have one bit of data going into them, the current air pressure, and this isn't really enough to know what the weather's doing now, let alone what it's going to do in the future.

Fortunately, in the modern world, we have access to supercomputers chomping thousands of data points to create weather forecasts that are at least vaguely accurate. Let's use this to create a device that we can understand with a simple glance, but that's actually accurate.

The first thing to think about with any data display is 'what do you need to know'. That isn't the same as 'what information do you have' or 'what information is easy to display'. What we really want to know is what information do we need to make useful decisions. When it comes to weather, we need to answer questions like:

- Will it rain on the way home from work?
- Should I wear shorts or trousers today?
- Can I hang clothes on the washing line?

To make these decisions sensibly, we need to know how the weather's going to change the next day. We decided that we wanted to highlight four things (but you might find other information useful):

- Precipitation
- Cloud cover
- Temperature
- Wind strength

In order to enable users to tell at a glance what's going to happen, we decided to use an LED matrix to display the data. Each row on the matrix represents one type of data, and the colour of the LED shows the data. For example, on the temperature line, LEDs are lit on the blue-purple-red scale to show what the temperature will be. It's hard to know the exact temperature from the colour, but it's easy to see if it's getting colder or warmer.

Each LED will represent a three-hour period, so a row of eight shows a 24-hour day. Since we're using an 8x8 matrix, and there are four data lines, we can show two days' worth of data.

### KEEPING THINGS SIMPLE

We're going to use a SparkFun LuMini Matrix. This is a tiny matrix which means that the device will fit nicely into our home and not be a big obtrusive thing. We simply mounted it on a short section of 2x1 inch pine, leaving enough space to mount the SparkFun Thing Plus on the back. You could use the exact same setup to work on a wide range of different microcontroller and LED options. Most ESP32 microcontrollers should work, but ESP8266 boards may struggle unless they've got additional RAM.

While you could use any LED matrix (it doesn't even need to be 8x8, you could change the code to work with a wide range of form factors), we selected the LuMini Matrix because of its size.

The LuMini Matrix is made up of APA102 LEDs which are a little different from WS2812B NeoPixels. There are a few technical differences, but the most obvious one for casual use is that there are two data wires rather than one. The FastLED library that we use

**It's hard to know the exact temperature from the colour, but it's easy to see if it's getting colder or warmer**

### OPTIONAL UPGRADES

The look you go for is up to you. We like the little, bright lights, but that's just us. A larger matrix with some diffusion could also look good, as could a design made using separate LED strips for each line.

Our lights are always on, but you may want to include some way of turning them on or off, a button could be added, and the ESP32 has some touch-sensitive pins that you could use as well. A PIR motion sensor could also be added to just light up when someone's near.

We're using our device to show the weather, but you could display anything that you can get data for. Hay-fever sufferers may wish to show predicted pollen counts; you could show UV strength, a warning for ground frost, or anything that's important to you.

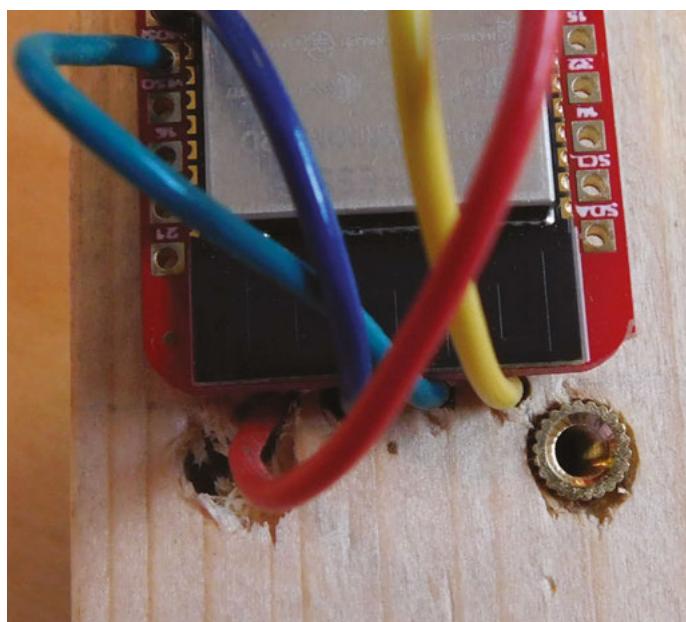
to drive this can also drive WS2812B (and other WS28XX LEDs), so it shouldn't take much to switch to a different LED technology. If you want to use a multiplexed LED panel, then you'll need to rewrite the output sections of the code.

There's not too much wiring involved in this project. We can get enough power from the USB connection, so connect VUSB to the 5V

in on the LEDs. Ground goes to Ground, MOSI goes to DI, and SCK goes to CI. However, before you solder all these together, make sure you've got the physical setup right. We were mounting the LuMini

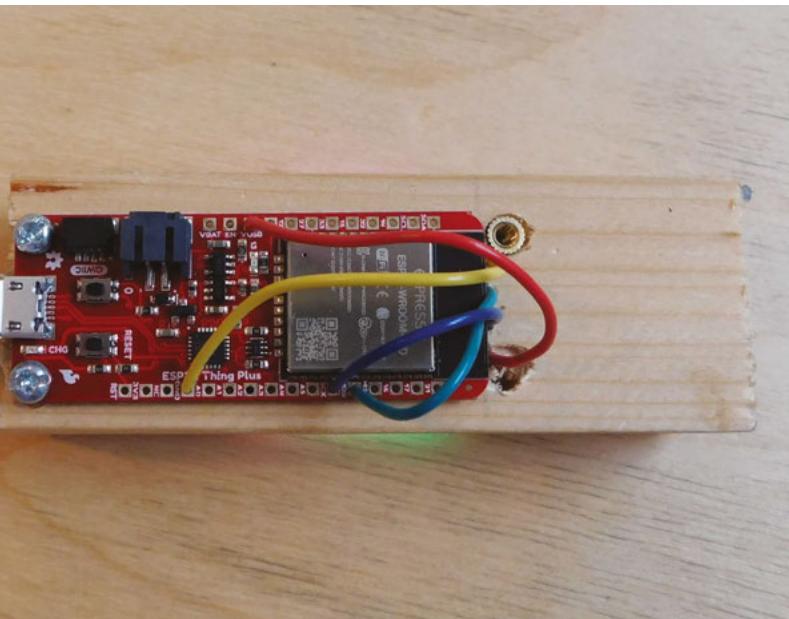
Matrix on a separate side of the wood to the Thing Plus. To keep things neat, we drilled four small holes to feed the wires through and lined these up with the solder points on the LuMini Matrix.

We mounted both the Matrix and the Thing Plus using machine screws and threaded inserts in the wood. These brass inserts can be pushed into tight-fitting holes and allow machine screws to securely hold wood, plastic, or other materials that wouldn't usually fit in. We originally intended to use inserts that have an outside thread and can be screwed into wood, but when we came to build this, we found that we only had M3 size and up which were too large for this build, so we used push-fit inserts, and they've held well. →



**Left** ◆  
Four small holes let us pass power and data through to the LED matrix

## TUTORIAL



With everything bolted and soldered together, let's move onto the software.

### WEATHERDUINO

You'll need to install the Arduino IDE and set it up to be able to communicate with the Thing Plus. There are details on doing this at [hsmag.cc/MCwBPP](http://hsmag.cc/MCwBPP).

Now let's now take a look at the code. The SparkFun Thing Plus is based on the ESP32 microcontroller, so we'll use the in-built WiFi library. We'll also use FastLED to control the LEDs and ArduinoJson to parse the data (that we get from OpenWeatherMap), so you'll need to install these if you don't have them already.

**Above** We made a mistake when first mounting the matrix. Rather than waste the wood, we flipped it around, so this is on the unseen back of the device

**Below** The SparkFun Thing Plus works with the Adafruit ESP32 Feather Arduino board definition

```
#include <FastLED.h>
#include <ArduinoJson.h>

#define RAIN_COLOUR 0x0000FF
#define RAINY_DAY_COLOUR 0x00FFFF
#define SUNNY_COLOUR 0x00FF00
#define CLOUDY_COLOUR 0x008000
#define OVERCAST_COLOUR 0x808000
#define FOG_COLOUR 0x800080
#define NIGHT_COLOUR 0x000080

FastLED.show();

void setup() {
    // Initialize the matrix
    for (int i = 0; i < 16 * 4; i++) {
        matrix[24 + (i - 8)] = rain_colour;
    }
}

void loop() {
    // Now let's get the temperature
    for (int i = 0; i < 16 * 4; i++) {
        matrix[24 + (i - 8)] = rain_colour;
    }
}
```

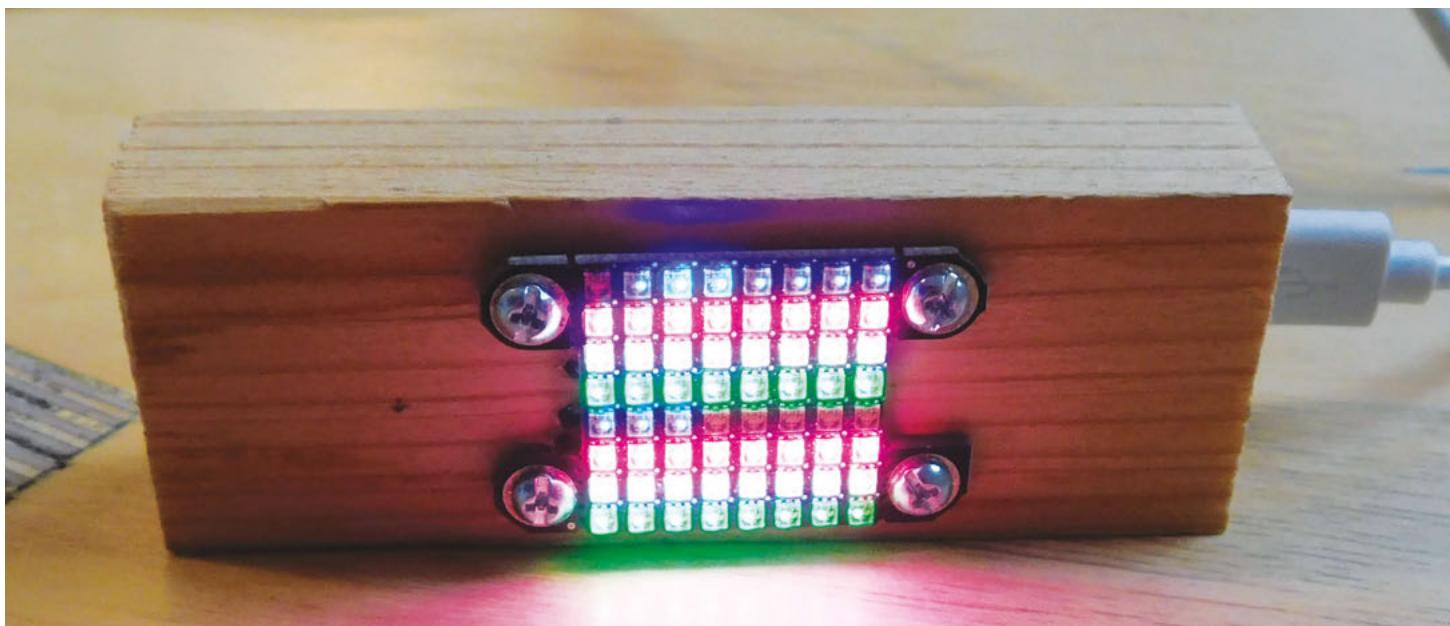
We won't go through the code line by line (you can download it from [hsmag.cc/egoYov](http://hsmag.cc/egoYov)), but instead, look at the key parts. The JSON deserialisation uses a lot of memory, so there's quite a lot of memory tracking code – we've left this in, rather than remove it, as it might be useful for anyone adapting the code, but we won't include it here.

Here's the code for grabbing the latest forecast and decoding the JSON response:

```
WiFiClient client;
if (!client.connect(host, port)) {
    Serial.println("connection failed");
    return;
}
Serial.println("Connected!");
client.print((String)
    "GET /data/2.5/forecast?q=bristol&appid=<insert
your appid> HTTP/1.1\r\n" +
    "Host: " + String(host) + "\r\n" +
    "Connection: close\r\n\r\n");
unsigned long timeout = millis();
while (client.available() == 0) {
    if (millis() - timeout > 5000) {
        Serial.println(">>> Client Timeout !");
        client.stop();
        return;
    }
}
String line = "";
while (client.available()) {
    line = client.readStringUntil('\r');
    if (line.indexOf('{') >= 0) {
        DynamicJsonDocument json_doc(60000);
        DeserializationError json_error =
deserializeJson(json_doc, line);
        if (json_error) {
            Serial.println("parseing failed");
            Serial.println(json_error.c_str());
        } else {
            //process json here
        }
    }
}
```

In order to run this, you'll need to acquire a free APPID from [openweathermap.org](http://openweathermap.org).

This uses the ArduinoJson library to decode the response from OpenWeatherMap – we'll look at how to use the data in the next code block. The basic challenge here is that decoding JSON requires quite a lot of memory (at least in microcontroller terms). The ESP32 has 520kB of RAM, so that's quite a lot to play with, but we're also using quite a bit to establish the WiFi connection, and to handle



the LEDs. We allocated 60kB of heap to the JSON deserialisation, which proved to be enough. If you're working with other JSON documents, you may need more or you may be able to get by with less.

The fundamental use of this library is quite straightforward, but the devil is, as always, in the details. Fortunately, the library is well documented at [arduinojson.org](http://arduinojson.org) if you need to use it for a different purpose.

**“There are loads of things you could display to help you make good decisions about how to go about your daily life”**

Now, let's take a look at how to use this processed JSON document to light up the LEDs. We won't go through all of it because each of the four types of data are handled in a similar way, and you can take a look at the full source if you're interested. As an example, though, here's how we handle the 'rain' LEDs:

```
for (int i = 0; i<16; i++) {
    String rain = json_doc["list"][i]["rain"]
    ["3h"];
    if (rain != "null") {
        rain_colour[2] = min(max(2,int(rain.
        toInt()*10)), 255);
    }
    else {
        rain_colour[2] = 0;
    }
}
```

```

    }
    if (i < 8) {
        matrix[56+i] = rain_colour;
    }
    else {
        matrix[24 + (i-8) ] = rain_colour;
    }
}
```

This pulls the data out of the pre-created `json_doc` object. The data is the amount of precipitation expected in the three-hour period (if it's null, that means no rain). We set the blue value for the LED with the calculation `min(max(2,int(rain.toInt()*10)), 255)`. This turns the value into an integer and multiplies it by ten (to make the blueness sufficiently visible). If the value is 0 (i.e. less than 1 mm of rain is forecast), we set the blue value to 2. Finally, we use the outer `min` function to make sure this never goes above 255, as this is the largest colour that the LED can take.

The rain values correspond to two rows on the matrix (one for the first 24-hour period and one for the second). This matrix is addressed in a zigzag fashion, so the first 24-hour period is LED 56 counting up, while the second is from 24 counting down.

The rest is all fairly straightforward, and if you're interested, you can take a look at the full code. There's lots of data available about the environment, while it's useful to know, we have to build the right indicators into our daily lives. This is just one example, but there are loads of things you could display to help you make good decisions about how to go about your daily life. □



**Above** Our finished display showing just how rainy it's going to be

# Getting the most from 'Super Glue'

Cyanoacrylate glue can do a lot more than stick workpieces (and your fingers) together



**Gareth Branwyn**

@garethb2

Gareth has been a lifelong practitioner (and chronicler) of DIY tech, media, and culture. He is the author of ten books, including *Tips and Tales from the Workshop*, and is a former editor for Boing Boing, Wired, and Make:.

## YOU'LL NEED

- ◆ **Bottle of cyanoacrylate glue**
- ◆ **Accelerator / kicker**
- ◆ **CA debonder**
- ◆ **Baking soda**
- ◆ **Flexi-Tips**
- ◆ **Replacement nozzles**
- ◆ **Poke-y thing (needle, safety pin, brad nail)**

**C**yanoacrylate. Superglue. Krazy Glue. CA glue. Whatever you call it, we all use it, and we all both love and hate it. We love the speed, convenience, and holding power of cyanoacrylate, but we hate the way it seems to want to stick to you before sticking to anything else.

Cyanoacrylate (pronounced: sai-a-noh-a-kruh-leit) glue is a fast-acting, strong-bonding adhesive commonly found in industry, medicine, and for home and hobby use. Some of cyanoacrylate's other attributes include binding a wide range of materials (metals, plastics, ceramic, wood, elastomers) and holding up well to weather and ageing.

## LITTLE BOTTLES

The iconic image of cyanoacrylate glue is in the tiny tubes branded 'Krazy Glue' and 'superglue'. These small tubes actually make sense for the periodic users because cyanoacrylate doesn't have a great shelf life (around 30 days). But if you use it regularly, there are many sizes of bottles, working times, and delivery methods to choose from.

Pro and 'prosumer' brands like Bob Smith Industries, Satellite City, and others offer cyanoacrylate in a range of quantities. Two-ounce bottles are common, and you can get replacement 'snip-tip' plastic nozzles for your bottle size. You can also get much larger bottles (and refill the easier-to-use 2 oz bottles). You can extend the shelf life of your cyanoacrylate glues by keeping them in an airtight container with some silica packets. The ideal storage temperature ranges between 35–40 °F (2–4 °C).

Cyanoacrylate glues come in different thicknesses, from super-thin to extra-thick to gel. Which thickness you use depends on the materials you are bonding. Thicker glues are used when you



## Above

A selection of CA glues of different thicknesses and working times, accelerator, needle and Flexi-Tip applicators, and replacement 'snip-tip' nozzles

want to create a very substantive join or add a gap-filling function. Cyanoacrylate glues are also available with a variety of working times, from a few seconds up to an hour.

The number of different formulations of cyanoacrylate glue can be overwhelming. Start with a medium thickness glue with a ten-second (or under) working time and experiment from there for your particular needs.

## ACCESSORIES

Besides the glue itself, there are several other accessories you can add to get more from your glue:



**Poke-y thing** – CA loves to linger in whatever applicator and clog it up. This is not entirely bad. Keeping moisture away can extend its life. Always have a straight pin, safety pin, or brad nail close by to reopen clogged applicators.

**Kicker** – A cyanoacrylate activator, also known as a kicker, can make bonding time near-instant. A sprinkle of baking soda works as an accelerator, so too does compressed air.

The most common kickers are commercial sprays that leave little to no residue. The common activator method is to glue on one side of the join, spray accelerator on the other, and push the pieces together. Hold for a few seconds, and it's done. You can also glue and then spray kicker over your join. Accelerators do result in a weaker bond, so avoid if you need maximum strength.

**Debonder** – Oh no, you just glued your good side cutters together (or your hand to your head)! No worries. A debonder will take care of that. Nail polish remover (acetone) is a commonly available debonder. And there are commercial debonders available. You won't use this often, so a 1 oz bottle is all you'll need.

**Flexi-Tips** – These small plastic tubes come in packs of 10, 25, and 50. They fit over the tip of most common plastic applicators and allow you to deliver a very small and precise bead of glue.

**Needle bottles and applicators** – Also for precise delivery and control, you can use medical syringes and needles and applicator bottles that have needle tips. These are easily found online.

**Replacement nozzles** – It is inevitable that you're going to gum up the applicator on your glue bottle.

Packs of replacement nozzles are available for most small bottle glue brands.

## USES

Besides its voracious appetite for bonding, cyanoacrylate adhesives can be used as everything from a chemical clamp to a kind of low-tech 3D building material.

**As a clamp** – If you want to quickly join workpieces where wood glue or another slow-drying glue is your main adhesive, add CA glue to the pieces to establish an immediate clamping hold.

**To add strength** – Kinetic sculptor Tom Haney on using CA glue in wood-carving: "I 'saturate' softwoods, like bass-wood and pine, with clear, water-thin CA to make the pieces harder and more durable after carving."

**To repair** – Combining baking soda and CA glue can create a strong 'Bondo'-esque material that you can sand, file, cut, and paint. This has long been a go-to material for repairing musical instruments that have been bashed, gashed, or have small missing pieces.

**To build** – Baking soda and CA glue can even be used to build up enough material, in layers, to fashion a broken part. Check out this video where Shelby of

"Oh no, you just glued your good side cutters together (or your hand to your head)! No worries"

## Left ♦

You can even use CA glue and baking soda to fashion makeshift parts, like this hinge tab for an antique computer monitor

## QUICK TIP

If you use a needle to apply your glue, to unclog the needle the next time you use it, run the flame of a lighter beneath it to remove the dried glue inside.

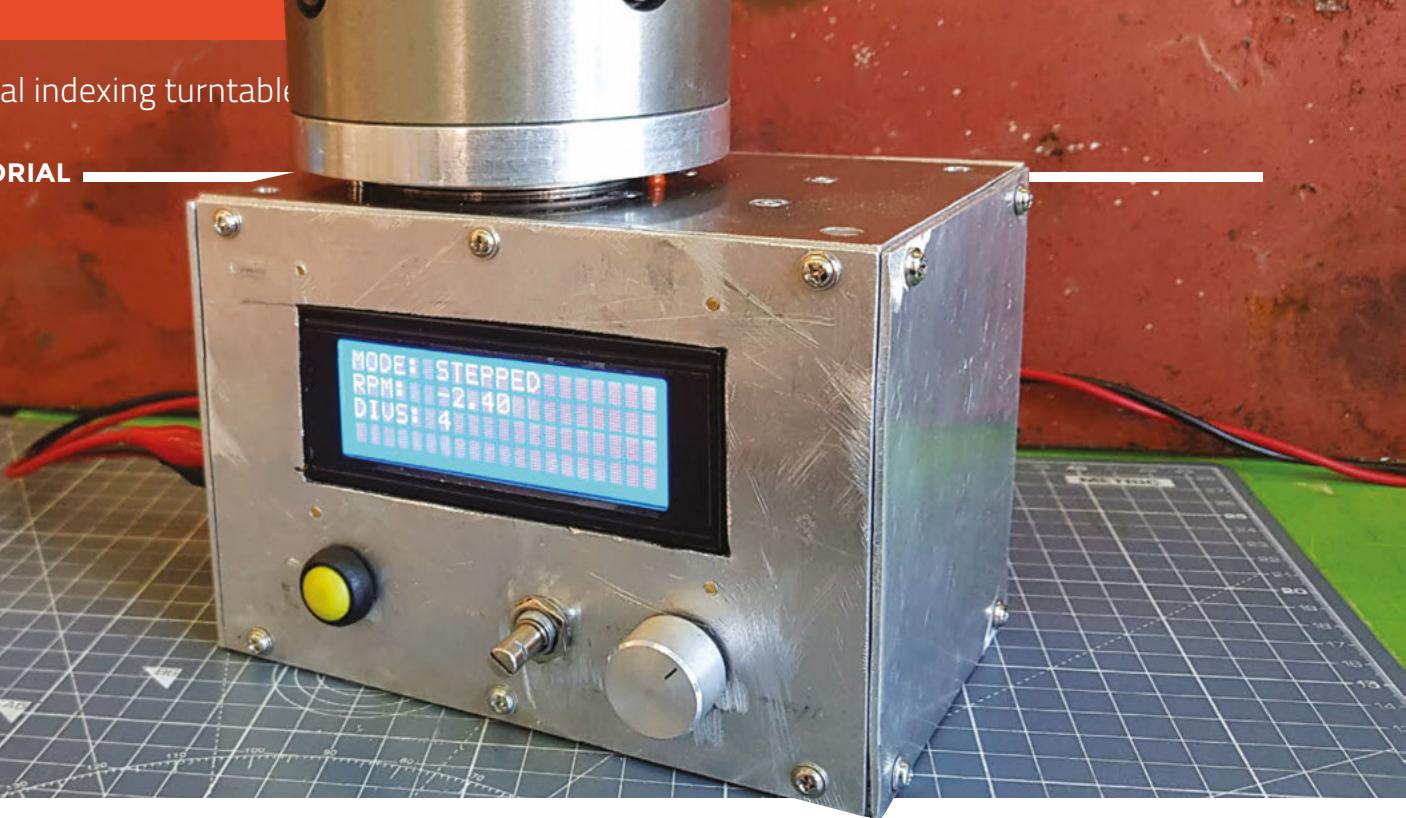
the antique computing YouTube channel, AkBKukU, builds up and then files to shape a hinge tab for an old computer monitor: [hsmag.cc/cmANqB](http://hsmag.cc/cmANqB).

**Double sticky** – Double-sided tape can leave residue on workpieces. Instead, put masking tape on both pieces and CA glue the tape pieces together. To remove, pry apart the workpieces and remove tape.

**Skin care?** – Guitarists have long used CA glue on sore fingertips caused by steel guitar strings, and it can have medical applications for closing wounds. While useful in this area, we recommend consulting a medical professional before attempting to glue yourself back together. □

## THANKS

Thanks to the following makers for input on this article: Tom Haney, Martin Rothfield, Jason Babler, Lenore Edman, Nora Lockshin, Miguel Valenzuela, Michael Colombo.



# Digital indexing turntable

Build an Arduino-controlled turntable for accurate drilling and easy brazing



**Dr Andrew Lewis**

@monkeysealor

Dr Andrew Lewis is the owner of [Shedlandia.com](http://Shedlandia.com), a restorer of old tools, a fabricator for hire, a research scientist, and a founder member of the Guild of Makers.

## YOU'LL NEED

- ❖ **Arduino Uno**
- ❖ **Push-button switch**
- ❖ **10 kΩ panel-mount potentiometer**
- ❖ **10 kΩ 10-turn panel-mount potentiometer**

**T**

urntables are useful beasts to have in a workshop. Whether you're trying to drill holes around a central point, brazing a pretty bead around a piece of cylindrical stock, taking accurate measures or scans, or photographing

or painting a model, a turntable makes the job much easier. If you're doing any of these tasks regularly, it's a good idea to buy or build a turntable designed specifically for that task. If you just want a sturdy general-purpose turntable that can stand up to some abuse, however, this project will show you how to make one. This turntable will revolve in either direction, constantly or incrementally. In addition to some basic metalworking, you'll see how an Arduino can be used to control more powerful stepper motors, and how to avoid some of the pitfalls associated with stepper motor control.

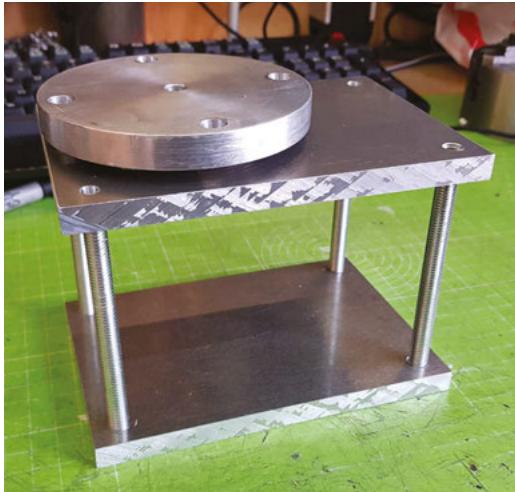
## MEASURE TWICE

Start by preparing the thin pieces of aluminium. These pieces will form the sides of the turntable, protecting the electronics and holding the thicker top and bottom plates together. On the two larger (100 mm × 150 mm) pieces, mark and drill 3 mm diameter holes 10 mm in from the shortest sides and 5 mm from the longest sides. Drill an additional hole

5 mm in from the edge at the centre of the longest side. One of these side pieces will be used to mount the controls for the turntable. You will need to mark and cut the sheet to accept the buttons, dials, and LCD. The measurements will vary depending on the exact components that you use, so just remember to position each component so that it doesn't interfere with the motor or other parts of the case, and check everything twice before you start cutting.

On the two smaller pieces (100 mm × 110 mm) of aluminium, drill holes 5 mm in from the edge of the shortest sides, and 10 mm from the longest sides. The power socket for the Arduino will pass through one of these panels. As with the turntable controls, the exact position will depend on the final mounting position of the Arduino, so you'll need to measure this and drill it later.

Mark and drill the hole for the turntable shaft. You need to offset the turntable on the 10 mm aluminium plate so that you'll have room to position the electronics and motor. Drill 50 mm from the edges of the top plate so that the circular turntable will be at one end of the top plate rather than in the middle. This hole needs to be quite large (22 mm) to accept the flanged bearing, so a step-drill is quite useful for this. If you're more sensible than this author, you'll remember to mark the position of the grub screws



mentioned in the next paragraph before you drill the 22 mm hole. Fit the flanged bearing – the flange of the bearing should be on the inside of the turntable, not the outside.

Next, drill and tap three holes for the M3 grub screws that will retain the thrust bearing. These holes should be positioned 120 degrees apart at the edge of the thrust bearing, holding it in place. Their distance from the centre of the turntable shaft should be the sum of the radius of the thrust bearing and the grub screw, which should be

34 mm assuming you're using the parts recommended in the parts list. The corner holes for the threaded bar need to be tapped, so drill them at 7.5 mm, and then tap them by hand to 8 mm. It's tempting to use a power tool to tap these holes, but aluminium is a soft metal, and it's easy to strip

**“** This turntable will revolve in either direction, constantly or incrementally **”**

## STAYING TRUE

The top and bottom of the turntable should ideally be as close to parallel as possible so that any holes you drill on the turntable are as close to true as possible. To do this without a milling machine, you can use four pieces of M8 threaded bar as legs that screw into threaded holes in the top plate, and rest in recesses in the bottom plate. This way, you can tighten or loosen each threaded leg until the top is exactly parallel to the bottom, then lock the threads into place with a little bit of resin. The sides of the turntable will screw into the top and bottom plate, preventing them from pulling apart, while the metal legs will transfer any load from the top to the bottom plate without stressing the thinner side plates. The load is transferred from the turntable to the top plate via a thrust bearing, which sits between the two.

**Left** ◇  
Aluminium is soft, which can make it more difficult to drill. Use a light oil and check your drill bit isn't getting clogged and tearing the metal. Break up chips of aluminium by ‘pecking’ with the drill rather than applying constant pressure

threads with an electric drill. Drill and tap M3 holes along the centre line of the edge of the plate to match the holes in the thinner aluminium side pieces. These holes will accept the screws that hold the sides in place when the turntable is assembled.

## BE EITHER ACCURATE OR ADJUSTABLE

Finally, the holes for the motor mount need to be drilled through and countersunk. For a NEMA 17 motor, that means drilling four 3 mm holes, in a 31 mm square. The exact position of the motor holes on the top will depend on the length of drive belt you're using, but if you're using a

92-tooth GT2 belt, then the first hole should be about 34 mm from the side of the top plate. If possible, create slots instead of holes, to allow for easy belt tensioning. Put the 40 mm M3 bolts through the hole. The bottom plate of the turntable is considerably easier to make, and requires only a blind M8 hole →

## YOU'LL NEED CONT...

- ◆ **DRV8825 steppstick module**
- ◆ **20x4 I<sup>2</sup>C LCD**
- ◆ **NEMA 17 high-torque stepper motor**
- ◆ **12 V 2 A power supply**
- ◆ **Round aluminium billet**  
— 100 mm diameter by 10 mm thick
- ◆ **2 x 10mm aluminium plate**  
— 100 x 150 mm
- ◆ **2 x 3mm aluminium sheet**  
— 100 x 150 mm
- ◆ **2 x 3mm aluminium sheet**  
— 100 x 110 mm
- ◆ **4 x 115mm M8 threaded stainless steel rods**
- ◆ **50 mm M8 threaded stainless steel rod**
- ◆ **3 x M6 10 mm stainless steel grub screws**
- ◆ **4 x M3 40 mm countersunk machine screws**
- ◆ **4 x M3 lock-nuts**
- ◆ **24 x M3 5 mm machine screws**
- ◆ **20-tooth 10 mm GT2 pulley**
- ◆ **60-tooth 10 mm GT2 pulley**
- ◆ **92-tooth GT2 belt**  
(188 mm)
- ◆ **65 mm OD needle roller thrust bearing**
- ◆ **608ZZ flanged ball bearing**
- ◆ **100 mm lathe chuck** (optional)

## TUTORIAL

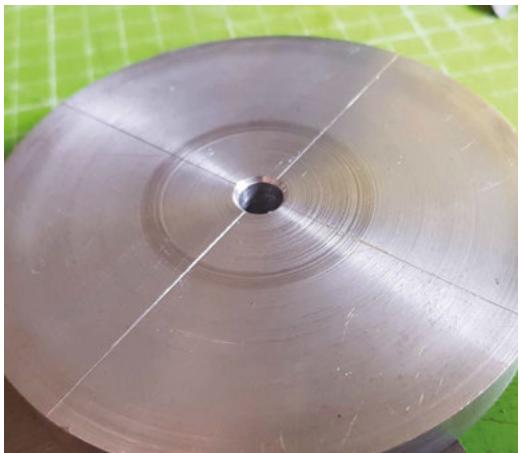
**Top Right** ♦  
For this project, the blind holes in the base plate don't have to be completely blind: as long as the rods are supported at their base, a small pilot hole will have no effect

**Right** ♦  
Finding the centre of the turntable is important, so try to be as accurate as possible. Use a centre finder or a set of dividers to get the best results. Applying dye to the aluminium can make it easier to see your scribe marks

**Below** ♦  
Mixing mechanical and electrical parts means thinking about the position of wires and gears. Make sure that no wires can get caught in a mechanical part, and no mechanical parts can fall off into electrical circuits. The pulley here is held in place by a thread and two grub screws. The wires can be held down with cable ties

### A BIT TENSE

Belt tension is important for accuracy. If the toothed belt is too loose, then there will be backlash in the turntable. If the belt is too tight, it can cause the motor to skip and flex the turntable shaft. You can either tension the belt manually by making the motor holes slotted and applying the tension before you tighten the bolts in place, or you can add a sprung idler pulley to apply the tension automatically. In the photographs for this project, the motor is mounted through holes in the top plate, without an idler pulley fitted underneath. This is a mistake, and the holes will be extended to allow tension adjustment the next time the turntable is disassembled.

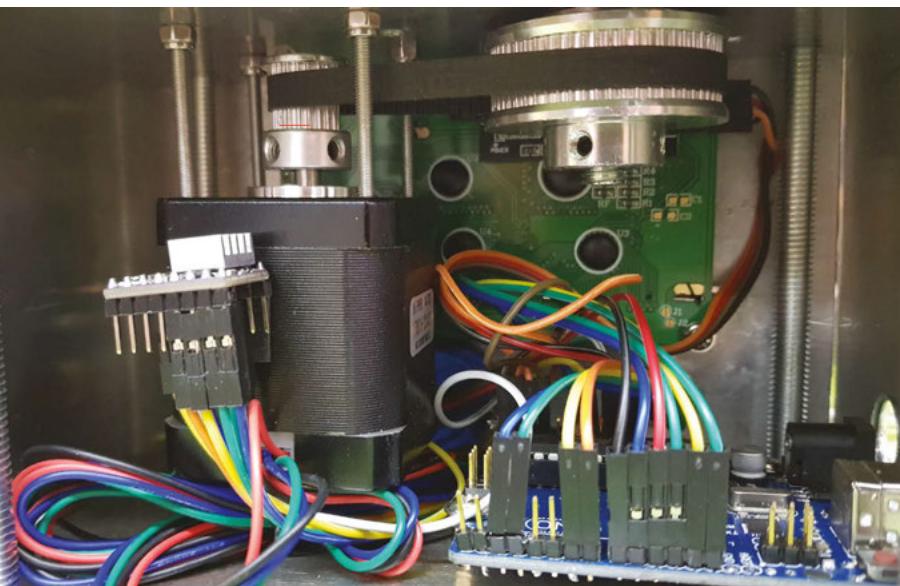


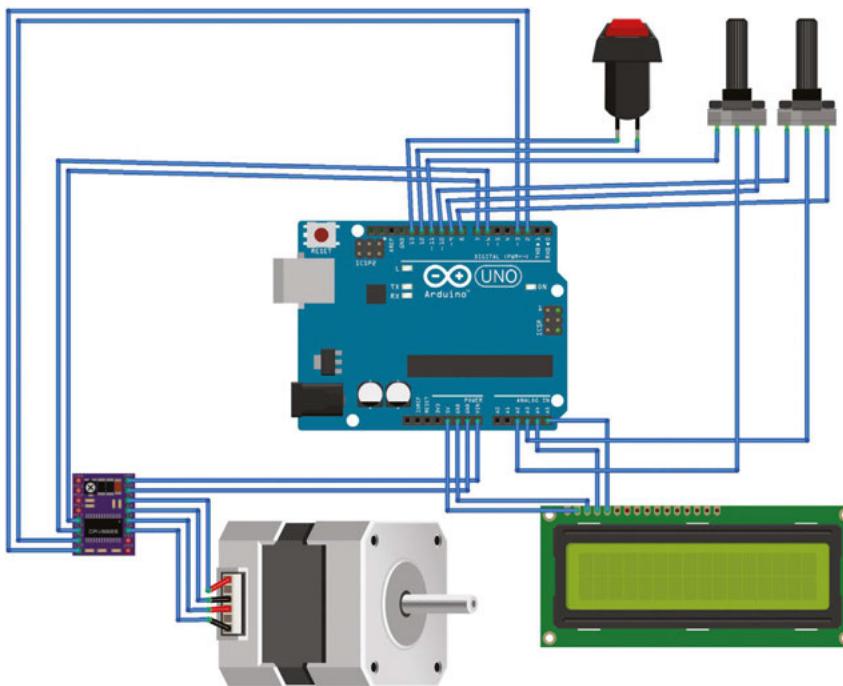
5 mm deep in each corner to accept the threaded bar from the top plate. You will also need to mount the Arduino to the base plate, at one end of the plate so that the power socket is accessible. The measurements for this are not critical, and the easiest way to do this is to offer up the Arduino to the plate and use a marker pen to transfer the screw holes from the PCB to the bottom plate. Drill and tap the plate to accept M3 PCB stand-offs, and fit them with some insulating tape under the Arduino to prevent accidental electrical shorts. Drill and tap M3 holes in the edge of the plate for the side panels, as with the top plate.

The turntable itself needs to be as flat as possible. If you have a lathe, face the round billet and take a skim from the edge to get it round. Drill a 7.5 mm hole in the centre and tap it with an M8 thread. If you don't

have a lathe, glue a sheet of abrasive paper onto a flat surface, and use it to lap one side of the aluminium billet until it is smooth. Mark the centre of the billet with a centre finder, and drill and tap with an M8 thread. Flip the aluminium over, and scribe a line around the edge of the (uneven) top. Use this as a guide to flatten the top using a combination of filing and lapping. It will take a while, but it's worth the extra effort to make the turntable as accurate as possible. If you are mounting a chuck on the turntable, transfer and drill the mounting holes onto the turntable, adding appropriate countersinks or clearance to the back of the turntable.

It's time to assemble the mechanical hardware for the turntable. Screw the four M8 threaded legs into the top plate, and put the free ends into the M8 blind holes in the bottom plate. Screw the M3 grub screws into the top plate, drop the thrust bearing and washers into place, and adjust the grub screws so that they sit about 1 mm below the top of the thrust bearing's height. Add a little thread-lock or nail varnish to the grub screws to keep them from coming undone. Fit the 20-tooth pulley onto the motor shaft and lock it in place. Put the M3 40 mm bolts through the slots/holes in the top plate and into the motor mounts, using the





**Figure 1** ◆  
The wiring diagram.  
For details of pin  
connections, see the  
table below

locking nuts to keep them in place against the top plate. Fit the Arduino, LCD, and controls into place, and wire them as in **Figure 1**. Mount the DRV8825 onto the side of the motor using foam tape. Screw the spindle into the turntable, and lock it in place with thread-lock or by drilling a small hole along the edge of the thread and adding a locking pin. Add an M8 washer underneath the flanged bearing, put the turntable spindle through the bearing, and fit the

60-tooth pulley. If you have the facility, tap the pulley with an M8 thread and screw it onto the shaft, then tighten the grub screws. Or use a lock nut on the end of the shaft and tighten the grub screws on the pulley to hold it in place. The turntable should be snug against the thrust bearing, but not so tight that it binds. Upload the code (from [hsmag.cc/issue24](http://hsmag.cc/issue24)) to the Arduino, and screw on the sides of the box. You should be ready to give the turntable a test. □

## TURN THE TABLES

The DRV8825 steppstick is a motor controller board that combines current-limiting and micro-stepping to give you much more control than a simple H-bridge controller. The AccelStepper library makes controlling the steppstick easy, but there are a few things you need to do to your hardware and in your code to make sure you get the best from a DRV8825. Firstly, you need to set the current limit level to match the motor you're using. This is done by adjusting the small surface-mounted potentiometer on the steppstick, and measuring a reference voltage at the centre of the potentiometer on the DRV8825. Making a few assumptions, the reference voltage is equal to half of the current, so a 1 amp stepper motor would need 0.5V. If this sounds a bit fiddly and complicated, some people just estimate the correct value by running the motor and adjusting the potentiometer until the motor starts to skip, then backing off again and checking that the chip on the controller isn't getting too hot. On the Arduino, the motor control code is timing dependent, so anything that slows down your loop can potentially affect the smooth rotation of the motor. It's also worth keeping in mind that if you rely on 'while' loops to move the motor, then your board is going to be tied up until the motor has finished moving.

Pin	Connects to
2	DIR on 8825
3	STP on 8825
6	SLP on 8825
7	RES on 8825
8	+5V on Step Pot
9	+5V on Speed Pot
10	GND on Step Pot
11	GND on Speed Pot
12	GND on Step Button
13	Step Button
A5	SCL on I <sup>2</sup> C LCD
A4	SDA on I <sup>2</sup> C LCD
A3	Pin 2 on Step Pot
A2	Pin 2 on Speed Pot
VIN	VMT on 8825
GND	GND on 8825

## QUICK TIP

Aluminium swarf sticks to everything, especially fleece clothing. It also galls up under machine-ways and under threads. Clean up frequently.

## QUICK TIP

You can edit the code to change the maximum speed and number of divisions for the turntable. You can even add extra code to control acceleration and deceleration to counteract the inertia and momentum of bigger loads.

# Get FM radio on a microcontroller

Link your Arduino up to the airwaves and pick up some banging tunes

# W

**hen you hear the word 'radio' in 2019, you may well think of Bluetooth or SatNOGS, or any of a myriad of other high-tech applications that are using these waves to send digital data.**

However, even in the modern day, there's still a worldwide network of good, old-fashioned FM broadcasters around, sending music and chat over the airwaves.

Building an FM tuner is an interesting project if you want to learn more about how radio works, but you don't have to start from scratch. You can start with a pre-built radio tuner breakout. There are a few

available, but the most common ones are built on a Si4703 chip. These are available for a few pounds on direct-from-China websites, or for a bit more with from SparkFun (which come with more support and documentation). Unlike basic tuners, the Si4703 takes commands from a microcontroller.

Wiring is mostly straightforward. You need to connect power and ground, and then SDIO and SCLK to your board's SDA and SCK pins (which may or may not be labelled as such) – take a look at your board's documentation for details. On the Adafruit Grand Central that we tested with, these are pins 20 and 21.

Most Si4703 breakouts aren't 5V tolerant, so make sure you're either using a 3.3V microcontroller or a logic level shifter.

```

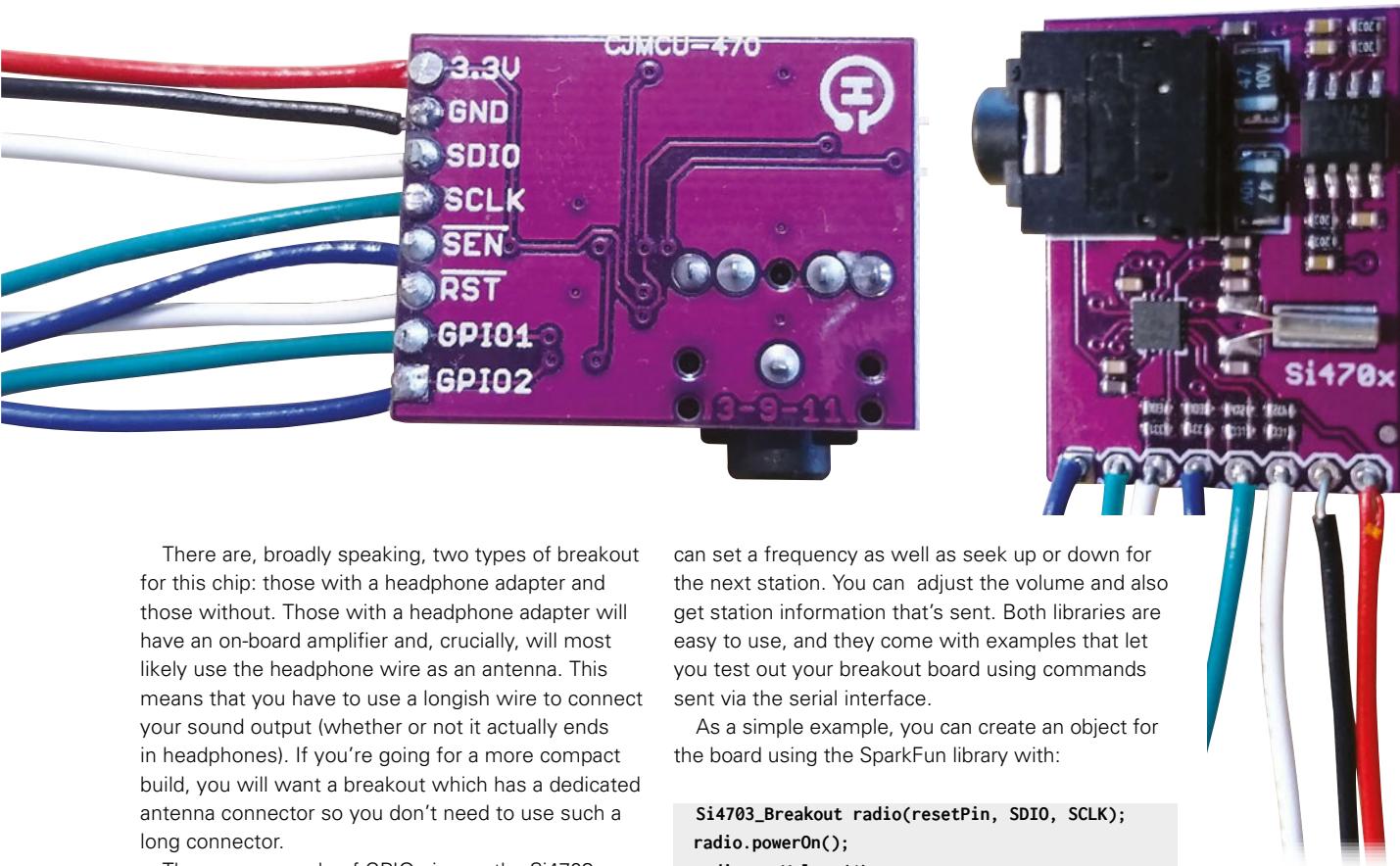
ScanRadio | Arduino 1.8.5
File Edit Sketch Tools Help
ScanRadio
22/// History:
23/// -----
24/// * 17.05.2015 created.
25/// * 27.05.2015 first version is working (beta with SI4705).
26/// * 04.07.2015 2 scan algorithms working with good results with SI4705.
27
28 #include <Wire.h>
29
30 #include <radio.h>
31 #include <RDA5807M.h>
32 #include <SI4703.h>
33 #include <SI4705.h>
34 #include <TEA5767.h>
35
36 #include <RDSParser.h>
37
38 // ...

```

Adafruit Grand Central M4 (SAMD51), Enabled, 120 MHz (standard), Small (-Os) (standard), 50 MHz (standard), Arduino, Off on COM19

## Right ◆

There are Arduino libraries to help you get started quickly and easily with Si470x radio tuners



There are, broadly speaking, two types of breakout for this chip: those with a headphone adapter and those without. Those with a headphone adapter will have an on-board amplifier and, crucially, will most likely use the headphone wire as an antenna. This means that you have to use a longish wire to connect your sound output (whether or not it actually ends in headphones). If you're going for a more compact build, you will want a breakout which has a dedicated antenna connector so you don't need to use such a long connector.

There are a couple of GPIO pins on the Si4703, but their use isn't supported by any of the libraries we've found. There's probably not much use for them as you need a microcontroller to use the device, and you'll likely have better control over the GPIO on the microcontroller. However, if you do find yourself a pin or two short, there is some code showing how to access the GPIOs on the breakout directly in SparkFun's GitHub repository for the board: [hsmag.cc/xyAdbe](https://hsmag.cc/xyAdbe).

### ON THE SHOULDERS OF GIANTS

There are a couple of libraries available to help you control this chip. SparkFun has a library that you can download from here: [hsmag.cc/hh0Cqa](https://hsmag.cc/hh0Cqa), while [mathertel.de](http://mathertel.de) has an alternative library at [hsmag.cc/4zf1GL](https://hsmag.cc/4zf1GL).

We've tested both of these libraries out, and they both work in a very similar fashion, which essentially gives you the programmatic control that you would expect as a user of a radio tuner. You

can set a frequency as well as seek up or down for the next station. You can adjust the volume and also get station information that's sent. Both libraries are easy to use, and they come with examples that let you test out your breakout board using commands sent via the serial interface.

As a simple example, you can create an object for the board using the SparkFun library with:

```
Si4703_Breakout radio(resetPin, SDIO, SCLK);
radio.powerOn();
radio.setVolume(4);
```

Then you can use the `radio.seekUp()` and `radio.seekDown()` functions to find the station you're looking for. Alternatively, you can jump straight to a particular frequency with something like `radio.setChannel(974)`.

### WHAT WILL YOU BUILD?

This is a fun little board, but it is very specialised to one use: playing FM radio. There are a few things we could think of building with this, including adding a radio alarm function to a clock build, and creating a radio with a unique interface (this could be big buttons to hit for different stations, or perhaps a phone app to change the station). You could even hook it up with your own radio transmitter to send audio data between two devices – make sure to follow local laws on broadcast frequencies and strengths if you do, though. We're sure you'll come up with a whole range of other options for this little module as well. □

**Above left** ■  
GPIO1 and 2 are available, but rarely used

**Above** ♦  
All the solderable connectors are on one side, so wiring up is easy



# Multicoloured 3D-printed jewellery

Make custom jewellery for yourself, or as a special gift for someone else!



**Sophy Wong**

@sophywong

Sophy Wong is a designer, maker, and avid creator. Her projects range from period costumes to Arduino-driven wearable tech. She can be found on her YouTube channel and at [sophywong.com](http://sophywong.com)

**T**hese days, 3D printing filaments come in many different colours and finishes, from neon to metallic to UV colour changing, and beyond. Making jewellery is a fun way to experiment with different colours and showcase the more exciting filaments in your stash. Here, we'll look at a simple way to create dynamic, multicoloured prints, using a basic printer with a single extruder!

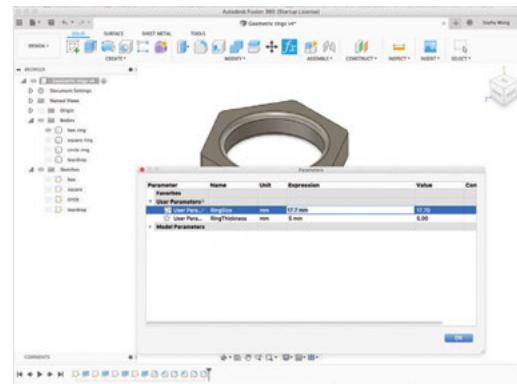
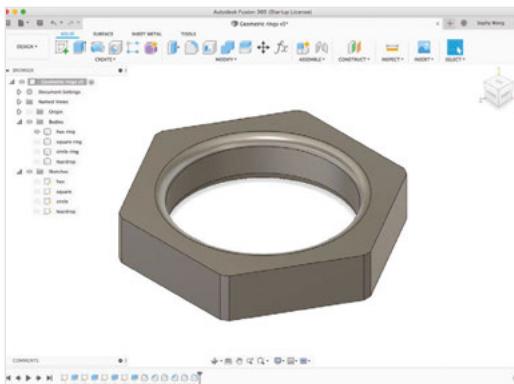
This tutorial assumes working knowledge of the 3D printing process, but if you're brand new to 3D printing, there are many great resources on the web for getting started. On YouTube, check out Angus Deveson at Maker's Muse, Devin Montes at Make Anything, and Joel Telling, the 3D Printing Nerd. The Maker's Muse channel has a fantastic playlist of '3D Printing 101' videos that will teach you the processes and terminology you'll need to get up and running with your first prints. If you don't own a 3D printer, head to a local makerspace to give it a try!

Jewellery pieces tend to be small, and are often satisfyingly quick prints – each of the bright, single-coloured rings shown here took about 15 minutes to print. However, when printing such small objects, expect to do some experimentation with settings in your slicer to achieve successful results.

In general, we found it helpful to print with a smaller layer height. This results in a 'higher resolution' print, which can make a big difference when you're trying to print tiny details in jewellery. Small prints with thin walls, such as rings, may have trouble staying adhered to the bed due to their minimal footprint – try adding a raft or a brim in your slicer for better hold.

As usual, you may need to experiment to find the settings that work best for your specific 3D printer and filament. All the prints shown in this article were modelled in Autodesk Fusion 360, sliced in Cura 4.3.0, and printed on a Creality CR-10S printer.

Autodesk's Fusion 360, a popular 3D CAD program, is used by industrial designers to create everything from water bottles to cars. It's also free for students, hobbyists, and makers. Having access to such a powerful program is amazing, but there's a lot to learn if you're new to 3D modelling. Autodesk has a large library of Fusion 360 tutorials on its website that can get you up and running in the software. For this tutorial, we'll assume a working knowledge of 3D modelling in general. We'll demonstrate our design process in Fusion 360, but we'll focus on design concepts that you can use to create your own jewellery in any 3D modelling program.



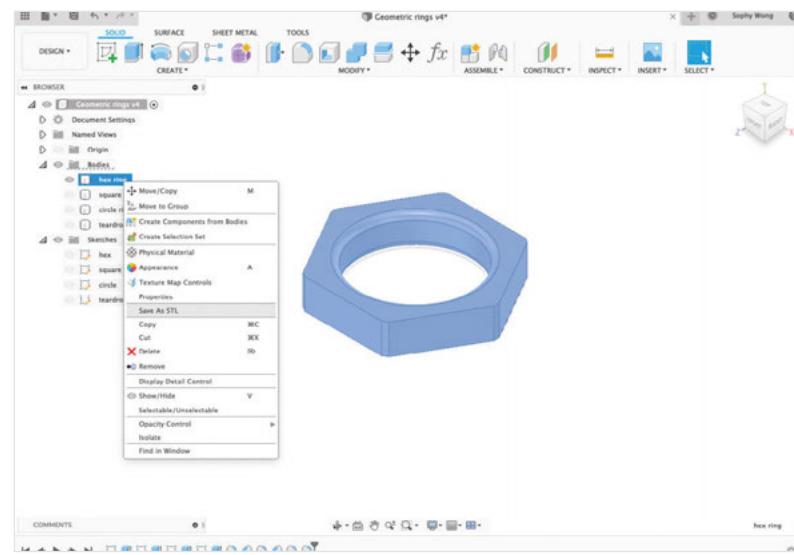
**Far Left** ♦  
You can download  
the models from  
[hsmag.cc/issue24](http://hsmag.cc/issue24)

If learning how to 3D-model your own jewellery is a bit overwhelming, don't worry! You can download our models and skip right to the fun part: slicing and printing. We're using Cura as our slicer to process the 3D model and turn it into G-code instructions for the printer. Cura provides a handy 'Pause at Height' feature, which makes it easy to change filament in the middle of a print. We'll take advantage of this feature to create multicoloured prints on a standard printer with just one extruder.

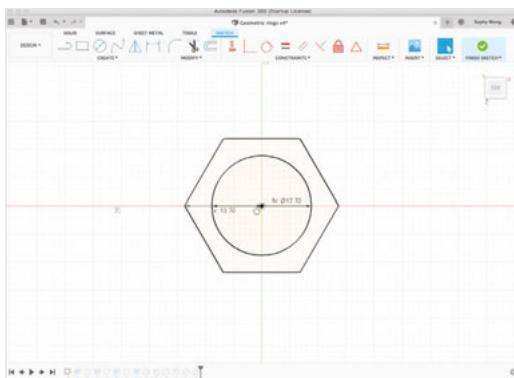
We'll start by using this filament-change trick on simple prints for a two-toned effect. This is a great way to practise the technique and see which filaments work well together. Then, we'll take this concept further and show you how to design models strategically to make use of colour changes at specific heights. With some planning and maths in the design phase, a filament-swap can highlight shapes in your model and add striking depth to your print.

## GEOMETRIC RINGS

Let's start with the simplest jewellery designs in this collection: geometric rings. These rings are just 2D sketches extruded vertically, with no overhangs. They're quick, easy prints that are perfect for trying out an experimental technique like this!



**Above** ♦  
You can create  
impressive rings with  
simple extrusions



### Above ♦

Start simple and build into more complex pieces once you've got some experience

Start by downloading the Geometric Rings file and opening it in Fusion 360. Each ring design is a separate body in the file, listed in the object browser on the left. Click the eye next to each body to view the rings one at a time. We've designed our rings with parametric dimensions, to make it easy to change the size of the rings before printing.

To find your ring size, use callipers to measure the inner diameter of a ring that fits you well. Alternatively, a ring sizer is useful if you want to make rings based on standard ring sizes. Select the size you want on the sizer, and measure its inner diameter. Open the User Parameters window, and enter your ring size in the RingSize parameter. All the designs in this file will be updated with the new dimension.

To design our rings in Fusion 360, we started by creating a sketch on the X plane, and drawing a circle with the diameter of our RingSize parameter. This is the inner contour of our ring. Then, we drew the outer contour shape of the ring around the first circle. For this geometry-themed set, we used a square, a hexagon, a circle, and a triangle as outer →

## TUTORIAL

shapes. A triangle is an awkward shape for a ring, so we rounded it into a tear-drop shape. Once we were happy with our shapes, we extruded all of the rings to the RingThickness parameter: 5 mm. You can change this value in the User Parameters window to make a thinner or thicker ring. It's a good idea to avoid sharp edges on jewellery, so we rounded off the corners and inner circle edges with fillets.

Once you've updated the file with your ring size, you can export STL files from Fusion 360 by

**It's a good idea to avoid sharp edges on jewellery, so we rounded off the corners and inner circle edges with fillets**

When you've finished entering your settings, click 'Slice' to generate the G-code for your printer. Click 'Preview' to see a visualisation of your finished print. Zoom in a bit and use the vertical slider on the right to scrub through the layers of your print – it's always wise to take a good look at the preview and make sure everything looks correct before printing. For single-colour rings, this is where you'd export the file and start printing. However, for the multicolour filament-change trick, there are a few more steps before exporting.

For a two-toned look, we're going to change our filament halfway through the print. This means we'll need to determine which layer number is at the midpoint of the ring. In the preview window, move the vertical slider on the right to the top, and note the number above the slider. This is the total number of layers in your print. Divide this number in half, and you've got your middle layer. At a .12 mm layer height, our 5 mm tall ring will take 41 layers, so we are going to change our filament at layer 21.

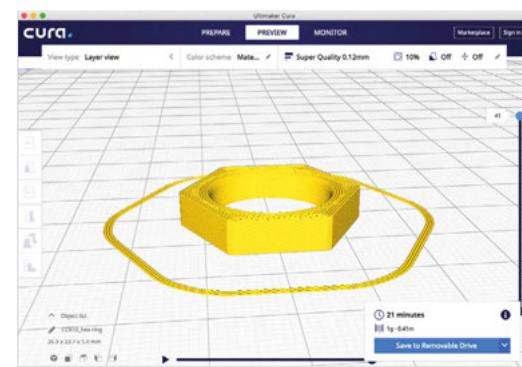
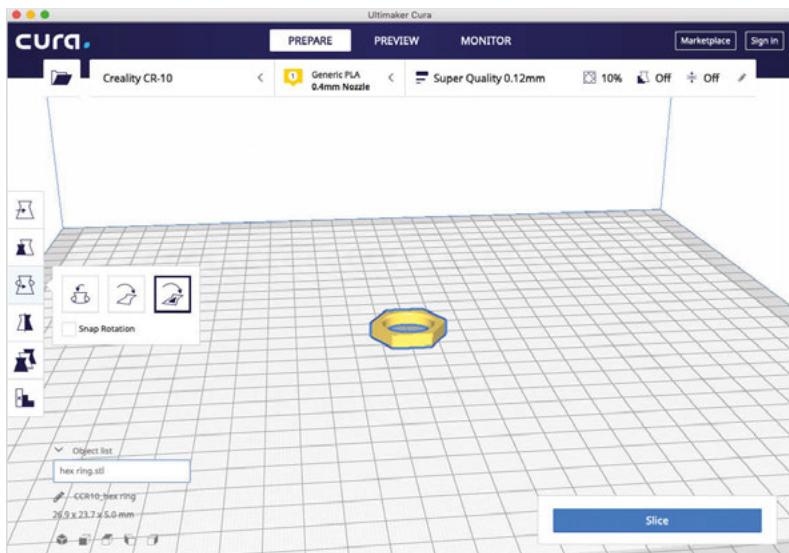
Now that we know what layer we want to change the filament at, we could watch the print, counting

right-clicking on each body in the object browser and selecting 'Save as STL'. Click 'OK' in the dialog box, then name and save the STL file. When you've exported all the STL files, move on to slicing our models in Cura. Be sure you are using the latest version of Cura, 4.3.0, for this project.

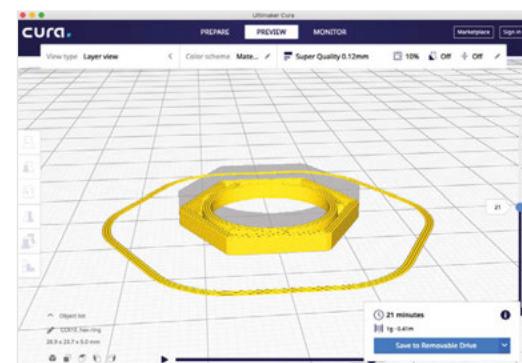
Open Cura and click the folder icon to import one or more of the STLs you created. Use the rotate tool to orient the rings on the bed so that they are lying flat on their sides. Click on the pencil icon to choose your print settings. You can start with Cura's 'Super Quality' settings and adjust values from there until you are happy with your prints. If your rings lift off the bed while printing, you can add a brim or a raft in the 'Bed Adhesion' section of the settings panel.

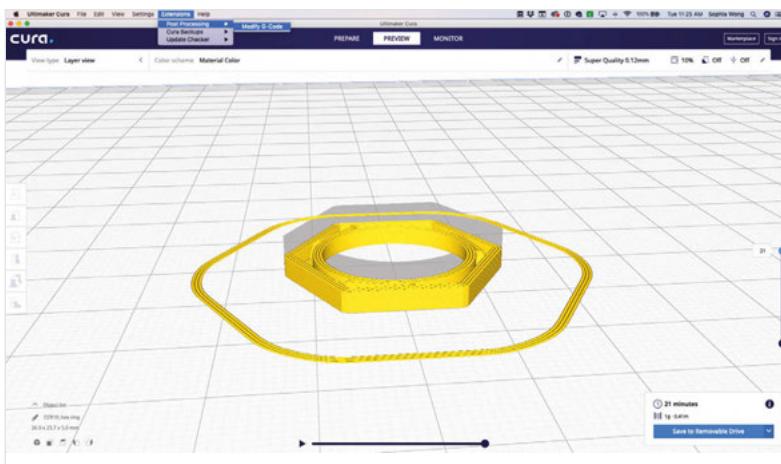
**Right** Smaller layers mean higher quality but slower print times

**Below** Cura allows you to customise the print settings



**Below** Preview mode gives you a final chance to check your object before printing





layers as they are printed, and manually pause the printer at layer 21 to change the filament. But Cura provides a much easier and more dependable option, by modifying the G-code itself. (The script used here works well on your author's Marlin-based Creality CR-10S printer, but printers running other firmware may require a different script.)

Click on the Extensions drop-down menu, and select Post Processing, then Modify G-Code. This will open the Post Processing plug-in, which allows you to select from various useful scripts built into Cura. Click on 'Add a script' and select 'Pause at Height'. In the settings pane, change the first box from 'height' to 'Layer No.' and enter '21' in the 'Pause Layer' box. Note: the pause will occur at the start of this layer, before the layer is printed. This means layers 1–20 will be the first colour, and layers 21–41 will be the second colour. Remember this when planning your designs.

Check through the remaining settings boxes. The 'Park Print Head' boxes allow you to choose an XY position for the print head to move to while paused. The default setting (190,190) moves it away from the print, which makes the filament change easier. Our prints worked fine without retraction or extrusion values, so we left those at zero. Make sure to set the standby temperature to the same value as your

print temperature: for us, this was 200°C for our PLA filament. Do not forget to set the standby temperature, or you may have trouble resuming your print after the filament change.

When you've finished entering your settings, close the Post Processing

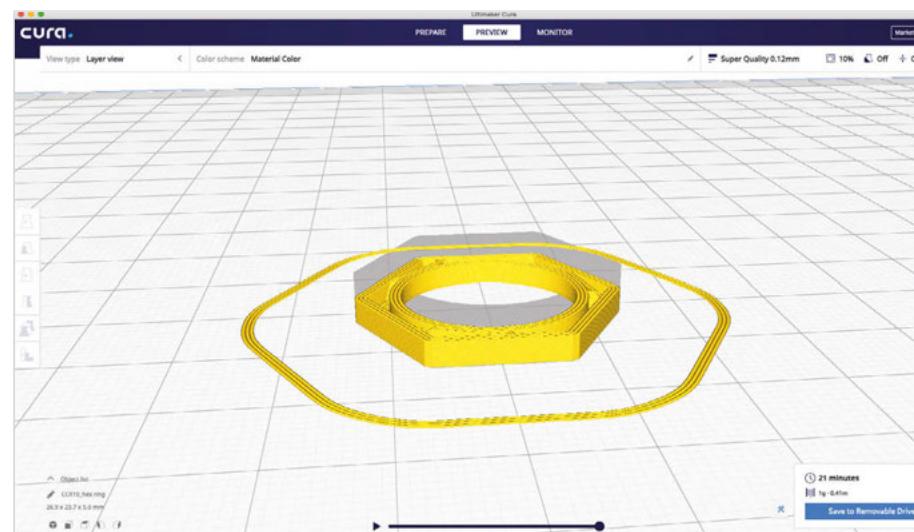
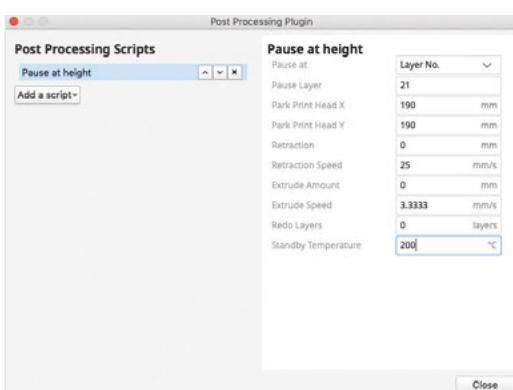
plug-in window. You will now see a hammer and wrench icon next to the Slice button, indicating that you are including a post-processing script. (Cura will add the pause script to all future sliced models until you remove it by clicking the X next to it in the Post Processing plug-in window.) Click 'Slice' again to generate your new G-code, and again scrub through the preview to make sure everything looks correct. Save the file, and send it to your printer for printing!

Load the first colour of filament into your printer, and begin printing the ring. Don't wander off: you've got a filament change coming up at the halfway mark! At layer 21, the printer should pause and move the print head off to the side of your print. Change the filament as you normally would, being careful not to move the print head or printer bed. Extrude as needed to fully prime the nozzle with the new colour. With your second colour loaded into the printer, use your printer's control panel to resume the print. The printer should pick up right where it left off, finishing your print with the second colour. →

**Above** The post-processing settings change how the printer runs

**Below Left** Enter the pause height for the filament change

**Below** The G-code tells your printer how to move the print head



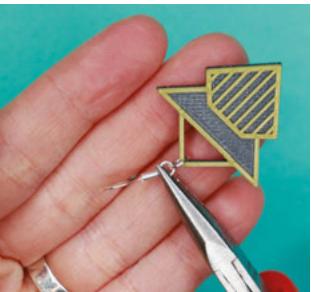
## TUTORIAL



**Above** Printing white first makes the colour change easier

**Right** There's a wide range of jewellery in the downloadable files: pick your favourites and get printing!

**Below** Silver and gold is a classic combination in jewellery



### WHAT COULD GO WRONG?

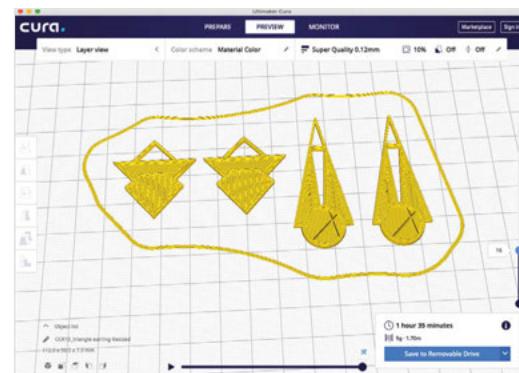
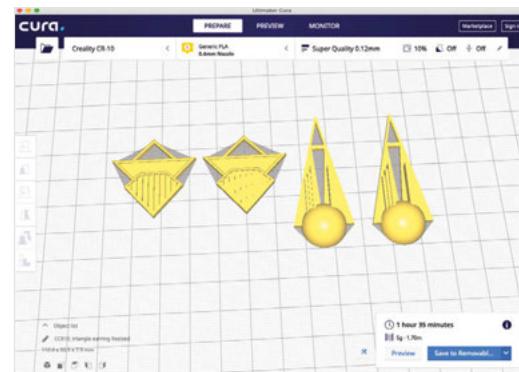
We've had great results with the 'Pause at Height' script in Cura, but keep in mind that modifying G-code is an advanced technique. G-code controls every aspect of your printer, and an error in your code can cause unwanted heating or movement, and damage your printer. We do not recommend manually modifying your G-code unless you are a G-code expert!

Our most common error when attempting this method was forgetting to set the standby temperature in the Cura Post Processing plug-in. When this happened, the extruder temperature dropped to zero during the pause, and we were unable to resume the print. In these cases, we had to cancel the print, remove the half-finished pieces from the bed, and start over. If this happens to you, don't despair! With an experimental technique like this, expect to make some mistakes the first time around, as we did. Practise on small, 15-minute prints first, to get the hang of the process with your particular printer and test your filaments for compatibility, before tackling larger multicolour projects.

When choosing multiple filaments for the same print, you'll want to make sure that both filaments print well at the same temperature. If printing two highly contrasting colours, like black and white, print the lighter colour first, as it may take longer to clear the dark filament out of the extruder.

### GOING FURTHER WITH MULTICOLOUR PRINTS

Of course, 3D printing is great for making multiples of things, and if you're going to change the filament mid-print, it's nice to make more than one tiny ring at a time. With this in mind, we designed all of our



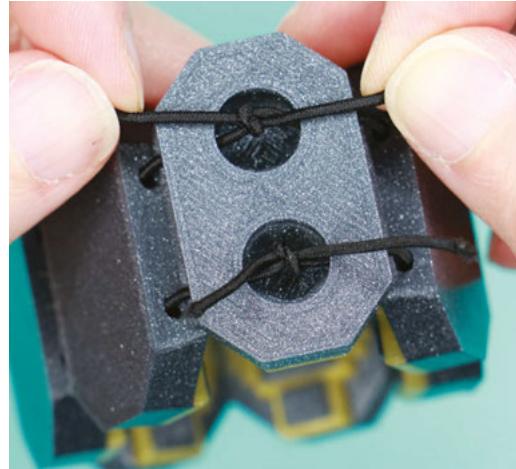
geometric rings to be the same thickness. This way, the midpoint is the same layer for all of them, so you can print them all together – just change the filament once for an entire set of two-toned rings.

We designed an Art Deco-inspired collection with raised details that really pop when printed in a second colour. We designed each piece to take advantage of a colour change at a specific height. Features below this height would be the first colour, and features above would be the second colour. All pieces designed with the same 'colour change height' can be printed at the

If printing two highly contrasting colours, like black and white, print the lighter colour first

same time with the filament-swap technique, because their raised details will start on the same layer. See our downloadable chart for the colour change heights of each model ([hsmag.cc/issue24](http://hsmag.cc/issue24)), and the print settings we used. Raised lines and volumetric shapes look great on top of a contrasting background colour.

For example, our Dome Earrings and Lined Earrings both change colours at 1.75mm. Import both STL files into Cura, duplicating each one for two earrings. To determine which layer to pause and change filament at,



follow the same steps in Cura as before to generate a sliced preview of the model. Zoom in and look at your model from the top-down view. Use the slider to scrub through the preview, and find the layer that the raised details start on. With a 0.12mm layer height, this should be layer 16. Enter this as the 'Layer No.' setting in the Pause at Height plug-in, and print as before, changing filament at the printer pause.

To finish the earrings, add ear wires to the top of each, using large jump rings if needed. Chain-nosed jewellery pliers are useful for opening and closing jump rings without distorting the wire.

Similarly, our pendants are designed for a colour change height of 3mm, and can be printed together. With a layer height of 0.12 mm, the filament change should occur at layer 26. After printing, the Rectangle Pendant can slide directly onto a narrow chain or cord as a necklace. To finish the Sunset Pendant, you'll need to add a jump ring to the small loop at the top of the pendant, before threading it onto chain or cord.

Our most ambitious design in this collection is the Art Deco Tile Bracelet. We designed the tiles to look like gemstone settings. If you're up for it, try printing these with two filament changes. We chose a dark, sparkly grey for the base shape, which gives the look of pewter. Next, we printed the 'setting' layers in gold, and finally the rectangular 'gem' shapes in the sparkly grey. We also experimented with clear translucent filament for a 'diamond' look.

We've provided two files for the Art Deco bracelet: Tile A is the standard tile design, Tile B has two large holes in the back for tying knots in the elastic cords. Print as many of the tiles as you need for your bracelet, including one of Tile B. File down any sharp edges before assembling your bracelet. Each tile has two sets of small holes running through them, for stringing

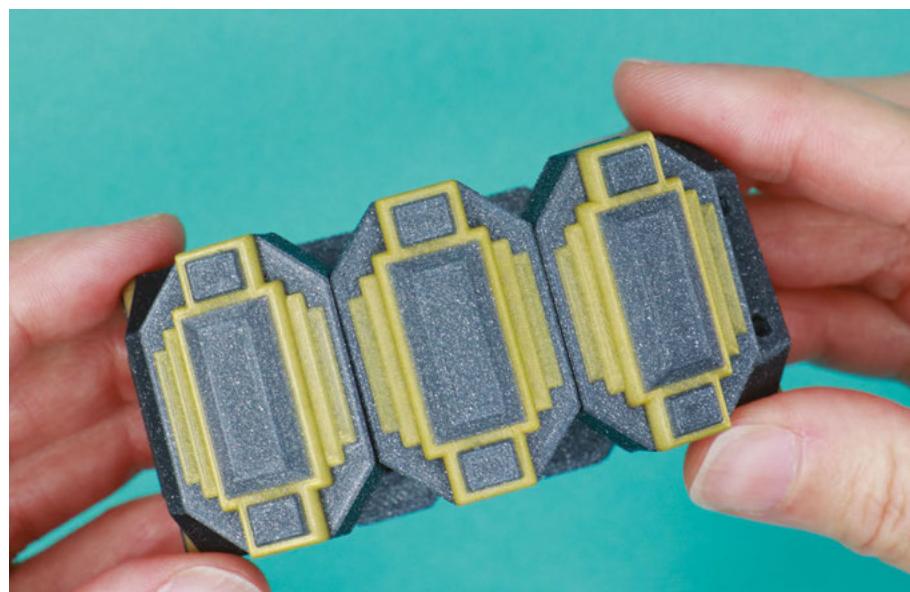
the bracelet together with elastic cord. Cut two lengths of elastic cord, and thread the bracelet together, starting and ending with the large holes in Tile B. Tie off each cord with a tight knot, and secure with a dot of CA glue. (Using two cords to assemble the bracelet instead of one will keep the bracelet tiles from twisting when stretched.)

Now that you know how to change filament mid-print, you can use this technique to get creative. When designing your models, think about using different colours at various heights, and build your object accordingly. Experiment and practise with small, quick prints like rings, then go bigger with a three-colour print like our Art Deco Bracelet. Show us your multicoloured 3D prints at [hackspace@raspberrypi.org!](mailto:hackspace@raspberrypi.org)

**Far Left** ◇  
Two lengths of elastic complete the bracelet

**Left** ◇  
Art Deco: perfect your *Peaky Blinders*-inspired outfit

**Below** ◇  
Three colour changes allow for more complicated effects



DON'T MISS THE BRAND NEW ISSUE!

Issue 87 | November 2019 | magpi.cc

YOUR OFFICIAL RASPBERRY PI MAGAZINE

# The MagPi

The official Raspberry Pi magazine

RASPBERRY PI

A+K

TOP 10 AI PROJECTS

Build smarter kit with machine learning

HACK YOUR KITCHEN TOOLS

Precision cooking with Raspberry Pi

£5.99

**SUBSCRIBE FROM JUST £5**

- **FREE!** 3 issues for the price of one
- **FREE!** Delivery to your door
- **NO OBLIGATION!** Leave any time

## FREE PI ZERO W STARTER KIT\*

With your 12-month subscription to the print magazine

**magpi.cc/12months**



\* While stocks last

**Buy online: store.rpipress.cc**

# FIELD TEST

## HACK | MAKE | BUILD | CREATE

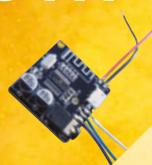
Hacker gear poked, prodded, taken apart, and investigated

PG  
**114**

DIRECT FROM SHENZHEN:

### BLUETOOTH AUDIO

Upgrade your old hi-fi with  
a wireless connection



PG  
**122**

### CAN I HACK A VIDEO BUSINESS CARD

Yuppie accessory or source of  
hackable parts? We investigate

## REVIEWS

- 124 Tool sharpener**  
Keep your blades in shape



- 126 Dremel router**  
An extra skill for your rotary tool

PG  
**116**

### BEST OF BREED

Let your next project see the world with  
our pick of lidar and radar scanners



- 128 Template maker**  
Fold paper into (almost) any shape

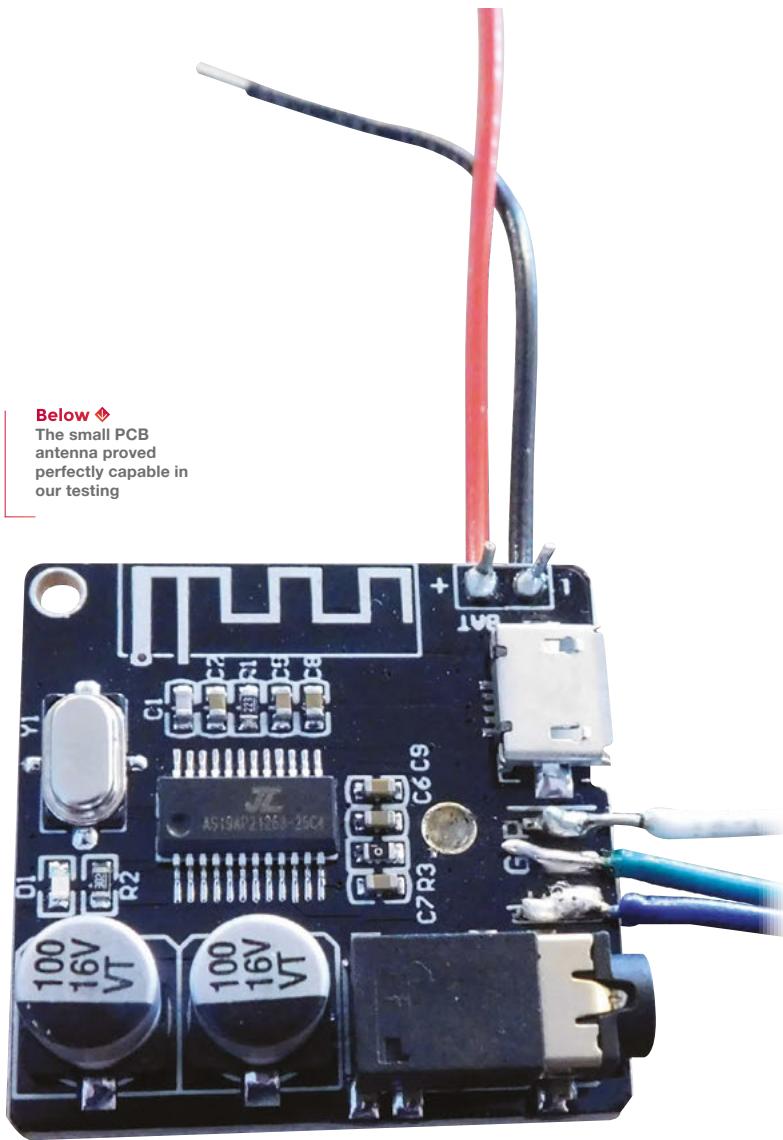
- 129 Booze: River Cottage**  
A journey of fermentable delights

# Bluetooth audio

Revisiting the options for wireless audio

By Ben Everard

 @ben\_everard



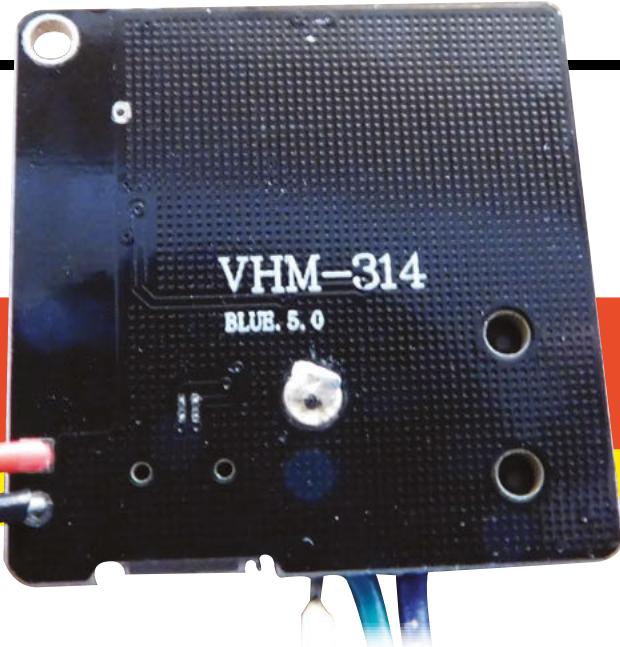
**Below** The small PCB antenna proved perfectly capable in our testing

**W**e've looked at a Bluetooth audio receiver before (in issue 18).

Then, the board we received couldn't put out decent audio. Perhaps it doesn't make sense to buy a bundled receiver and amplifier board. After all, the subject of audio amplifiers is complex, with options costing from a few pounds to... well, we're not aware of any upper limit on the amount you can pay for an audio amplifier. In contrast, a Bluetooth receiver is a much simpler proposition – it receives a digital bitstream and converts this into a low-power analogue stream. Yes, there are quality concerns, but they're much more limited because the digital nature of Bluetooth audio puts a finite upper limit on quality. Once we've got a decent Bluetooth receiver, we can pair it with an amplifier of our choice, whether that's a new one or feeding the audio into the line-in on an existing system.

We've previously used a KRC-86B Bluetooth module, but this seems to be less available and it's gone up in price significantly since we first experimented with it several years ago. Now, the most common affordable option is the VHM-314. We bought one from Global Purchase Store on AliExpress for £1.92, including delivery to the UK.

There are two sets of connectors: solderable ones and plug-in ones. For power, there's a micro USB connector or a solderable 'BAT' connector that can take 3.7–5V (a range that includes LiPo batteries, three AA batteries, and USB power sources). There's nothing special about the BAT connection (such as charging or power management) – it's really just a voltage in, and if you're planning on powering this from a LiPo, you'll need additional battery management hardware.



Audio out comes via either a 3.5mm jack or three solderable connectors (LGR). These solderable connectors are surface-mount in that they don't have any holes. They may fit some form of connector, but we soldered the wires to them. It's not the easiest soldering job, as it's slotted between the jack and micro USB connector, but shouldn't be too hard.

There aren't any components on the back of the board, so unless you solder into the through-hole battery connections, you can mount this board on a flat surface using the two mounting holes.

Considering the price, this feels impressively well constructed. The 30 mm × 30 mm circuit board is solid, and everything feels firmly attached. It's certainly a lot more solid than many PCBs we've received over the course of putting together this section over the past two years.

### READY TO CONNECT

Add power and the light on the unit should start flashing – ours was blue, but some documentation for the unit says it's red. At this point, it's ready to pair. Your phone, computer, or other Bluetooth device should pick it up in a scan. You will, however, have to figure out which device it is in the list.

The seller page informed us that it should show up as 'XY\_BT'; the documents linked from the seller page said that it should show up as 'VHM-314'. However, it actually shows up as XIDADIANZI. It shouldn't be too difficult to work out which one is the correct device by seeing what appears when you power on the board.

Herein, though, lies our biggest complaint with cheap Bluetooth boards: it's not usually possible to change the name of them. We'd like this one to identify as 'Kitchen radio' or 'Lounge

hi-fi', but alas, we can't. It's possible to change the name that they show up as on your phone, but that doesn't help other people. The biggest issue here is that if you have more than one speaker built on the same type of hardware, it's a recipe for confusion. However, perhaps if we'd ordered more than one, we'd have been lucky and got one that followed the documentation and identified itself as XY\_BT or VHM-314.

Beyond this minor annoyance, the board works as expected. It connected and streamed audio and is of a quality we're happy with. The reception worked at the distances we'd expect it to (with no problems up to about 5-10 m).

The on-board connectors mean that you could easily add Bluetooth audio to an aging stereo without any soldering at all. Just connect up the wires and you're good to go. With a bit more work, you can build it into your hi-fi equipment a little more neatly. At just 30 mm × 30 mm, there's a good chance you'll be able to mount this inside your existing equipment somewhere. Alternatively, pair this up with an amplifier board of your choice and build your own Bluetooth audio system.

We really like modules like this that do one thing well and are easy to use. You don't need

to program them, you don't even need to solder onto them, and they can add real value to users. There are thousands of old music systems that can play great-quality music, but are being thrown out because no one uses cassettes or CDs any more. And while vinyl is undergoing something of a resurgence, it's tiny compared to the streaming revolution. For just under £2, you can resurrect these systems and get yourself a great hi-fi system, and keep some waste out of landfill. □

**Above** the flat back of the PCB makes it easy to mount (if you don't solder power lines on)

DIRECT FROM SHENZHEN

ONLY THE  
BEST

# Know your surroundings

Lidar and radar has entered the DIY arena

By Marc de Vinck

@devinck

Sensing your environment is a popular subject among DIY electronics enthusiasts. In previous articles, we've looked at many different environmental sensing solutions ranging from time and temperature, to motion and gestures. But in this article, we are going to look specifically at measuring distance.

We all know and love components like the classic ultrasonic and infrared distance sensors, but what happens when you need accuracy and speed? This is where light detection and ranging (lidar) sensors and radar come into play. Many of these technologies are still relatively new to the DIY scene, but their availability is growing every day.

In this Best of Breed, we'll be looking at some more expensive, and also more accurate, methods for sensing distance in your environment. Unlike a simple and inexpensive IR sensor, lidar and radar systems can add up to 1000s of dollars for a complete system. But sometimes you need precision, or need to measure longer distances, or in direct sunlight. That's where these sensors really shine. And don't worry, we've selected a few sensors and technologies that are much more affordable for the average robot builder. So, let's jump right in and look at a few of my favourites.



**Left ▶**  
Lidar can capture landscapes (Avebury and Silbury hill neolithic sights shown here)

Image  
Mark Walters

# Slamtec RPLIDAR A1 vs Garmin LIDAR-Lite Optical Distance Sensor

Keep your Raspberry Pi going with intermittent power

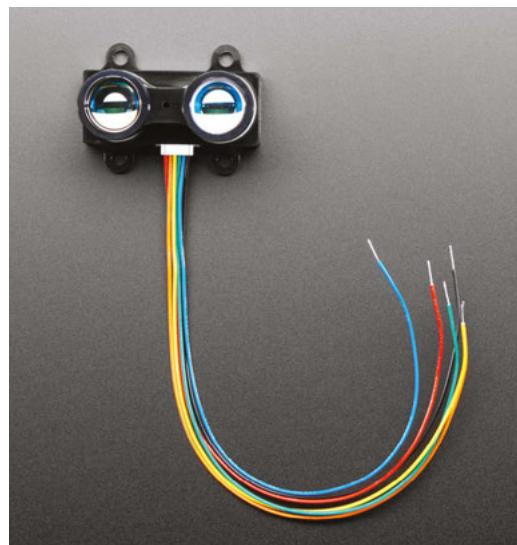
**SLAMTEC** \$114.95 | [adafruit.com](#)

**GARMIN** \$130 | [adafruit.com](#)

The Slamtec RPLIDAR, available at Adafruit, is a low-cost true lidar solution for your robotics project. That's not to say that this is inexpensive, but just a few years ago the thought of a true lidar system at just over \$100 USD was crazy talk! We've come a long way in just a few short years, and we can't help but think it's because of the autonomous car craze.

The specifications of the RPLIDAR, coupled with its affordability, is what really impressed us. Many DIY lidar systems only include the actual laser and sensor. But this unit includes all those parts, and the motorised housing which allows for fast 360° rotation of the laser beam. This gives you extremely accurate, down to 0.2cm, 360° measurements in a twelve-metre range. The sample rate is adjustable from 2–10Hz, which is measured in complete rotations, allowing for fast data acquisition. It's a near-perfect solution for a moving platform like an autonomous robot.

The RPLIDAR comes with an on-board connector with power and data pin breakouts, allowing you to theoretically control this device via a serial port, but most people will want to power it via the included dongle and attach it to their computer to handle all the incoming data. Head on over to the website for complete details on using the Slamtec RPLIDAR. ☐



**Left** Lidar can give your robot anthropomorphic eyes

**Below** A reliable and fast lidar module for long-distance measuring

If you don't need the 360° rotational power of the RPLIDAR, then the Garmin LIDAR-Lite might be a good option. Version 3 of the Garmin sensor is a high-performance and compact lidar solution capable of measuring up to 40 metres away. Garmin is known for its high-quality GPS systems, and their high standards come through in this lidar module.

The module itself only draws 130mA, so powering it up for extended periods shouldn't be an issue. And when you need to hook this unit up to your microcontroller, it's as simple as using the popular I<sup>2</sup>C protocol. There are example libraries and code for Arduino and CircuitPython available on the Adafruit website, which will get you up and running quickly. When you need accuracy, reliability, and long-distance measuring, be sure to check out the Garmin LIDAR V3. ☐

## VERDICT

Slamtec  
RPLIDAR A1

Great value for fast sensing in 360°.

**10** /10

Garmin LIDAR-Lite Optical Distance Sensor

Reliable and fast.

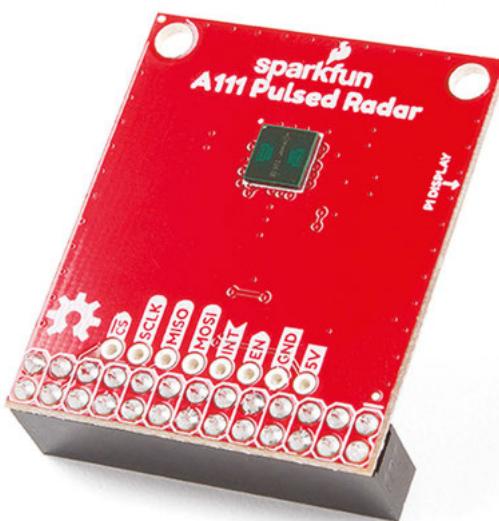
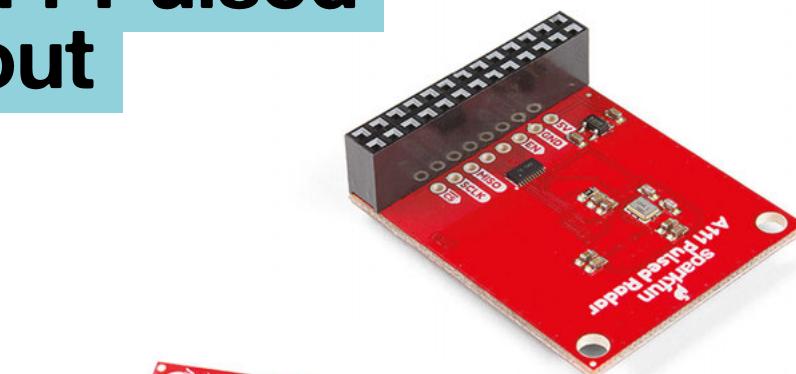
**8** /10

# SparkFun A111 Pulsed Radar Breakout

SPARKFUN  \$60 | [sparkfun.com](http://sparkfun.com)

**N**ow let's look at something a bit different: the SparkFun Pulsed Radar Breakout board. Not only does this board measure distance up to two metres, but you can also sense gestures, speed motion. And it does it by radar, which is truly amazing technology for the DIY enthusiast. The A111 is a single-chip solution for pulsed coherent radar which includes an integrated antenna and SPI interface.

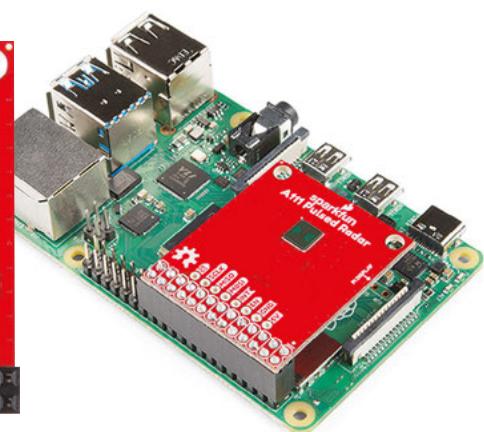
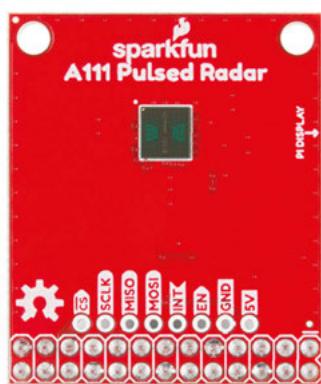
The headers on the board are Raspberry Pi-friendly, and it also includes proper voltage regulation and translation. The A111 can simply plug directly into your Raspberry Pi B+, or newer model, allowing for easy setup. It also works with many different ARMv7 or ARM Cortex-M4 platforms. There is a visualisation tool written in Python that demonstrates how you can collect the A111's data in real-time and graph the distance. When you want the benefits of 60GHz radar integrated into your next project, this is for you! □



Right  New tech enters the game

**VERDICT**  
On the cutting edge of technology.

**10** /10



# SF30-B High Speed Laser Rangefinder

**PARALLAX** \$299 | [parallax.com](http://parallax.com)

If you are planning on building a UAV or any type of moving robotics platform, taking accurate measurements at a high rate of speed is going to be critical to the robot's success. That's where the SF30-B High Speed Laser Rangefinder from Parallax comes into play. This lightweight sensor is capable of taking 18,317 measurement readings per second up to 50 metres. Those are some impressive numbers!

The unit runs on 5V and is configurable to work with both digital and analogue interfaces, making it easy to integrate with most flight controllers. The sensor will smooth out its data, but if speed is what you need, you can access the raw output and interpolate the data as needed. Check out the product page for additional information, including safety information, sample code, and more. □



**Left** This sensor allows you to detect motion

**VERDICT**  
Speed, at a price.

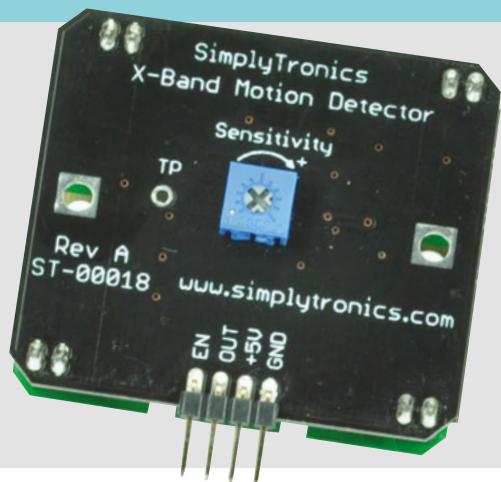
**8** /10

## X-BAND MOTION DETECTOR

**SIMPLYTRONIC** \$39.99 | [shopsimplytronics.com](http://shopsimplytronics.com)

Now for something a little more unusual. The X-Band Motion Detector from SimplyTronics is a fascinating motion and distance sensor. Instead of the commonly used infrared or ultrasonic technology to detect motion, the X-Band sensor operates at 10.525GHz and can detect any oscillations in that spectrum, which in turn means motion. What makes this product really interesting is its ability to work through walls and windows. Yes, we said walls!

We've used this product on several occasions while prototyping, and it's really fun. Just keep in mind that this sensor is not FCC or CE approved. If you are planning on using this sensor in your project, you must go through the process of having it approved by your national licensing agency. It's an arduous process, but it just might be worth it if you need this sensor's unique capabilities.



Know your surroundings

BEST OF BREED

## RPLIDAR A3M1

SPARKFUN  \$699 | [sparkfun.com](http://sparkfun.com)

**N**ow let's take a look at a more high-end lidar system which starts to go beyond the average DIY enthusiast.

The RPLIDAR A3M1 has some very impressive specifications, like being able to take up to 16,000 measurements per second, in a full 360°, and at a range of 25 metres. But all that speed comes at a hefty price. Although, if your project requires that kind of accuracy and speed, you might be thinking this isn't so expensive considering the alternatives, which can be significantly more costly.

The RPLIDAR A3M1 has some other nice features, besides its more than capable speed and accuracy. You can also use it in two modes. One is specifically designed for high-speed indoor measurements, and the other is tuned for outdoor operation, reducing inaccuracies from brighter lighting situations. It's a nice, close to turnkey, solution.

Another thing to carefully consider about this product is the fact that every unit is tested to make sure it passes the strict eye safety standards of an IEC-60825 Class 1 product. Better safe than sorry when dealing with laser technology!

SparkFun also sells the slightly less powerful RPLIDAR A2M8, which also comes with a lower price tag of \$370. Check out their product pages for complete comparisons. □



You might be  
thinking this isn't so  
expensive considering  
the alternatives

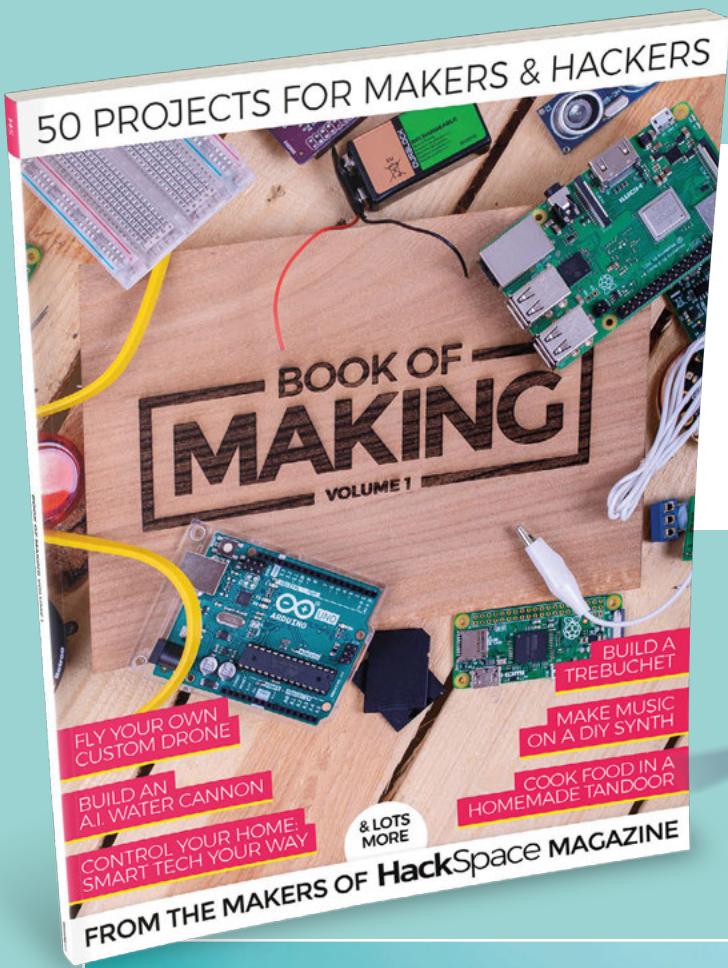


Above  The RPLIDAR A2M8, a slightly less powerful and less costly alternative to the RPLIDAR A3M1

### VERDICT

High-end  
360° sensing.

8 /10



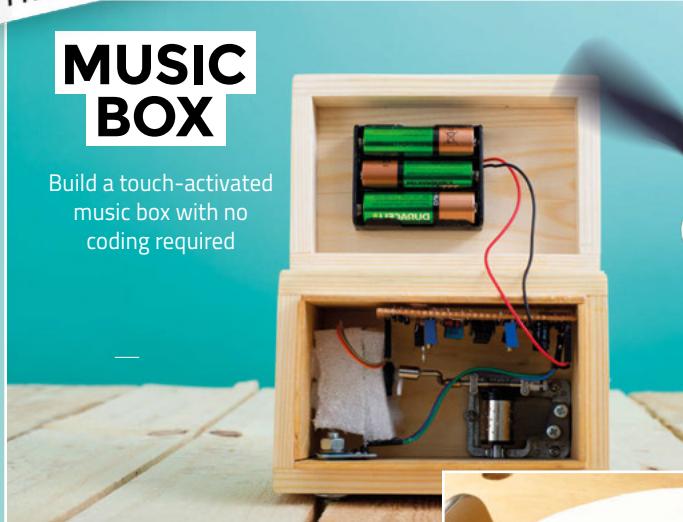
# THE BEST PROJECTS FROM HACKSPACE MAGAZINE

## THE ULTIMATE SKILLS, TRICKS, AND MAKES



### BUILD A DRONE

The ultimate guide to making  
your own quadcopter



### MUSIC BOX

Build a touch-activated  
music box with no  
coding required



### LASER-CUT TURNTABLE

Create stunning 360° animated  
GIFs with this geared turntable

**£12.99**

**FREE WORLDWIDE SHIPPING**

BUY TODAY AT  
[STORE.RPIPRESS.CC](http://STORE.RPIPRESS.CC)

CAN I HACK IT? ■



# Can I Hack It? A video business card?

Can we hack a video business card?

**Above** On the outside, the card is very plain, but we have a lot of electronics in a small package



**Les Pounder**

@biglesp

Les Pounder loves taking things to pieces and seeing how they work. He teaches others how to be makers and tinkerers at events across the UK. He blogs at [biglesp](http://biglesp.com)

**B**usiness cards convey a message to the recipient, but they can only say so much. What if we had a video business card that could play a message to the receiver? Could we use it with sensors and buttons in a project? There is only one way to find out, and that is to take it apart!

## GENERAL CONSTRUCTION

We expected plastic, but no, there is none. To keep the costs down we see a fairly thick, plastic-coated card which is stuck to a chassis made from a material similar to MDF, using double-sided tape and hot glue. The entire thing is held together with glue, so to get inside, we needed a hair-dryer and a spudger to heat the glue and carefully slice our way in. Just go easy, as the electronics inside are exposed and a metal spudger will short out any exposed pins.

## ELECTRONICS

Externally the unit is very sparse. There is a 2.4-inch LCD screen and a mini USB port that is used to charge the device and to transfer videos to the internal flash memory, which is a Samsung K9F2G08U0C 256MB flash unit. The card appears as a USB flash drive when plugged into a PC. Charging the built-in 3.7V 300 mAh LiPo is made possible due to a voltage regulator which passes the correct voltage to the LiPo battery. Thankfully, the LiPo has its own protection circuit, which means that the LiPo will not over/under-charge.

At the centre of the board is an Artek AK2117 digital multimedia chip which handles audio and video processing. It connects to the LCD screen to display video, and via an XPT4890 audio amplifier and speaker so we hear audio. The AK2117 has connections broken out across the edge of the board, all of which are easily solderable and provide extra functionality, such as buttons for volume

## OTHER USES

So how could this video business card be used? Presently, there is a trend to build conference badges, and these can range in price from £5 to £50 depending on the tech inside of them. So, can we use this as a conference badge? Well, yes! The magnet to trigger playback can be hidden in a ring, and we can connect LEDs and other components to the spare GPIO pins around the perimeter of the board.

We have it all in one package. Sound, video, GPIO, rechargeable battery, and a decent box to contain it all which can be adapted and decorated with relative ease.

control and a microphone. These are not connected as standard, which is a pity as volume control would be handy to control the rather shrill speaker.

Playback is triggered by opening the card. Inside the cover is a magnet which triggers a sensor inside the card. The sensor has a resetting state of HIGH, and when the magnet is passed over it, the sensor registers a LOW signal, causing playback to start.

## SOFTWARE

The business card video player has a very particular need, and that is an archaic video format called AMV, which is a modified version of AVI. The AMV format was used on older MP4 video players and has since faded into obscurity. In fact, this caused us quite an issue as converting typical video formats to AMV proved quite difficult. We tried HandBrake, FFmpeg, and Sony VEGAS Pro 15. Nothing would convert to AMV. After a few hours searching the internet, and avoiding many sketchy websites which offered 'free' tools to download and convert the file, we found a tool to do the job. Video needs to be encoded as AMV, at 320x240 pixels to match the screen resolution (the video resolution will not scale!) and audio needs to be at 22050Hz mono.



## YOU'LL NEED

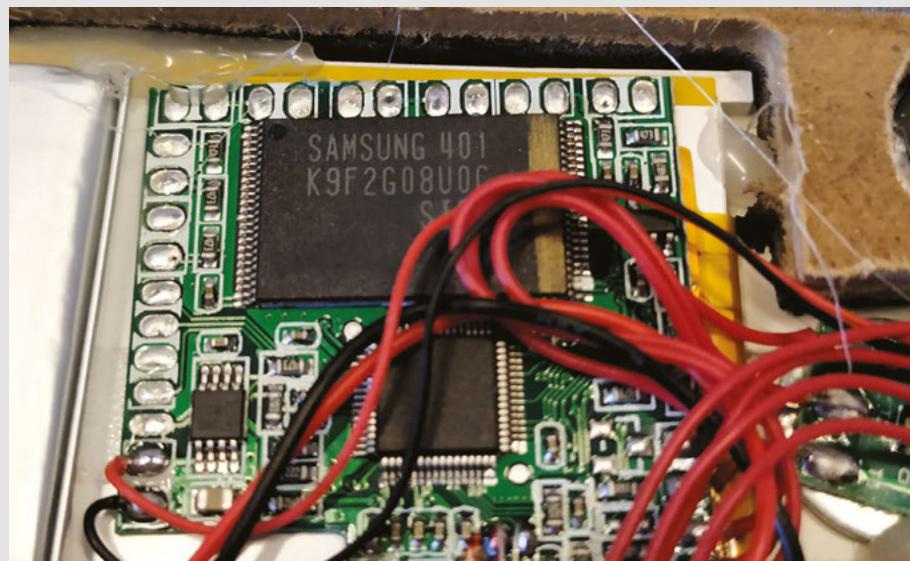
Recordable Video Business Card - 2.4" screen - Blank Talking 256MB

## COST

£15.95

## WHERE

eBay



## HACKABILITY

With access to the AK2117 available via the exposed GPIO pins around the perimeter of the board, we have plenty of expandability. The AK2117 offers typical GPIO (on/off) PWM (pulse-width modulation) used for the LCD backlight, and I<sup>2</sup>C/SPI which is used to communicate using only a handful of pins. The board runs at 4V which is an unusual voltage: it is too high to directly interface with a Raspberry Pi and too low for an Arduino. But, for either device, an interface board would be required to safely work between these voltages.

## CONCLUSION

This is not a cheap thing to be given out. At £15 per unit, this is something to be used sparingly. Combined with the rather archaic video format, this board is not an ideal platform for hacks. If you can work around these issues, then this is a fun little board to build into a project. Just take care with your voltages and removing the board from the card. □

## Top

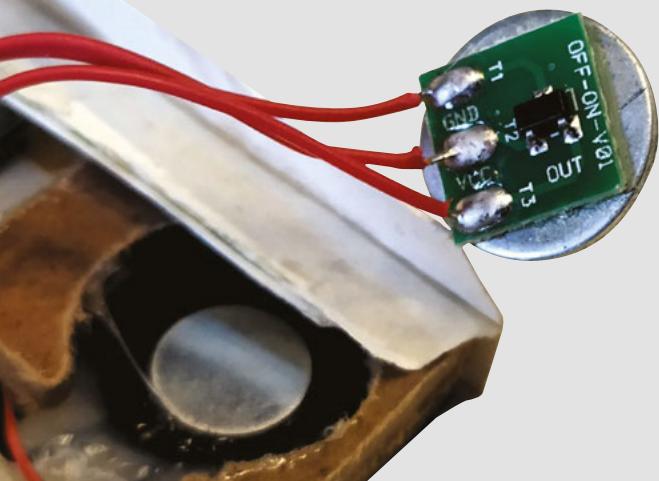
The mainboard controls video playback, battery charging, and has access to many more features via the GPIO

## Above

Access to the AK2117 is via the GPIO which is handily broken out around the edge of the board

## Left

The sensor that detects the cover magnet is easy to remove, and each pin is easy to identify



# Multifunction sharpener

Put an edge back on your knives, chisels, and drill bits

**FERREX** ♦ \$14.99 | Aldi.com

By Ben Everard

 @ben\_everard



We got this tool from Aldi under the brand name Ferrex. Identical looking tools are available under different brand names from other sources, but we have only tested this one.

This sharpener tool has three different modes, which are set by clipping plastic accessories to the side: knife and scissor, chisel, and drill. The rest of the unit is a motor with a simple on/off control and a diamond grinding wheel.

The good news is that the metal and diamond grinding wheel means there's no risk of the wheel disintegrating at high speed, as can happen with a ceramic wheel. That is just about the only good point of this tool.

There is only one grinding wheel, and therefore only one coarseness. It's not identified just how coarse it is, but we'd suggest somewhere around 80 grit – in other words, it's very coarse. This is too coarse to put a final edge on a blade, but perhaps it could be useful for shaping the edge before a final manual grit to finalise the edge?

## IN THE TEST LAB

We started by testing out the knife sharpener. There are two key problems with this. Firstly, it's hard to hold the blade in place – there's no option to adjust the angle, so you're stuck with the preset angle (around 20 degrees), and there's only a small, slightly flimsy, plastic ramp to hold the blade against. While this doesn't make it impossible to grind a smooth edge, it certainly makes it difficult.

### Left ♦

The knife and scissor attachment makes it hard to get a consistent edge

The second problem, though, is a bit bigger. The grindstone is lower than the height of the control box, and this means that you can only grind with the handle facing outwards. This means that one side of the knife is ground with the grinding wheel going into the blade and one side with the wheel going away. Again, not an impossible situation, but another added difficulty. When combined – the one coarseness, the difficulty holding the blade in place, and the inability to grind in the preferred direction, we found this tool much more adept at destroying blades than sharpening them. It's probably possible to sharpen a knife on this, but the amount of practice it would take for mediocre end results would be better spent learning a more manual method.

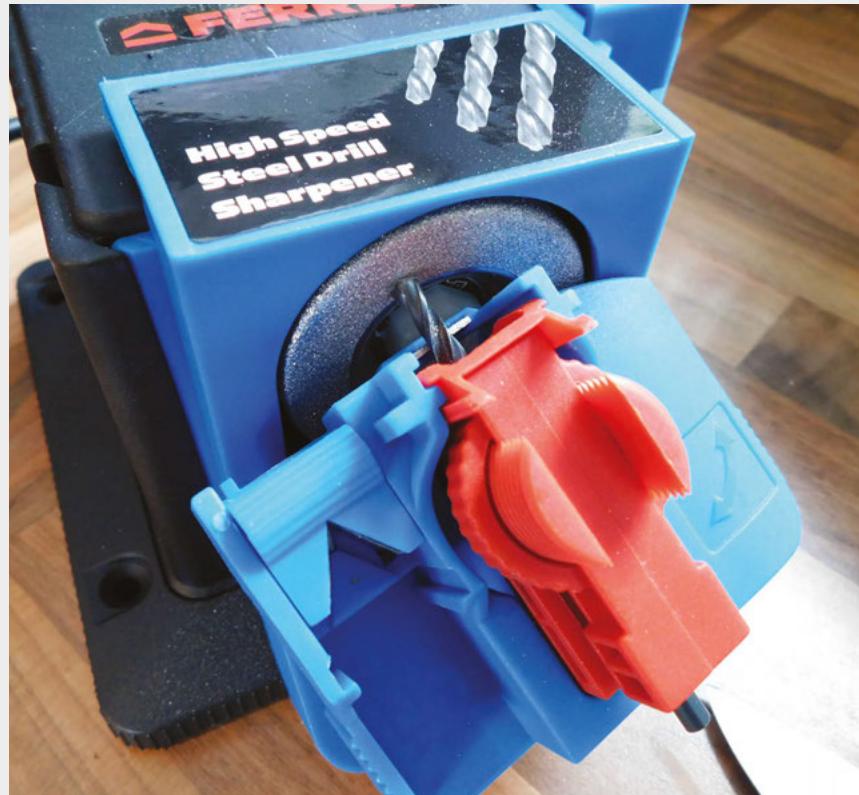
#### TOOL SHED

We were nervous about testing the chisel and drill bit sharpening attachments for the simple reason that while we have a sacrificial knife, we don't have any sacrificial drill bits or chisels. Still, there was at least some reason to be optimistic – the problems with the direction of the wheel and holding the blade in place should be less due to the design of these attachments.

Probably of all the tools that need sharpening, a chisel needs the most care to create an edge that is both sharp and flat. The narrow grinding wheel on this sharpener means that a lot of care has to be taken to ensure that the edge is flat. It's possible, but it's much easier to do on a larger wheel. The coarse grit on this means that it's completely useless for putting the fine edge on a chisel. It can be used for shaping an edge on a worn or damaged chisel, but the small size of the grinding wheel will lead to a slight curve in the bevel of your chisel, and this will cause a problem for the rest of the sharpening process.

The website for this tool claims that it works on 'any drill bit', but then qualifies this to say drill bits between 3mm – 13mm in diameter. However, it's only actually capable of sharpening twist drill bits with an angle of 118 degrees. Brad point, masonry, spade, and other drill bits won't fit in the sharpening attachment.

Of all the attachments we used, this is the only one that we had even slight success with. Despite the fact that the attachment should hold the bit comfortably in place, we found it tricky to get an accurate grind, but with a little practice, we could put a new edge on our bits. It wasn't a very smooth edge due to the coarse grit, but it was an edge, and it was better than a blunt bit. We prefer grinding our drill bits using, well, almost any other grinding medium as the drill bit attachment proved hard to get an accurate edge with, but it did work.



Replacement grinding wheels are available, but hard to source. We've only seen them on direct-from-China websites. While diamond grinding wheels are long-lasting, they are still consumable and will wear out. It feels like a travesty that stores selling tools like this aren't also selling replacements for the consumables. While it's unlikely that many people will

**Above** The drill attachment can hold twist drills between 3mm and 13mm in diameter

The website for this tool claims that it works on 'any drill bit', but then qualifies this to say **drill bits between 3 mm – 13 mm in diameter**

wear out the grinding wheel on this given how bad it is generally, we're still disappointed that consumables aren't easily obtainable. We call on Aldi (and others) to take responsibility for ensuring that customers can continue to use tools like this.

Despite the advances in modern technology, keeping a blade sharp is a task that requires some manual skill and a decent set of tools. £14.99 is very cheap for this task, and it turns out that there's a reason for this. We wouldn't let this anywhere near our good knives or chisels, but for revamping a set of drill bits, this 'multifunction' sharpener could perhaps find one function. It's not as useful as a proper grinding stone, but is much smaller and cheaper. □

**VERDICT**  
Destroyer of  
knives and chisels,  
but perhaps some  
value as a twist  
drill bit sharpener.

**L 3 /10**

# Dremel plunge router attachment

Get extra skills for your rotary tool

DREMEL ♦ \$28.99 | [dremel.com](http://dremel.com)

By Ben Everard

 @ben\_everard

**T**here are quite a few different types of router, but they all do the same basic job – spin a bit that's designed to cut sideways (rather than downwards, as drills do). Plunge routers, as the name suggests, allow you to plunge the bit downwards and start a cut in the middle of a piece of wood (other routers require you to come in from the side). Using this edge, you can carve out grooves, or hollow out whole areas in wood and some plastics.

This isn't a product in its own right, but an adaptor for Dremel rotary tools to convert them into plunge routers. It should work with most official Dremels, and many rotary tools from other brands.

It comes as a set of parts, but it's easy to slot together. You should be able to unscrew the end of your rotary tool, and this screws into the router body to make your router. It contains all the basic bits you need for routing – in our test setup, we had a Dremel 3000 with a chuck (though a collet will work equally well).

There are all the features you'd expect of a plunge router: two solid handles enable you to push the bit



**Right ♦**  
The rotary tool screws into the top of this to create a plunge router

down into wood, an end-stop lets you limit the depth, and a fence to enable you to cut a groove parallel to an edge.

If you'd prefer a different routing setup, Dremel also sells a table router, a line and circle cutter, and a 'multipurpose cutter'. If you're of a more automatic bent, some people have created CNC jigs for rotary tools – there are some quite impressive looking builds like this, but we've yet to get one in our test lab.

## ON TEST

We've been using this tool for a few months now, and have put it through the test on a few builds, including on the 'word clock' from issue 20. It's done its job in each build. Bits have been spun, wood has been carved, and objects have been created. On that

**Bits have been spun, wood has been carved, and objects have been created**

very basic level, it's worked, but we do have a couple of fairly serious reservations about this tool.

By far and away the biggest limitation of the Dremel router is the chuck/collet size – it's far smaller than those on regular routers. The Dremel router needs bits with a 3mm shaft, while the standard is 6mm. The result is that there are far fewer bits available for Dremel routers. The official bit set of seven bits sells for £29, and there's also a common ten-piece set that sells under a range of off-brand names that expands on it slightly and contains:

- Slot cutter diameter 3.2 mm
- Slot cutter diameter 5.0 mm
- Slot cutter diameter 6.5 mm
- Rounding over cutter diameter 6.4 mm
- V-Slot cutter diameter 6.5 mm
- Combi cutter 6.5 / 2.5 mm
- Core box bit 3.2 mm radius
- Rebating cutter 6.4 mm
- Edge cutter with pin diameter 5.0 mm
- Half-round cutter diameter 13 mm

As far as we've been able to tell, these are the only bits available with a 3mm shaft. If you don't see all the bits you'll need here, then it's probably not the router for you.

The other thing we're not keen on is how unsubstantial it is. Plunge routers typically have a bit of heft to them, and this can make them a bit easier to control. The plastic-with-metal-rods construction is, at best, OK. It's not really flimsy, but there's a little more bend to it than we'd like. All the adjusters are a bit more sticky and jumpy than we'd like. All this means that you have to take a bit more care than usual to get your cuts in the right place.

We had hoped that this router would save some workshop space, but unfortunately, it doesn't pack up particularly small – perhaps a little smaller than a regular router, but not much.

There's certainly a case for this router. It's cheaper than even the cheapest plunge routers by 30–50% (if you've already got a compatible rotary tool). If you want a battery-powered setup, then the cost saving is even more. There's an environmental win by not bringing another electric motor and associated control electronics into the world if you don't need to. It's certainly capable of some reasonable routing, and if all you need is carving some grooves using the fence as a guide, then it's worth considering.

However, it's no substitute for a proper plunge router. If you need the full range of bits, or if you're going to be using it regularly, a purpose-designed tool will do the job better and easier. □

## VERDICT

Can handle basic routing jobs, but not as well as a dedicated tool.

**7** /10



# Template maker

Print your own boxes and decorations

**TEMPLATEMAKER** ♦ free | [templatemaker.nl](http://templatemaker.nl)

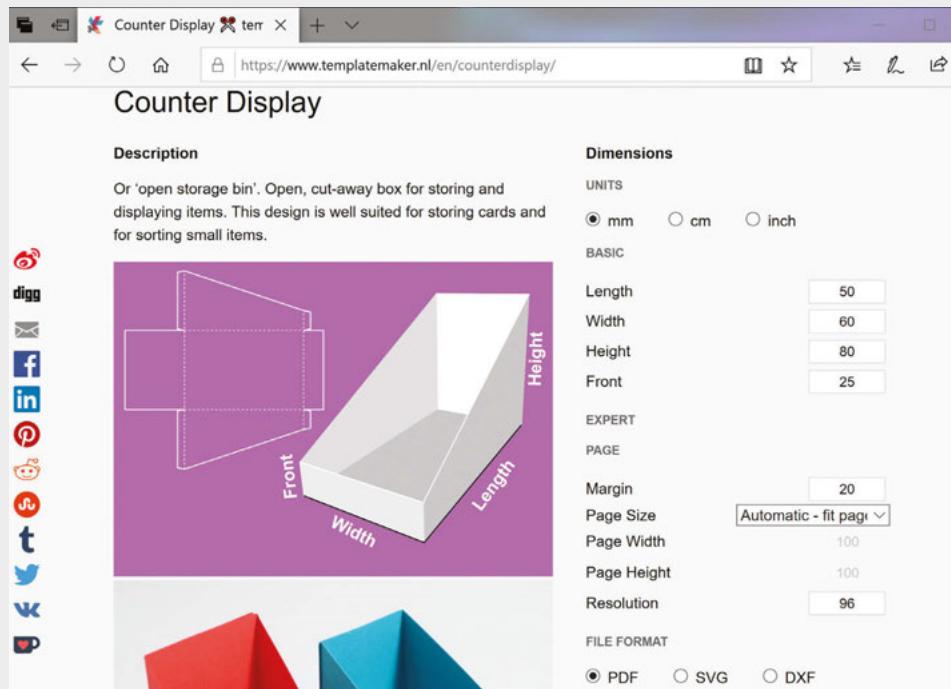
**T**emplate.nl is a website dedicated to paper templates of the sort you cut out, fold, and glue together. Each template has a diagram showing what the object will look like, and can be customised via a number of options. Once you've set up your design with the details you want, you can download the template in PDF, SVG, or DXF format and print it out on a normal printer.

Oh, and did we mention that all this is free? The vast majority of options are different types of packaging – boxes of various forms – but there are also a few decorative items such as stars.

The one feature we'd really like to see is the ability to scale while keeping the proportions the same. This would be great to change the properties while keeping the aspect ratio, but it would also be really useful for fitting an object to a particular paper size. It would make it easy to, for example, find the largest box you can fit in an A4 sheet. At the moment, the process for this is:

- Select Expert mode
- Select paper size you have
- Play with the options until it fits in the preview

This isn't the most onerous process (it would be if there weren't a preview, which shows just how



useful that feature is), but it could be much easier. While we're having a bit of a grumble, we'll also point out that the discoverability isn't great. There's no menu or search facility – the only way you can find models is by looking through the complete list (and there's quite a few!).

Overall, this is a great tool, and given that it's free even for commercial use (if you find it useful, you can support the makers via Ko-fi), we really can't complain too much about the features we'd like to see. It's certainly a page we'll be revisiting in a month or two when it comes time to box up gifts to go under the Christmas tree. □

**Above** ♦  
Design and print  
your own folded  
paper creations

**VERDICT**  
Loads of  
designs for you  
to customise  
and print.

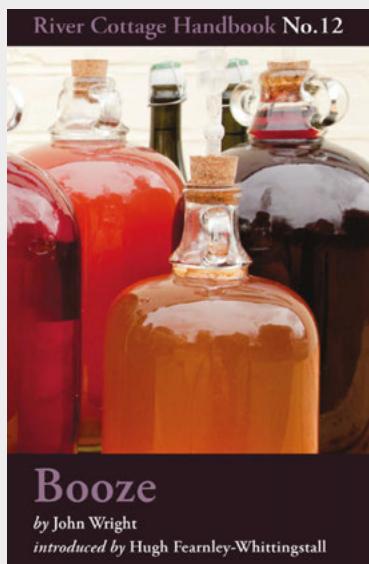
**8/10**

# Booze: River Cottage Handbook No.12

John Wright ⚡ £11.49 | [rivercottage.net](http://rivercottage.net)

By Ben Everard

 @ben\_everard



# W

e've been using this book to guide our brewing for several years now, and we particularly enjoy the breadth of brewing that it includes.

Whether you're making mead, country wine, cider, or beer, you'll find guidance here, and this breadth makes it a great book for setting off on your brewing adventure. Many of these brews are unlike anything available commercially, so you may be unfamiliar with them, but we'd encourage you to experiment freely as you find your way as a brewer.

The only reason we wouldn't recommend this book is if you have a particular drink you want to brew – for example, if you know you want to make only beer, then you'll be better served by a book dedicated to that drink.

We've had great fun experimenting with the drinks in this book and, for the most part, they've worked well (the only one that didn't work for us is the nettle beer, but perhaps that shouldn't be a surprise – nettles really don't sound like they should be in beer).

*Booze: River Cottage Handbook No.12* is a great source of inspiration and, after a quick browse, we're always brimming with ideas for our next brew – some of them are recipes from this book, while others are adaptions that we want to try. □

## VERDICT

The book we wish we had when we started brewing.

L 10 / 10

# high speed m echan ics

issue

#25

ON SALE  
21 NOVEMBER



*Maker  
Christmas  
Presents*

## ALSO

- DIY SYNTHESIZER
- BEARINGS
- POWER CARVING
- ARDUINO
- AND MUCH MORE

—  
**DON'T MISS OUT**

[hsmag.cc/subscribe](http://hsmag.cc/subscribe)



# Saccharomyces cerevisiae

We owe almost all styles of bread and alcohol (and Marmite) to this one species of yeast: *Saccharomyces cerevisiae*. These days it's most commonly added in the form of dried yeast that was first created for the American military during the Second World War. In the wild, it's found on the skin of fruits such as grapes. It's hard to imagine what life would be like without both alcohol and bread, but it's fair to say that the world would be a very different place without this tiny fungus.

#### Image

Mogana Das Murtey and Patchamuthu Ramasamy (18 February 2016). *Sample Preparations for Scanning Electron Microscopy – Life Sciences, Modern Electron Microscopy in Physical and Life Sciences*, Milos Janecek and Robert Kral, IntechOpen, DOI: 10.5772/61720.

