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ROCKETS **DYEING** WASSAIL **ANALOGUE**

Welcome to HackSpace magazine

This cover feature comes to you thanks to multiple requests. Soldering is a regular feature of our articles in HackSpace magazine, and there are a huge range of soldering irons out there, but we'd never spent much time really sitting down and comparing the options. We've looked at a few in reviews over the years, and some others have come across our workbench for various reasons, but when people came to us and asked 'what soldering iron should I get?', we honestly struggled to provide a good answer.

So, we decided to get our hands dirty and find out about the good, bad, and ugly of hobbyist soldering irons. We've tested out just about every sub-£100 soldering iron we could find, as we felt this was about the price that is affordable for most hobbyists. There were a few surprises, and we burned ourselves once or twice in the process, but we now think we can at least start to give sensible advice to anyone looking for a new soldering iron. Read on to find out more.

BEN EVERARD
Editor ben.everard@raspberrypi.com

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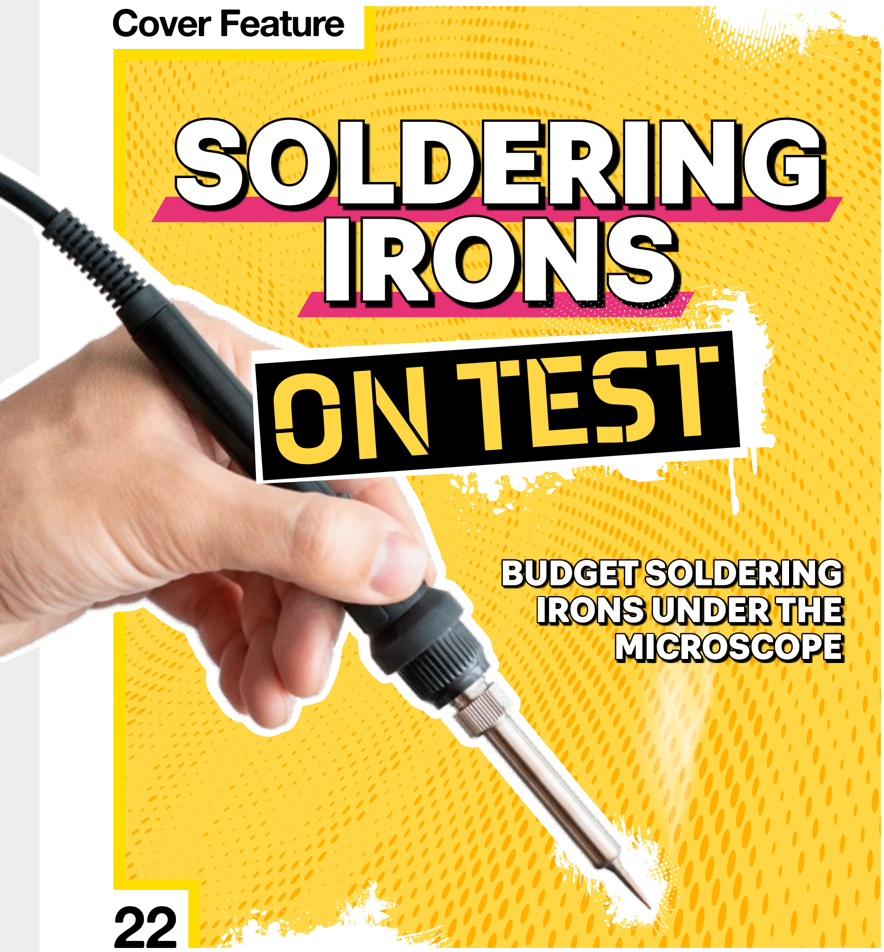

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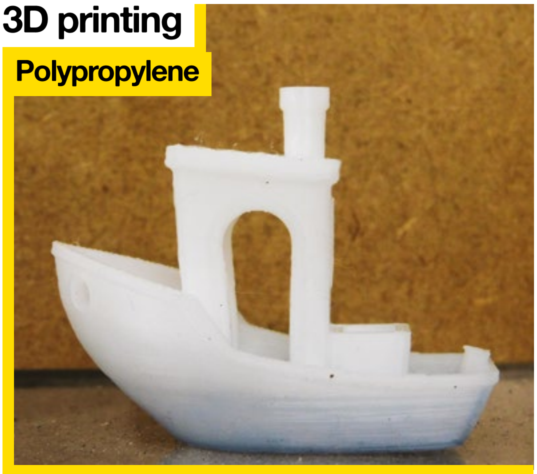

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Fortress planter

By **gazzaladra** instagram.com/gazzaladradesign

We found this model, by gazzaladra, on Printables. It's functional, it's decorative, it's designed and printed tightly enough that it's watertight, and it's perfect for any plant lover who spent their childhood being dragged around medieval fortifications.

Our favourite feature of this is the moat, which holds excess water so that the roots of your plant don't get drowned. It's a playful, functional detail, and we love it.

Right Even at low water levels, a moat is a useful protection. Wet ground makes it slippery underfoot, makes scaling ladders unstable, and exhausted soldiers in plate armour can drown even in puddles

Mario Pomodoro Timer

By CoderOK

hsmag.cc/MarioPomodoro

This 3D-printed block from the Mario games hides a Pomodoro timer, an essential tool for users of the Pomodoro Technique (a time management method), whereby practitioners break up their day into 45-minute bursts of productivity interspersed with 5-minute breaks to make a cup of tea, walk around the block, or anything that will make them more productive when they get back to work.

CoderOK listed the functionality he needed, then found a Mario block on Thingiverse, with enough space inside for the Arduino Pro Mini, piezo buzzer, real-time clock, battery, and the wiring that the project needed. He tweaked the 3D model to add holes for the button on the lid, and the 4-digit display that shows the time remaining, how many successful Pomodoro sessions you've achieved, and a few more key functions. It's a great example of a build that does one thing, and one thing well, but it won't give you mushrooms that make you twice your size.

Right You just need an Arduino Pro Mini and a few other bits

REGULAR

Musical cyberdeck

By **Jack** Instagram @JackAndTheOther

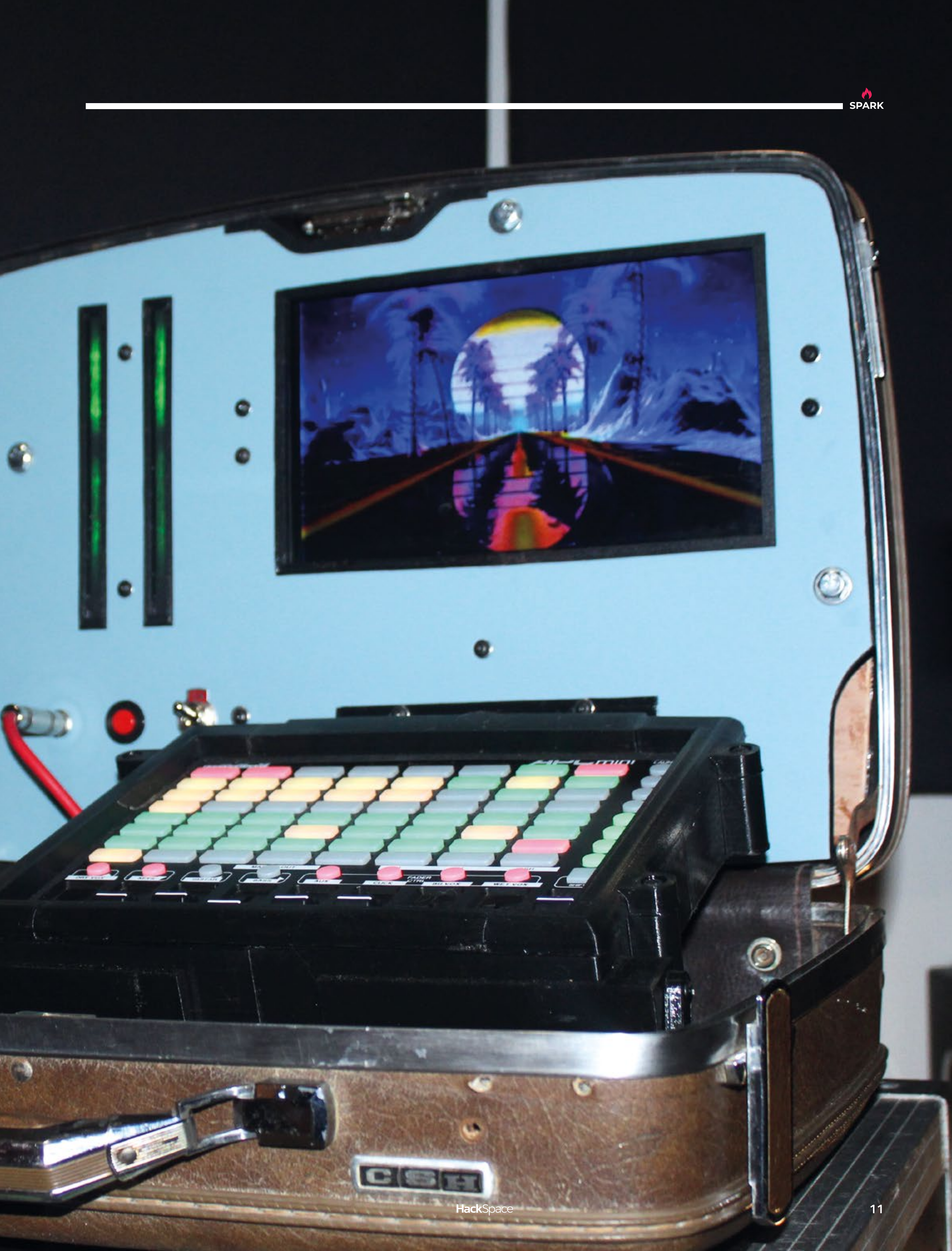
Writing about music is like dancing about architecture, as a wise man wrote; so to describe this beautiful musical cyberdeck, we're going to ask the person who built it. Take it away, Jack:

"My brother and I converted this old briefcase we found at a thrift store into a control centre for the rack-mount PC we use during our band Jack and the Other's live gigs. I've always loved the cassette futurism (aka retro-futurism) aesthetic portrayed in TV shows like *Maniac* and *Severance,* and wanted to create something similar with this. The briefcase contains a 10" touchscreen display, a midi controller which doubles as a computer keyboard, a trackpad mouse, and an LED VU meter (a type of audio decibel meter) with a 6.35 mm audio line-in jack that runs on an Arduino Nano clone using WS2812B LED strips.

The build itself was a combination of woodworking, 3D printing, and soldering/Arduino. After coming up with the design, my brother and I each 3D-modelled separate parts using Shapr3D and Tinkercad, respectively, while I handled the actual printing, VU meter, and construction of the briefcase. Because this was our first 3D printing project, as well as our first Arduino project, it took us a long time, but it was a great learning experience and undoubtedly will not be our last. I'd also like to give credit to fellow maker Scott Marley on YouTube, who personally gave me advice on creating the Nano portion of the project, and whose original VU meter design was, in large part, borrowed from (some might say almost entirely copied) for our project."

If you're in Atlanta, Georgia, you might catch Jack and the Other live at a venue near you (check for upcoming live dates at **jackandtheother.com**); otherwise you'll have to wait for the global mega tour, which will probably be soon; or you can listen on Spotify, Apple Music, TIDAL, and all the usual music streaming suspects.

Right Unbelievably, this is Jack and his brother's first Arduino project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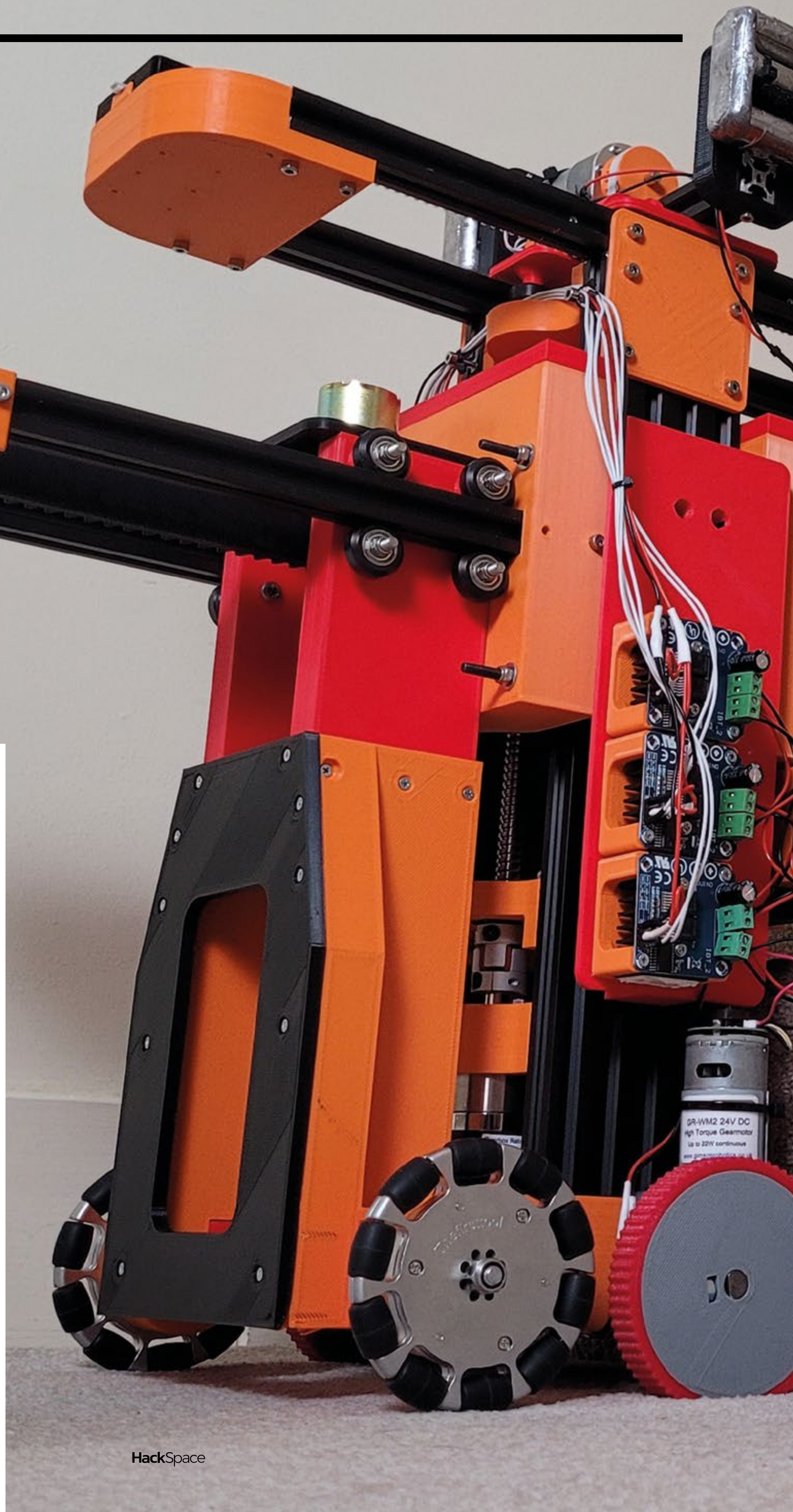

GR-WM2 24V DC
High Torque Gearmotor
Up to 22W continuous

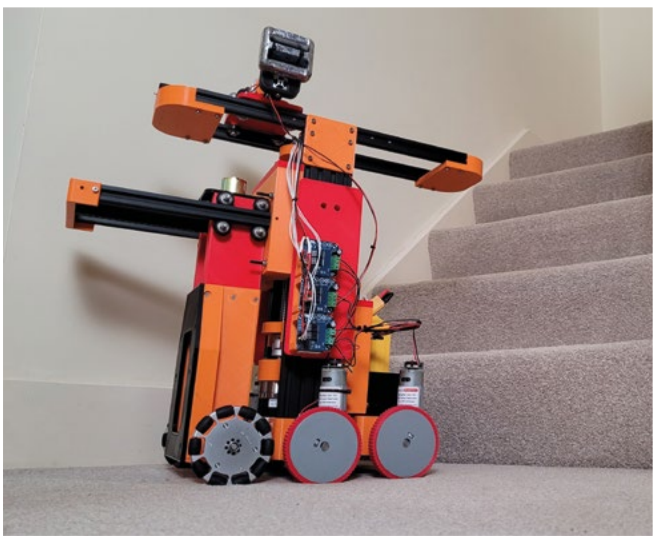
Stair-climbing robot

By James Bruton

hsmag.cc/StairClimbingRobot

Robots can do all sorts of things, but they've always struggled with stairs. Master robot builder James Bruton decided to change this, with a robot that can climb a carpeted staircase and, eventually, bring him a cup of tea. It's split into three vertical lifting sections powered by hefty motors and ball screws, with bearings and motors held in place by chunky 3D-printed parts and extruded aluminium.

There's a sliding section at the back that extends via a 3D-printed rack and pinion, and there's also a weight that moves towards and away from the middle section of the robot to keep its centre of gravity in a sensible place for climbing stairs. It's hard to explain, but it makes perfect sense once you see it in motion – head to **hsmag.cc/StairClimbingRobot** for more build information, and to see it in action.



Left
James claims that he wanted to build a robot that would carry a drink upstairs. We think he's going to sell this tech to the Daleks

Oddly satisfying clock

By **ragusa12**

hsmag.cc/OddlySatisfyingClock

This project embodies the spirit of the collaborative internet. Reddit user ragusa12 saw a GIF of a clock with the digital time represented on vertically sliding indicators, liked it, and made one himself. It's a little slower than the animation, and it makes a sound like (in the maker's own words) a full glass of water being pushed across a table. Nevertheless, it works, and when the digits all arrive where they're supposed to be at the same time, the effect is… satisfying.

The clock uses an Arduino Nano, four stepper motors, a 12-volt power supply, some LEDs, and a few more components. There isn't a circuit diagram, as ragusa12 worked it out as he went along rather than following a plan, but the project files can all be found at this link: **hsmag.cc/LinearClockFiles**, should you wish to make one for yourself.

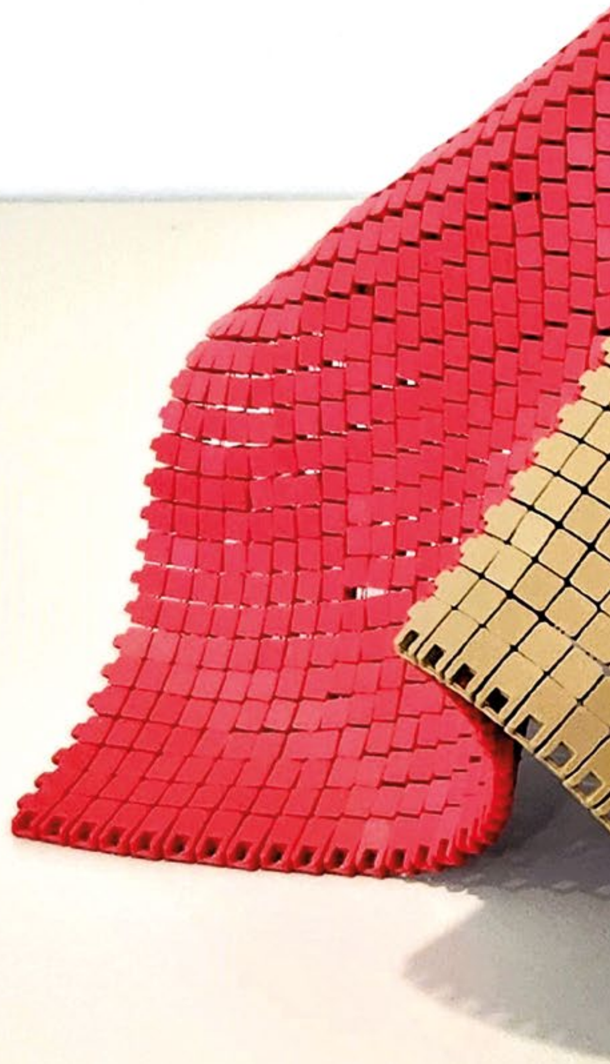
Right
We love it that this clock started life as a GIF made by an internet stranger


BDDs
1 8 0 1

REGULAR

Objet 3d'art

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



This 3D-printed fabric by 3DPrintBunny is an intriguing new take on something that's been tried in various forms before. Where most of us regard stringing on a 3D printer as something to be avoided, 3DPrintBunny has managed to control it, using strings printed in the X and Y axes to connect individual blocks that, together, form a flexible structure that moves like a fabric.

This innovative approach comes off the print bed as a single job, and you can clip sections together to form larger areas of fabric. Check out build videos, the iterative design process, and more here: **Patreon.com/3dprintbunny**. □

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**

CHOCOLATE FISH

It makes perfect sense that you can 3D-print chocolate – after all, it melts when it gets hot and solidifies when it gets cold. What doesn't make perfect sense (to me, at least) is that you can make such good-looking prints. I can't get PLA to behave that well, and that's pretty much purpose-built for 3D printing. Still, if Ellie Weinstein is taking requests, could you ask her for a white chocolate lithophane?

Paul
Northampton

Ben says: Absolutely not. Partly because white chocolate is opaque, so wouldn't let any light through, but mostly because white chocolate is a scourge upon the good name of chocolate. It's just chocolate with the chocolate taken out, and what good is that? It's the ghost of good chocolate and should be banished from the planet.

FLYING MACHINES

When I were a lad, we used to wait for the teacher to turn around and then throw paper aeroplanes at the blackboard. I know we shouldn't have done it – and the teacher got pretty upset – but it was one of life's little pleasures. There's just something so satisfying about flying machines. I suppose that at some point (if they're not already), kids in school will be using tablets and laptops, not paper and pencil. It's probably best not to hurl a quadcopter at the teacher, but it's good to see there are some flying machines that they'll be able to make.

Ali
Sheffield

Ben says: Paper planes are a rite of passage for young makers. I have two small children (the eldest has just started school). I can assure you that, for now at least, they're still using pencil and paper, and have respect for the fine art of folded-paper flying machines. Hopefully they're not launching them at the teacher, though.

KEVINGPT

Can someone check on Kevin McAleer? He's been everywhere and doing everything. From YouTube to magazine interviews to social media. The rate at which he puts out new builds makes me feel a bit dizzy. Are you absolutely sure he's not a carefully crafted Python script feeding the output of ChatGPT into Deepfake? If he's definitely flesh and blood, then I take my hat off to him. Sterling work, sir, on all those projects.

John
Middlesbrough

Ben says: I have it on very good authority that Kevin is, in fact, a human. If he's not, he is an astoundingly lifelike robot and has fooled many who've met him in real life. We, too, are full of admiration for the amount of work he's putting out. As yet, our paths haven't crossed, but I'm told he's a thoroughly nice chap, as well.

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LENS

HACK | MAKE | BUILD | CREATE

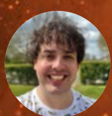
Uncover the technology that's powering the future

PG 36

HOW I MADE: AIR CANNON ROCKET

Achieve your dreams of flying a small rocket with compressed air and a big red lever

PG 42



INTERVIEW: MATT GRAY

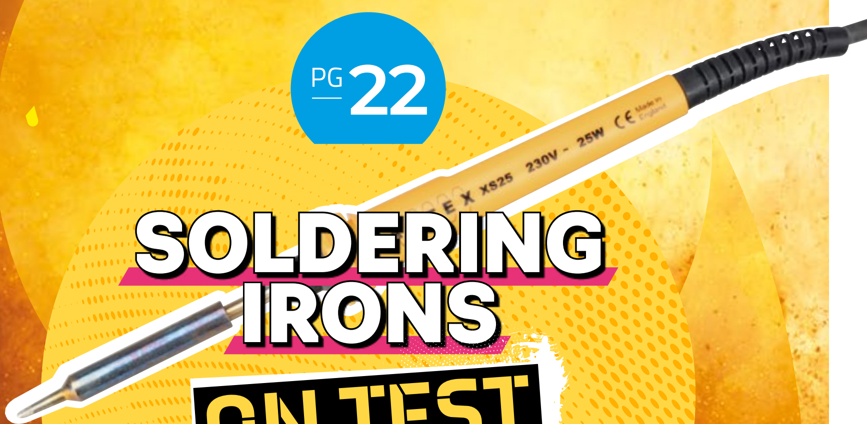
Do you have an idea? If so, get out there and do it – nobody else will!

PG 50

IN THE WORKSHOP

Laser cutting for a good cider harvest, and winding very thin wires

PG 22



SOLDERING IRONS ON TEST

Your ultimate guide to choosing the best solder melter

SOLDERING IRONS ON TEST

BUDGET SOLDERING IRONS UNDER THE MICROSCOPE

Soldering is one of the core maker skills. It unlocks the world of electronics and allows you to build permanent, high-quality PCBs at home. This could be predesigned kits, or it could be designing your own circuits (either using proto-board or getting PCBs made).

There's a mind-boggling range of soldering irons available and the costs range from a few pounds to several thousands of pounds, yet they all do basically the same job. Why is there such a huge price difference? Is it deserved?

We decided to limit ourselves to hobbyist soldering irons, which we decided meant soldering irons under £100 – this meant that one or two of the big names in soldering irons are completely absent from this test. Even with this limitation, there's a huge range of irons available, and it's not always clear what's a different iron or a rebadged version of the same hardware. We've attempted to get a representative range of soldering irons and, hopefully, we can give you some ideas for what to look for if you're interested in buying one, even if it's not one on our list.

Perhaps the hardest part of this test was deciding how to judge the soldering irons. There are a few hard numbers – such as the wattage and the heat-up time – but these have very little bearing on the actual user experience. Some soldering irons advertise the power of the built-in microcontroller, but this is almost entirely irrelevant to how it actually feels.

And in terms of capability, they all – with only a few exceptions that we'll talk about later – could solder exactly the same joints to the same standard. →

> "There's a huge range of irons available"

SOLDERING IRON VS STATION

Perhaps the biggest physical split between soldering systems is that between stand-alone soldering irons and soldering stations which have a control unit away from the iron itself.

Obviously, soldering stations need more space to store and use, and they're bigger to carry around. However, it gives much more space for controls.

Once upon a time, soldering stations were more expensive, but now that seems to have fallen away. Modern stand-alone irons can be comparably powerful and have good temperature control (features once reserved for stations).

Deciding which you want is more down to personal preference than anything. This reviewer used stand-alone irons for almost all of his soldering until very recently, and is now a complete convert to using stations. They don't take up that much space, and it means not having to fiddle with tiny little controls.

Instead, the actual important things in soldering are almost impossible to measure quantitatively. They're about feel and speed of use, and ergonomics. Basically, they all come down to the word 'nice'. That word is hated by reviewers because it's almost impossible to define, and means very little.

In an attempt to find some structure, after going through all the soldering irons, we did find some things that we liked. No soldering iron in the test has all of them. Some have few of them, but are still really good soldering irons to use. Some things here might seem really simple, but can actually make a big difference to how pleasant the iron is to use.

SILICONE CABLE The cable might seem like an unimportant part of a soldering iron, but it can make a big difference. A silicone cable is more flexible, which means that the iron is easier to move around. It's also heat-resistant, so less likely to burn if it comes into contact with the hot end.

LIGHT, COMFORTABLE HANDLE Ergonomics are important. Large soldering iron handles can be more awkward to move around.

TIP THAT DOESN'T OXIDISE TOO MUCH AND IS EASY TO RE-TIN All soldering iron tips should have a copper core covered in iron, yet some just seem to need more cleaning than others.

TIP LIFE

Soldering iron tips need to be made from something that conducts heat really well, and copper is the obvious choice. However, copper is also soluble in tin, so you have to protect the copper from the tin, and most soldering iron manufacturers do this with an iron plating. However, iron oxidises in the air. This means that you also need to protect this iron from the air, and a small coating of solder does the trick. This triple layer of metal (solder / iron / copper) is essential to a functioning soldering iron tip. If there's no solder, the iron will oxidise. If there's no iron, the copper will dissolve.

Soldering irons can get a bit of rough treatment. They're poked, scraped, heated, and cooled. Iron is the most vulnerable of the three layers because it's quite thin. If the iron layer is compromised, the tip will very rapidly dissolve. If you've not seen this before, it can be quite startling as large chunks of the tip disappear in each joint.

Soldering iron tips are considered consumable – eventually they all wear out. However, how quickly they wear out depends entirely on the soldering iron and the tip. We've had some degrade within an hour or two, and some last huge amounts of time. Good thermal regulation is absolutely key to prolonging the life of your tips. Once you go over 400 °C, the life expectancy of your tips drops dramatically.

When buying a soldering iron, you should make sure that new tips are available, as you will need them sooner or later.

WATTAGE

Our experience on this test is that the wattage of a soldering iron is a poor indicator of performance. Things like the thermal mass of the tip and the responsiveness of the control system had a far greater impact on performance than the maximum amount of power that a soldering iron could take.

TEMPERATURE INDICATOR This doesn't have to be complex, but it's helpful to know when an iron is up to temperature. With experience, you can tell from the way the iron behaves, but it can be more difficult for a beginner. Crucially, there doesn't just have to be a temperature indicator, it has to be accurate! Many soldering irons will happily claim to be at temperature while they're still cold.

TEMPERATURE CONTROL RATHER THAN POWER CONTROL Many soldering irons have some semblance of control. However, this isn't always what you might think. On some soldering irons, it controls the target temperature, so the iron will use its full wattage to heat up to that temperature and then hold it. On some, it will control the amount of power going into the iron, so it will continuously supply a particular wattage, regardless of temperature.

AUTO SHUTDOWN Some soldering irons have movement sensors that will turn the soldering iron temperature down if it's not been moved for a little while. Honestly, this isn't something we're huge fans of because we prefer to explicitly turn off the irons when not in use, rather than hoping that the firmware does it for us, but on the whole, it seems better to have it than not.

OFF BUTTON Yes, this sounds like a really little thing, but not all soldering irons have an off button – they rely on being unplugged (or being turned off at the socket). Depending on your setup, this can make it hard to know if your soldering iron is currently on or off.

BOOST This is a feature that we'd not come across before, but now we quite like. If you hold down a button, the temperature increases a preset amount. Handy if you have a few larger joints. However, this only works if the button is easy to press without moving your hand.

PRE-TINNED TIP Most soldering irons come with a solder coating already on the tip. Make sure you know if yours does because, if it doesn't, you need to tin it as soon as it warms up. If it oxidises before you've tinned the tip, it can be very hard to re-tin it later.

THE IRONS

ANTEX XS25

PRICE **£33** | WATTAGE **25 W** | GROUNDED TIP **Yes**

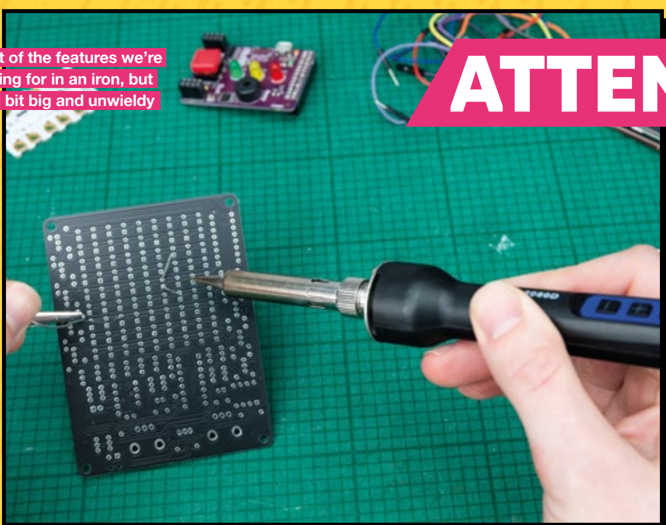
On paper, this doesn't look like a great iron: there's no temperature control, it's only 25W, and it takes an age to heat up. However, as we said at the start, soldering is an area where there aren't hard-and-fast rules about what a soldering iron should have, and it's more about feel. This iron has a large chunk of copper in the tip, so once it's up to temperature, it can push that heat into the joint very quickly – even a large joint.

While we are, in general, fans of temperature control rather than power control, this is one iron that seems to work well, and hold a good soldering temperature. We're also fans of the hoof-shaped tip. This is more rounded than most hoof tips, and we found it worked really well for transferring heat into a joint.

The main downside of this iron is that it's not great for surface-mount work where a bit more delicacy is needed.

A minimalist soldering iron that we've found easy to use and reliable

> **"This is more rounded than most hoof tips"**



Most of the features we're looking for in an iron, but it's a bit big and unwieldy

ATTEN 80W ST2080D

PRICE **£47.70** | WATTAGE **80 W** | GROUNDED TIP **Yes**

This is a great example of an iron that does a lot right in theory, but is a bit uncomfortable in practice. The user interface worked well and let us adjust the temperature (in 25 degree increments), and turn it on and off from the handle. The tip was a little chunkier than most and delivered heat into the joint well.

However, the iron is massive, and the cable is really stiff. These two things combined to make it just feel clunky to use.

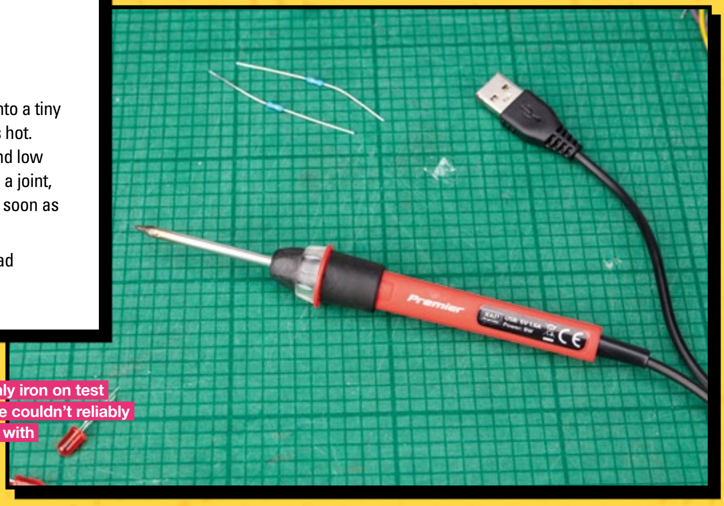
This is a real shame because in every other way, it's a great iron. How these two factors play off against each other is down to personal preference. If you're looking for an all-in-one iron (rather than a soldering station) and don't want one of the USB-PD powered options, then this is an excellent choice. →

PREMIER

PRICE **£12.41** | WATTAGE **8 W** | GROUNDED TIP **No**

This little 8 W iron plugs into a USB port and funnels all that power into a tiny tip. This means that, despite being only 8 W, it heats up fast and gets hot. However, it's not an iron we'd recommend. The tiny thermal mass and low power mean that the temperature swings wildly. Before you put it in a joint, it's probably too hot. However, there's very little thermal mass, so as soon as you start using it, it cools down quickly.

It's not impossible to solder with this iron, but it is very easy to get bad solder joints, and we'd recommend staying clear of it.



The only iron on test that we couldn't reliably solder with

VELLEMAN VTSS5

PRICE **£26.99** | WATTAGE **50 W** | GROUNDED TIP **Yes**

We'd not come across tips like this before. On the website, they're described as 'ceramic', and have a rough finish that does feel quite a bit like ceramic. When you first use them, this coating emits a bit of smoke that the instructions assure is quite normal. We took a saw to one of these tips to find out just what's on the inside and it does have a copper core, as you would expect on a soldering iron. There is also a silver metal around this. We have no idea what the outer coating is and the company has not responded to our enquiries.

Like most soldering irons on test, these come pre-tinned, but they have an unusually heavy coating of solder. They stayed clean with minimal cleaning and generally worked well. The tips are a little unusual, and we found they struggled to get heat all the way into their points – which was a challenge for surface-mount – but worked well for through-hole and were easy to keep clean.

The downside of this iron is that it's power-controlled rather than temperature-controlled. That is, it will supply a continuous amount of power, but you can turn the knob to adjust what this amount is. Once you've got some experience with it, you can get this dialled in quite well, but if you're not used to soldering, it might be hard to set the temperatures correctly.

A slightly unusual tip and slow heat-up time, but a good option for the price if you want an adjustable iron

This iron has a soft-touch handle that feels good in the hand, but got too hot and destroyed all the soldering tips in very little time

WELLER IR3023

PRICE **£35.17** | WATTAGE **30 W** | GROUNDED TIP **Yes**

It's common to hear some soldering irons described as 'hot poker' or 'fire stick'. It's a type of iron that's not that common now without thermal regulation. The Antex XS25 is this type, yet manages to be balanced well. This iron from Weller, however, falls into the worst stereotype of the fire stick.

It comes with an untinned tip, so you have to make sure you tin it as soon as it heats up, otherwise you'll never get solder to wet it.

It heated up far too hot and incinerated the flux as soon as it hit the iron, which made it harder to create reliable joints. The worst part of this iron, though, was that the tips didn't last very long. After just an hour or so of soldering, the tips would start to dissolve and rapidly disappear into the joints. Presumably this was due to the high temperature of the tip.

The one unique feature of this line of soldering irons is the LED halo to light up the work. When soldering PCBs, it's usual to be at a desk where you can control the lighting well, so in this situation it's not that useful. However, it's not uncommon to need to solder in place, possibly in a poorly lit case, and a bit of extra lighting would be welcome. However, the halo flickered slightly. It wasn't lots, but enough to feel a little uncomfortable on our eyes.

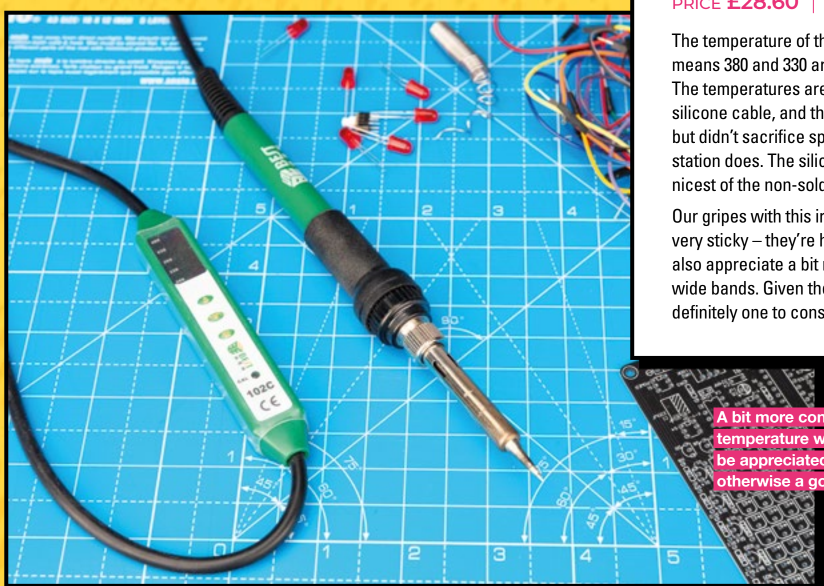
> **"The silicone cable is lovely to use"**

BEST 102C

PRICE **£28.60** | WATTAGE **60 W** | GROUNDED TIP **Yes**

The temperature of this iron is adjustable in 50-degree increments. This means 380 and 330 are probably the two temperatures you're likely to use. The temperatures are adjustable by a small control box that sits on the silicone cable, and this setup worked well. It kept the iron small and nimble, but didn't sacrifice space or portability in the same way that a soldering station does. The silicone cable is lovely to use. Overall, this is probably the nicest of the non-soldering station irons on test.

Our gripes with this iron all come down to the control box. The buttons feel very sticky – they're hard to press and get stuck down sometimes. We'd also appreciate a bit more control over the temperature than 50-degree-wide bands. Given the price and how comfortable this iron is to use, it's definitely one to consider. →



A bit more control over temperature would be appreciated, but otherwise a good iron

We've been unable to get our Pinecil working reliably

PINECIL V2

PRICE **£24** | WATTAGE **to 60 W** | GROUNDED TIP **Possible**

The Pinecil has been a darling of the maker community since they released the first version, and we know many happy users, though this is the first time we've had one in the HackSpace lab. The big selling points are the price and the open-source software.

While we are, on the whole, fans of open-source software, we struggle a bit with the concept of needing software on a soldering iron – especially software as complex as the Iron OS system on Pinecil.

Like the TS101, there are two buttons and a small screen. We found the layout much less ergonomic than the TS101. For example, there is a boost button, but it's in a position that's not comfortable to press while soldering so, in practice, we wouldn't use it.

While, on paper, there's a lot to like about the Pinecil, ours arrived faulty and we've been unable to use it reliably. We're working with PINE64 to try to resolve this, but as of now, this is as much as we can say.

> “We've been unable to use it reliably”

DURATOOL D01843

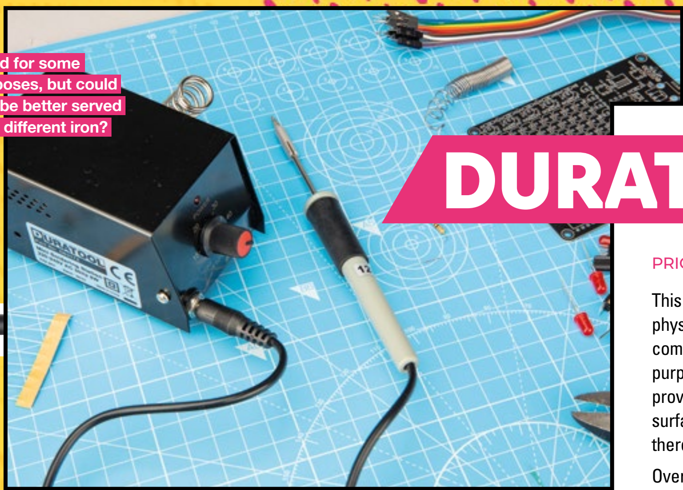
PRICE **£20.34** | WATTAGE **48 W** | GROUNDED TIP **Yes**

This soldering iron is very similar to the Velleman VTSS5, and takes the same tips. We similarly found it works reliably, albeit slightly slow to heat up. The dial is slightly different in that it lists temperature rather than power. We strongly suspect that the temperature given on the dial is just an estimate of the temperature based on the power going in. Even so, this can be useful to give you a starting point.

This soldering iron lacks the oomph of many of the more expensive soldering irons, but it's cheap, comfortable, and reliable.

The available tips are a bit chunky for finer surface-mount work, but for through-hole and larger surface-mount, this is a good choice if you're looking for a soldering station on a budget.

A little slow, but comfortable and easy to use



Good for some purposes, but could you be better served by a different iron?

DURATOOL D03172

PRICE **£11.04** | WATTAGE **8 W** | GROUNDED TIP **No**

This iron is unlike most of the others on test. It's absolutely tiny, both in physical size and power (it supplies just 12 W to the tip). Both of these combined mean that it struggles to heat larger things, so it's not a general-purpose soldering iron. It could handle some through-hole soldering, provided the joints didn't need too much heat, and it really shone on larger surface-mount work. The tip struggled a bit with smaller surface-mount, and there's not a great range of alternative shapes available.

Overall, we don't dislike this iron – and there are some things that it does well – but we do wonder if there's anyone for whom it's a good choice. If you want a small, cheap iron that can only do small (but not too small) soldering, then this could be worth a look. In reality, almost everyone will be better served by a more general-purpose iron. →

RS PRO

PRICE **£67.38** | WATTAGE **50 W** | GROUNDED TIP **Yes**

There are a few almost identical soldering stations available, and we tested out this one branded RS PRO and the one overleaf (with different controls) branded Tenma. In both cases, there's a chunky station with controls on the front and a power switch on the side, and a soldering iron extension. The soldering iron itself is small, light, and comfortable to use. The base station on this one gives a twiddly knob for adjusting temperature, though it's lower power than the Tenma. However, we found the knob much faster to make adjustments on, so any advantage the power of the Tenma might have in heating up quicker is offset by the extra time it takes to set it to the right temperature.

As well as the knob, there's an off switch on the side, so you can leave it set to your preferred temperature.

It's easy to use, and we found it performed excellently for both heavy-duty soldering and more fine work. The iron itself is small and nimble. Overall, this is a great option that we enjoyed soldering with. It is, however, one of the most expensive soldering irons on test.

A chunky box and lightweight iron is a great combination

PRE-TINNING

Most soldering irons arrive pre-tinned. That means they already have a bit of solder on the tip. If yours doesn't, you need to add solder as soon as it heats up for the first time, otherwise it'll be very difficult to ever get solder to stick to it again. If you're unsure, it's safer to tin the tip straight away, as there's no harm in doing it twice.

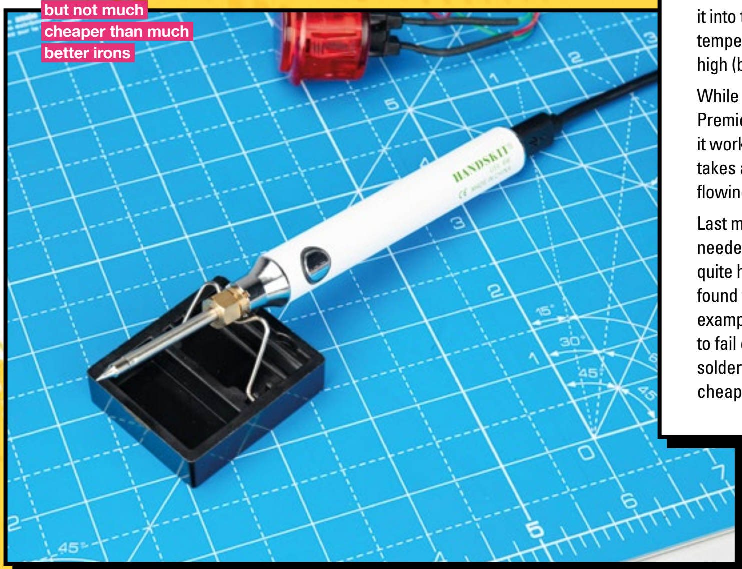
HANDSKIT

PRICE £9.70 | WATTAGE 8 W | GROUNDED TIP No

Like the Premier, this takes 1.6 A at 5 V from a regular USB socket. This is more than some USB sockets provide, so be a bit careful when plugging it into things. It's a slight improvement because it does have some temperature regulation, and you can set the temperature to low (green) or high (blue) with the press of the single button.

While it still suffers from low thermal mass and lack of power like the Premier, the temperature regulation does do just about enough to make it work. However, the heat is unreliable and is prone to cooling down. It takes an experienced eye to make sure the joint is heating up and solder flowing properly.

Last month, we wrote a feature on learning to solder. As part of that, we needed some examples of poorly soldered joints. It turns out that this is quite hard to do once you've got muscle memory for soldering well. We found that this soldering iron was the best for making bad joints for those example photos because it was good enough to solder, but bad enough to fail easily. This is a usable soldering iron, but only just. It's the cheapest soldering iron we tested that we could use reliably, but it's not that much cheaper than much less frustrating soldering irons.



Just about works, but not much cheaper than much better irons

TENMA

PRICE £73.95 | WATTAGE 80 W | GROUNDED TIP Yes

In almost every way, this is identical to the RS PRO iron, except that it's got a digital interface with three buttons and a screen. The three buttons can be used as preset temperatures or to scroll to a temperature manually. They work fine, and really it comes down to personal preference as to whether you prefer this or a twiddly knob.

In addition to this, there's extra power and a nicer (silicone) cable for the soldering iron. In both cases, these are only slight upgrades to the RS PRO which is already reasonably powerful and has a good PVC cable.

We didn't really notice the effect of the extra wattage in practice, but it was slightly faster to heat up. Both did a great job when soldering larger things.

A good choice for beginners or more experienced solderers

> "Adding more processor power isn't inherently a problem"

GROUNDED TIPS

Traditionally, soldering iron tips should be grounded. That means that any charge that builds up in them has a place to go. However, this isn't true of all soldering irons, because their power source isn't grounded. For example, anything powered by USB can't have a grounded tip because USB doesn't have a ground connection. Similarly, the small Duratool iron doesn't have a grounding connection for the tip.

Whether or not this is a problem depends on the electronics you're soldering. With the TS101, we had enough power in the tip to light up an LED as we soldered it. This didn't actually damage the LED, and most maker electronics can withstand a small amount of electricity as they're soldered. Lots of makers use non-grounded soldering irons every day without problems.

However, if you're working with sensitive electronics, then you will want to ensure that the soldering iron you get is ESD-safe.

You can add an additional grounding lead to some irons, including the TS101 and Pinecil, but this is a bit unwieldy.

This iron has become more refined in the newer version

TS101

PRICE **£51.74** | WATTAGE **to 65 W** | GROUNDED TIP **Possible**

The TS-series of soldering irons revolutionised the concept of hobbyist soldering irons. They popularised the idea of putting a programmable microcontroller in the handle of the iron, and using a common power supply – first barrel jack, and now the option of USB PD as well.

Both of these are a bit polarising. We've mentioned a few times that we think the cable is an important part of the feel of the soldering iron. If you take a common USB PD laptop charging cable, you'll probably find that it's not particularly flexible, at least, not compared with a silicone soldering iron cable. You can get silicone USB PD cables – in fact, one shipped with our TS101, but this depends on the options you select – but these only work if you have a power supply with a USB-C socket (as opposed to having one that terminates in a USB-C plug). Even if you do have a suitable power cable, having a plug and socket on the iron will never be as seamless as a properly strain-relieved cable.

With the microcontroller – adding more processor power isn't inherently a problem, but in order to make use of it, you need some form of interface, and there's precious little space on a soldering iron for this. The TS101 (like its predecessors) has two buttons and a small OLED screen. In our opinion, two buttons are not enough to make an easy-to-use interface. The TS101 interface kind of works, but is nowhere near as intuitive as soldering stations with a temperature knob. The Atten soldering iron is the only one we tested that has a good button and screen interface, and that does it by limiting the functions to just adjusting the temperature and turning the iron off.

Once you've got the iron set up, it's a comfortable one to solder with. There's been a slight change to the shape since the TS100, which makes it narrower around the grip and more comfortable to hold. We particularly like the boost feature of this iron, where you hold down one button and it temporarily increases the temperature. This was the only iron on test that did this feature well (the Pinecil also has it, but on that iron, the button is in too awkward a place for it to be easy to use).

Overall, this is a reasonably nice soldering iron to use, but unless you have a specific reason for requiring the power flexibility this iron provides (such as wanting to run off a USB PD battery), we'd still recommend an iron with a fixed power lead. →

ANTEX M12

PRICE £37.15 | WATTAGE 12 W | GROUNDED TIP Yes

This is very similar to the Antex SX25, but scaled back for more delicate work. Like the XS25, it's a thermally balanced iron on which you can't adjust the temperature. It also has a copper tip that helps keep the temperature stable when soldering, though it's not as large as on the XS25. This is designed for smaller soldering and surface-mount work.

It's a solid workhorse iron, provided you do only want to use it for its intended purpose – it doesn't cope particularly well when soldering larger things. That said, it would make an excellent companion to the XS25 – use the bigger iron for larger soldering and the M12 for smaller work. However, this is really only a good solution if you already have a larger iron as, for the price of two, you could get a very good soldering station that can handle both large and small soldering well.

The XS25's baby brother is more suited to smaller jobs

> "It would make an excellent companion to the XS25"

UNBRANDED FROM EBAY

PRICE £13.99 | WATTAGE 80 W | GROUNDED TIP No

On paper, it should be a great iron. There's adjustable temperature which is easy to use and works well. It's got a lot of power, and there's a wide range of tips available. Everything is packed into a medium-sized handle that's quite comfortable to use, though the cable is quite stiff. In our tests, this iron worked well. There are some complaints we could have – the temperature stability isn't as good as many irons – but, taking into account the price and performance of this iron, they're not significant.

It's surprising to us that this iron isn't grounded. Unlike the USB-powered irons, there's no reason this shouldn't be. It's got a ground pin on the plug that could quite easily be wired up to the tip.

Our biggest issue with this soldering iron is the build quality. The tip is prone to coming loose when soldering. We've been using very similar soldering irons for years and have had unfortunate experiences with them. We've had buttons fall off and tips that disintegrate very quickly.

This, really, is the issue with buying unbranded items. Will it last? What are other people's experiences with it? Is it even the same iron that other people have tested, or completely different electronics crammed inside a similar case? We can't even tell you whether or not this iron is available or how to buy it other than 'look for something that looks the same'. Soldering irons should, and often do, last a very long time, and we're not convinced that this one will.

There's no branded soldering iron that can come close in terms of price and features, but if you have to replace it after a year, is it really good value?

OUR VERDICT

Overall, we were really impressed with the soldering irons on offer. Once we got past the very cheapest available, there were none that didn't work. Honestly, none of them were that bad, and really we were picking favourites more than anything.

We're not going to pick a winner, because the best iron depends on the person who will be using it. We will pick out a few that we think you should look at:

ANTEX XS25 This is a great 'just works' iron. There are no buttons or anything else on it. Just plug it in and wait (a little while) for it to heat up and go. The tip style is a bit unusual, but holds a lot of heat and delivers it quickly. Really 'punchy'. We also liked the style of 'rounded hoof' tip that isn't available on many irons.

TS101 There's a bit of a trend for USB-C soldering irons at the moment. While we do have our reservations about them, they can be a good option for some people. The TS101 fits comfortably in the hand and has easy-to-use buttons.

RS PRO If you're looking for a soldering station, this is a great choice. Because most of the control is in a box, the iron is small and delicate. Very similar models come from a few different manufacturers, including some that have digital controls rather than twisty knobs. We like twisty knobs, but if you prefer preset temperature buttons, then choose accordingly.

DURATOOL If you're looking for a budget iron, this is a great option. It's easy to use, comfortable in the hand, and solid. It struggled a bit with smaller surface-mount work, but that's a bit more specialist. □

HOW I MADE

By **Jo Hinchliffe**

AIR POWERED ROCKET LAUNCHER

There are lots of ways to launch rockets into the air. Most obviously, with a combustible engine but, here, we're going to look at a different method: compressed air.

We've kept in mind various safety considerations where we can. That said, there is some inherent risk. Make your own sensible judgements and don't put others in danger. Only attempt to recreate this project if your skill level and materials allow you to do it within your own risk tolerance.

Lots of these DIY cannon-type projects have historically used PVC waste pipe fittings, with many a recipe online referring to 'schedule 40' piping. This isn't a term that's used in the UK to describe pipes, but we were heartened to see, on a visit to our local DIY centre, that many of the waste pipe products in the UK are now manufactured from ABS rather than PVC. While this doesn't instantly make them impervious to pressure, ABS does seem safer in terms of toughness and how it fractures when compared to how PVC splinters.

What I used

- Length of 32 mm ABS solvent weld waste pipe
- Length of 21.5 mm ABS solvent weld waste pipe
- 2 × 32 mm ABS solvent weld coupler tubes
- 32 mm to 21.5 mm ABS reducer
- 32 mm ABS threaded inspection closure
- 21.5 mm ABS solvent weld 90-degree section
- 2 × 21.5 mm to ¾" BSP adaptor
- Brass ball valve male-to-male ¾" BSP
- Thread-on Schrader tyre valve
- PTFE tape
- Electrical tape and glue
- Sticky tack
- Card stock

Figure 1 ↑
Using pipe cement to solvent weld a coupler and inspection cap onto the end of our 32 mm pipe

The principle of the air launcher is there is a reservoir side of the system that has air pumped into it to build the pressure. This pressure is contained in the reservoir until a valve is released, allowing the pressurised air to be pushed out through the system. The rocket is then sat on top of a pipe on the low-pressure side of the system.

To build the high-pressure reservoir side of our system, we used a length of 32 mm waste pipe and some plumbing accessories. It's important that all the accessories are 'solvent weld'-style and are designed to be cemented together rather than 'push-fit', which use a simple pressure and gasket/seal system to clip together. The later push-fit-type components wouldn't be able to hold any useful amount of pressure. We cut a length of the 32 mm waste pipe to 75 cm using a hacksaw, taking care to keep the ends of the pipe as square as possible. There are special tools available that you may have in your toolbox for cutting plastic plumbing pipes and would give more perfect pipe ends, but a reasonably close to square cut will suffice.

At one end of the cut tube we fitted an accessory coupler, which allowed us to then glue into place the inspection-style threaded end cap (**Figure 1**). This is a pipe-closing accessory that has a threaded cap, allowing the pipe to be terminated but with the option of opening it if needed. The cap is sealed with a large rubber gasket inside and has worked well with an input valve placed through it. For our valve, we have used a threaded Schrader valve, the kind of which are used in bicycle and car tyres (**Figure 2**, overleaf). You can find the threaded versions online which have a flanged base, an inside and an outside seal, and a threaded shaft and nut. Drilling an 8 mm diameter hole through the inspection cap, we can insert the valve with a seal →

STAY SAFE!

The risk with this – or any pressurised system – is that if it starts to crack, it can suddenly explode. As a maker, it's up to you to understand and mitigate this risk to a level you feel comfortable with. The first thing you can do is keep the pressure manageable, and this means using a pump with a pressure gauge. Stay under 2 bar (30 PSI) – that's about most bike tyre levels. Secondly, make sure you're wearing appropriate protective equipment. At a minimum, that should be suitable eye protection. If you're handling it while pressurised (which we don't recommend), wear gloves as well.

The further you can be from the pressurised system, the safer you are, so any onlookers should stay back (especially younger makers). The person charging and firing the system should stay as far away as possible – for example, using a pump with a long hose gives you more protection than having to stand right next to it.

Finally, an extra protective layer around the high-pressure side provides even more safety. This can be a wrapping of PVC tape or (even better) a heavy blanket. It's impossible to make this project completely risk-free. It's up to you to decide how it fits with your own risk tolerance.

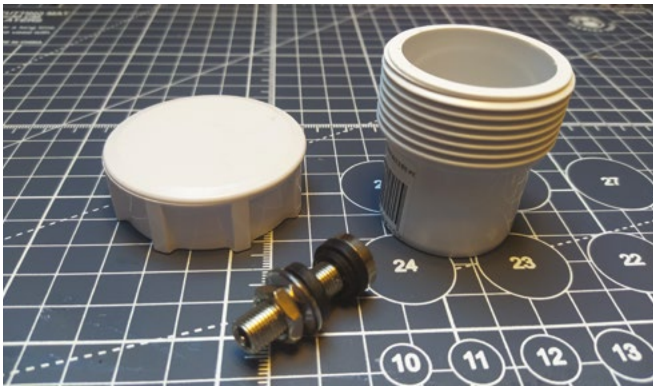


Figure 2 ↑
A threaded Schrader-style valve with rubber seals

each side and tighten the nut down. This creates a great seal. We can then, in turn, thread on the inspection cap to form that end of the reservoir.

At the other end of the high-pressure reservoir, we needed to step the 'tank' down to the 21.5 mm diameter pipe size which connects to our release valve. Simple solvent weld reducers are available, which again require an accessory coupler attaching to the 32 mm tube into which they are inserted. Once the reducer was in place, we cut a short length of 21.5 mm waste pipe to connect our reducer to the 21.5 mm to ¾" BSP threaded component. The component we used for this is slightly less common and not stocked in general DIY shops, but they are widely available online. We ordered a pair of them from **hsmag.cc/SolventWeld**.

"WE NEEDED TO STEP THE 'TANK' DOWN"

We should say that we bought these components to match the ¾" BSP brass ball valve that we had decided to use for this build. We wanted the valve throat of the release valve to be a similar diameter to the 21.5 mm tube; however, you may find another valve with a different threading which would suit, but ensure you can find a way to connect it into the system, though. With the 21.5 mm to ¾" BSP plastic adaptor cemented onto our small section of 21.5 mm pipe, we could then connect the brass ball valve (**Figure 3**). We'd explored some cheap solenoid valves considering we could make a decoupled launch system that could be operated remotely with a battery and a switch; however, we found that these valves, primarily made for water/liquid systems, would leak air and therefore weren't suitable. On assembling the plastic threaded connector onto the brass valve, we realised that, mechanically, this was the weakest point, and the plastic threaded section was slightly prone to leaking air. To rectify the leaks, we sealed the thread using some PTFE tape. After assembling the system and checking it, we opted to use some cement in the threaded cap to seal it into place, adding a little mechanical reinforcement.

We did exactly the same for the plastic threaded adaptor on the other side of the valve: sealing with tape and reinforcing with cement. These were the last parts that we cemented. We realised that the lower pressure/output side of the system didn't really need to be cemented together as the tubes are only really guiding the fast flow of released air. This provides a couple of advantages, one is that you can remove the output side, making the system smaller to transport, and also, you can experiment with different configurations and launch angles.

To make a rocket, we definitely encourage experimentation! We're sharing what we did, but feel free to try lots of different ideas. One of the most crucial factors for a successful rocket launch is that the tube that forms the rocket body is not too tight or too loose when slipped over the launcher's 'barrel'. Our rocket tubes are made by rolling card around a mandrel or form, with this being made from a length of 21.5 mm waste pipe, but with one strip of thin tape added to slightly increase the diameter of the mandrel. This seems to work well to get a good sliding-fit tube to base your rocket around. If your resulting rocket doesn't launch and rather the compressed air hisses out slowly, it's highly likely that your rocket is not a good fit – either too tight or too loose on the launcher.

For most of our rocket experiments, we've used around a 75 mm strip of card stock cut across the width of a portrait piece of A4 card. We found that this wraps around the mandrel with around 5 mm of

QUICK TIP

We've kept in mind various safety considerations where we can. That said, this is very much a 'do this at your own risk' project. Make your own sensible judgements, and don't put others at risk!

Figure 3 ↑
The reducer, 21.5mm to ¾" BSP couplers, and the brass ball valve installed

tab crossed over for gluing. Our technique is to pre-roll the card a little around the mandrel to get it to curve. Then, we wrap it tightly around the mandrel – don't worry too much if it's straight or twisted. Holding it in place with one hand, we then place around five rubber bands over the card on the mandrel to hold it in place. Once held, you can twist the card a little until the overlapping ends are even and square, and the tube isn't twisted. Once in place, we tend to shift one rubber band off the cardboard and place a smear of PVA glue under the flap and press it back together. After holding this section for a few seconds, you can then replace the rubber band over it to keep it in place. Then, in turn, move along the tube, adjusting the rubber bands a little at a time, inserting glue, and re-clamping with the rubber bands. Eventually, when you get to the other end, the seam should be neatly glued and closed all the way along. Leave the tube on the mandrel for a few more minutes, but then remove the rubber bands and make sure that the tube can move up and down on the mandrel, checking that it hasn't been glued on, then leave it to dry for an hour or so (**Figure 4**, overleaf).

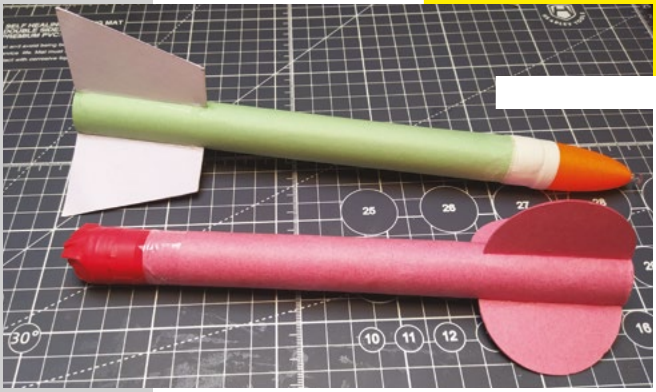
For simple sets of fins, we've found that cutting six fins of the same shape out of the same thin card stock as the body tube, and then laminating them together in pairs to form three fins, seems to make a tough enough setup. As for fin design, again, we'd urge you to experiment. We've hand-cut fins that are around 6 cm tall, with 2 cm on the leading edge and 4 cm on the trailing edge – these worked well. We've also got fancy and used our vinyl cutter to cut semicircular fins from card stock (we looked at cutting card with vinyl cutters in issues 58 and 59).

In larger, more accurate rocketry, people use all manner of fin guides and jigs to accurately place fins on a rocket body tube to ensure they are straight and true. For these air rockets, however, it's OK to hand-place them and judge by eye. One good tip for gluing on the fins is to place a drop of quick-drying superglue at either end of the fin and then put PVA glue along the middle section. This means that you →

GETTING STUCK

All of the permanent joints that aren't threaded together in our build are cemented using pipe cement to solvent weld the parts together. Solvent cement is widely available and reasonably priced and is often sold alongside waste pipe products in DIY shops or plumbing suppliers. It creates a very secure joint very quickly. You simply apply a generous layer, 1–2mm thick, on both mating surfaces and let them stand for around ten seconds before pushing them together. You'll tend to squeeze out some glue as the joint is pushed together, so it's handy to have some paper towels to hand to wipe off the excess. The joints are strong enough to handle after a few minutes, but not fully cured for a few more hours. Being cautious, we left our system for a day for everything to fully cure before testing it with any pressure.

Below ↓
Making rockets to launch is simple, quick, and cheap



FEATURE

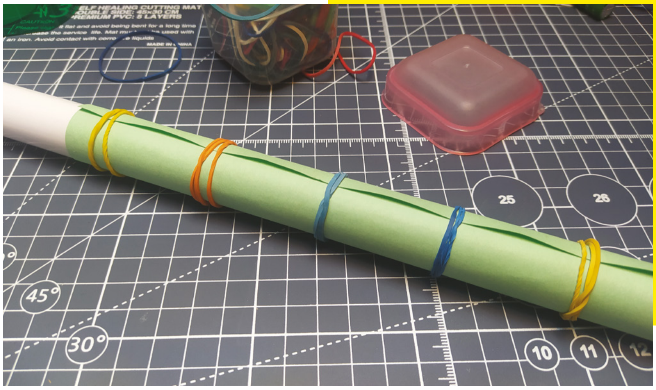


Figure 4
Using a section of 21.5 mm pipe, with a strip of tape added, to create a good-fitting rocket tube

can hold the fin in place for around 30 seconds – the superglue will 'weld' the fin in place, drying quickly, and then you can leave it unclamped for an hour or two while the PVA dries. It's worth adding glue fillets to the fins where they join the body tube. After the initial glue has dried, add more glue on either side of the fin, building up a couple of layers to add strength.

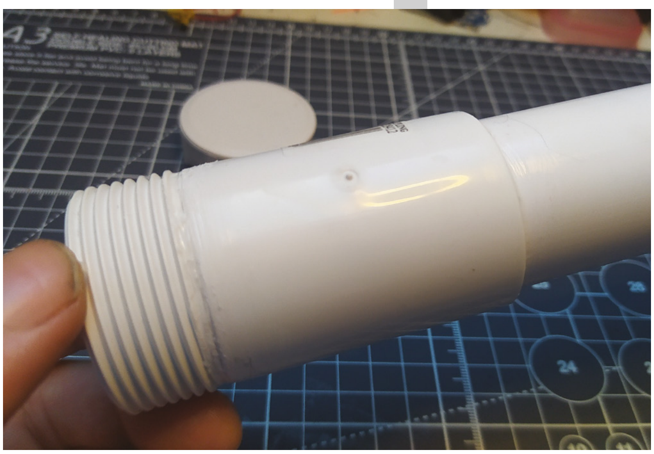
You'll need to add some nose weight to enable your rocket to fly well. You will also need to seal the end of the rocket so that the compressed air doesn't leak out. A simple but effective way to do this is to begin by adding a layer of tape around the upper end of the rocket and folding it into the inside of the rocket to make a little surface. We've then added about 5–7 grams of sticky tack in a ball pressed into that little tape shelf. Next, add a little more tape around the tube and press it over onto the sticky tack. It might take a few layers, but you should get to a point where the tube doesn't leak any air when you blow into it from the fin end.

Before you run off and test-fly the rocket, think about the area you are in – is it too small, or are there any hazards? If you are doing this activity with young children, they tend to get very tempted to try and catch the rockets – you might want to discourage that as, although they are quite light, they do come in pretty fast and could cause a paper cut! Make sure you've read and understood the safety stuff in this article before having a go! We'd recommend that for the first few attempts, you put very little pressure in, just enough to hop the rocket off a couple of metres, and then increase the pressure for more spectacular results. We've found that, even sticking to our 2 bar limit, we can get flights that are really impressive to onlookers (**Figure 5**).

It's a great system, and the rockets are so quick and easy to make that it really does encourage experimentation. One experiment we wanted to try was

"YOU'LL NEED TO ADD SOME NOSE WEIGHT"

Above
Our air cannon rocket launcher and LED-tipped rocket are ready to launch!



Right
Adding tape to allow you to press in some sticky tack to add weight before covering with more tape

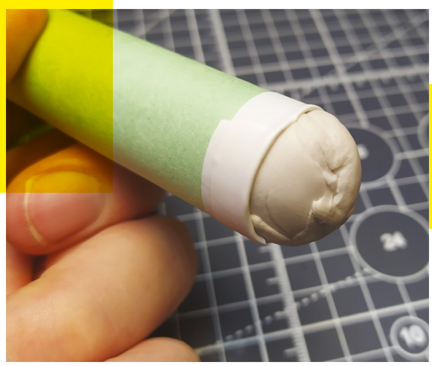


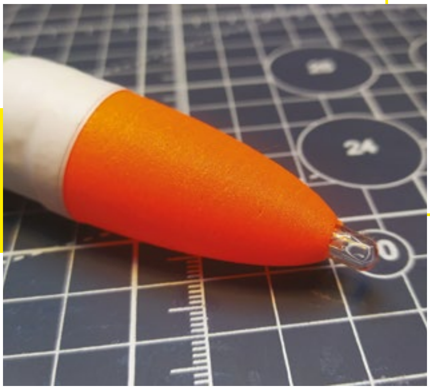
Figure 5
Great fun can be had launching rockets with only a little pressure

incorporating a flashing LED into the rocket for some night launches. Whilst you could totally tape an LED and coin cell onto a rocket, we wanted to try a slightly neater solution!

We wanted to incorporate the LED into a nose cone to make the upper end of a rocket look a little neater, and for it to be nice and aerodynamic. We quickly modelled a nose cone in FreeCAD using the excellent Rocket workbench add-on. We've compiled all the FreeCAD tutorial series into a book, *FreeCAD for Makers*, which explains how to install additional workbenches and more – download a free copy here: **hsmag.cc/freecadbook**. Having modelled a nose cone, we then used the Part workbench to create a cylinder to cut the tip off the nose cone, which would eventually form the 5 mm hole when we 3D-printed the nose cone using Vase mode.

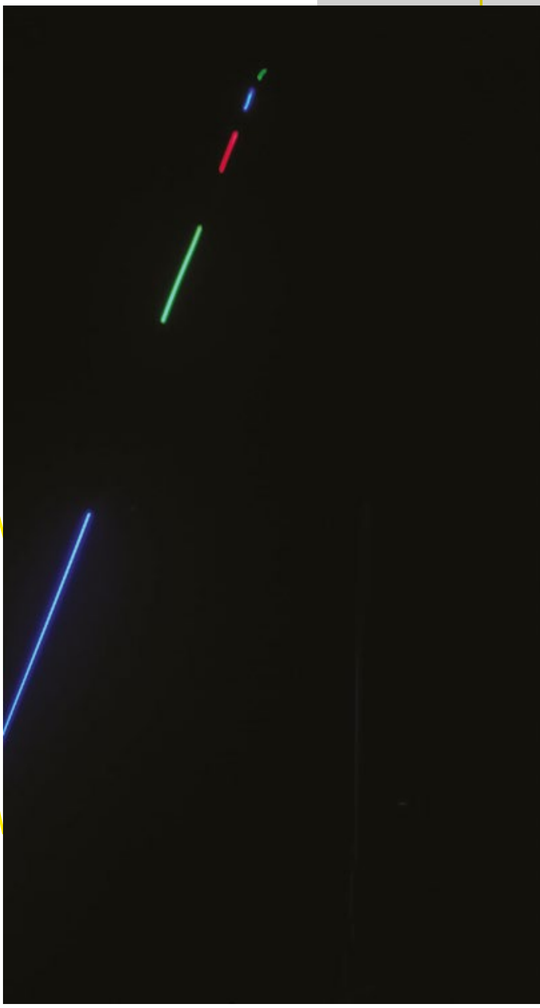
As the nose cone model had a base and the hole was closed, we used Prusa Slicer to set up Vase mode printing and told it to ignore the base and top layers. This means that the nose cone prints as a single wall and is open at both ends. We, again, have cut some corners to assemble the LED system, and it's a pretty quick experimental build. We inserted a fast-blinking RGB LED into the nose cone hole and splodged some hot glue behind it to seal it into position. The long LED component legs stick through into the interior of the nose cone, and you can insert a coin cell between the legs to power the LED. To keep the battery in place, we used a small amount of tape folded into a U-shape and pressed over the component legs and the battery and pressed together gently with a pair of pliers. We then back-filled around the battery with some sticky tack to help bring the nose cone up to weight and also to help seal the nose cone. Finally, we attached the nose cone using PVC tape, pulled and stretched tightly over the joint to try and stop any air leaks. The observant of you will note that there is no way to turn the LED on or off, so the battery and nose cone final assembly takes place just before launching!

The LED works really well as an effect, and also to track the rocket and recover it on landing. Launching over grass tends to help keep the nose cone intact, but if you do catch a stone, you can often bend and squash the assembly back into service. It's great fun trying to capture long-exposure images of the LED rocket. In our experiments, an exposure time of between two and four seconds seemed to work pretty well. It's great to look back at the rocket trajectory – you can make estimates of flight-time based on the images and the exposure time. □



Left
A simple nose cone with a fast-blinking LED glued into the tip for night flying

Below
A two-second exposure captured the night flight up to apogee quite well, showing the LED flashes on the way!



HackSpace magazine meets...

Matt Gray

If you can dream it, you can do it. Just don't bother with putting HP sauce in ice cream

Matt Gray is a TV and radio broadcast engineer, Game Boy enthusiast, artist, maker of unique things, enhancer of street furniture, and many other things. He's also a big fan of – to borrow Nike's phrase – just doing it. If you've ever thought of a cool idea, but left it on the shelf at the back of your mind because it's too hard/nobody else will like it, read on – Matt's a shining example of the hacker ethos that tells us to go ahead and make it ourselves.

He's online at **Mattg.co.uk**, or on all the social media as **@MattGrayYES**. He also exists in physical space, where he has been known to put baked beans in ice cream, sell beer from a moving hovercraft, and many, many more silly, wonderful things. →

Left Matt Gray, taking a rare break from broadcast engineering and building electronics

HackSpace Afternoon, Matt! You do a load of cool stuff. Where does it all come from?

Matt Gray The short answer to all of the random stuff is: you know when you're just chatting nonsense and someone comes up with a silly idea and you're like 'someone should make that'...

I have the advantage of doing the YouTube stuff, the making stuff on the side from my career. I work in a reasonably well-paid industry, so I do have some disposable income, and I like to spend that on making silly things, rather than on alcohol. And I've got loads of friends who are all enablers.

HS What is your day job?

MG I am a broadcast engineer, working in radio and TV. I do everything from building studios to training people how to use them, to making outside broadcasts. I was outside Buckingham Palace and Westminster Abbey for two weeks after the Queen died. I have been in Dubai and Hong Kong with the Capital Breakfast Show, and I've previously worked with Global, who own Capital, Heart, LBC, Smooth, Classic FM, and others. I managed their team of broadcast engineers in London.

I've always worked in the intersection of online video and radio and stuff, because I know video and online stuff.

HS So, all it takes is a little spark of an idea and you've got all the know-how to make a video and put it online. What led you to vandalise the Knightrider Court sign in London?

MG I was bored at home and remembered an idea I had before. I have a scatty, ADHD brain, so if a project takes too long, I'll forget it exists and it'll never get finished. So I have to rush to completion. So with this, I remembered it as an idea – I think The Hoff came up in conversation, which reminded me of the idea. And then I thought, right it's 6 pm. I could nip into central London, and have a look at the sign. The only thing stopping me from actually making anything right now is I have no idea how big that sign is. So, I went down with a tape measure.

I'd recently seen an article about a marketing campaign in which someone stuck LEDs all over Boston.

And the police there thought that it was a terrorist bomb thing. And I know what London's like, I know what security's like; I don't want to deface anything. So whatever I did, I knew it was going to have to be temporary. So from the beginning, I didn't want to leave something out there because electronics can explode when it gets wet. I don't want to leave lithium batteries all over the place. I don't want to be a nuisance, but I want to do it for the joke. I'd love to be able to leave it up there for a couple of months, but you need to get permission to do that properly.

> "It's such an easy thing to want to make, everyone's had a go at it, and there was no point me writing my own code"

So I went down there and measured it. I thought I could go down with a hard hat and high-vis to make me blend in. And I thought, 'No it won't. It's gonna be like 7 or 8 pm when I get there. No one's doing work in the street at that time of night.'

So, I just put a boring hat on and dressed like a normal person and, because it's London, no one will notice me.

So I measured the sign and, when I got home, I started 3D-modelling the sign so I could work out a way of clicking into it. I thought: 'It's on a wall. I can just stick it to a wall. It's only going to be there for 24 hours.'

I discarded hours of 3D design work when I realised that all I needed were some flashy LEDs, something to put them in, and a box to put the battery and microcontroller in.

I'd recently tidied up all of my electronic stuff and I knew I had an Adafruit GEMMA AT Tiny. It's at least five years old, tiny, cheap, they don't even make it any more.

And I harvested that from a project where I had made some flashing LED shoes that had got a bit too trodden and it all fell apart.

I Googled for someone's Larson scanner code [named after Glen A Larson, who produced the *Battlestar Galactica* and *Knight Rider* TV series, and who came up with the red scanning light effect].

It's such an easy thing to want to make, everyone's had a go at it, and there was no point in me writing my own code. I found one that just happened to be in an Adafruit tutorial for something else.

I measured how much current it was going to take. I've got a degree in electronic engineering, not that I can remember most of it, but I do know that the lower the current the thing uses, the longer the battery lasts.

So I measured how much current it was using. My little USB battery that I've got is worth about 3000 milliamp hours. The Larson scanner was drawing about 50 milliamps, so I worked out that it could run for about 60 hours, in ideal conditions.

I remembered if you're installing LED lights in, for example, a rich person's kitchen or a commercial installation in a bar that wants to look pretty, you've got these aluminium profile channels, which are just a bit of aluminium extrusion that is designed to take an LED strip, and has a plastic diffuser over the top of it to make the lights not look like pinpoints. I found one at Screwfix for seven quid.

I 3D-printed a box to hold the battery and the microcontroller, designed so that it would slide into that profile and kind of dangle off it.

If it was going to be there for any longer, I'd have put solar power on it and made it look prettier, but this was going to be there for twelve hours, stuck to the wall. Also, →

Above Matt could, potentially, make this permanent, but it would involve London Parish Council, so he probably won't when it's night-time, you can't see the box – you just see the flashing lights. And anyway, if I'd put more effort into it, then it would have taken longer and I'd never have finished it.

HS Done is better than perfect. I like it.

MG Just before I set off, I tested it. It worked for about 30 seconds and then turned itself off. The problem was that USB batteries are designed to charge a phone or something like that. The lights I'd made are so low-power that, for the battery, it was effectively off.

I had given myself ten minutes before I had to leave, and I had to work out how to make this use way more power so that the battery didn't turn off. So, I expanded the animation from being five LEDs to about 15 going back and forth. I needed to make it use over 100 milliamps, so I made it use 120.

HS Did anyone notice you putting it up?

MG It was a Saturday night, and the area around St Paul's isn't particularly touristy at night, because there aren't any bars or anything. One person did go by looking at it. And they walked up even further down the road and I heard them in the distance going, 'Oh, Knight Rider, I get it!'

The next morning, my friend, who was there with me, happened to need to go in that direction, and she saw people taking photos of it. I went back later on to replace the battery, because I'd made it use more power, and I sat in a café watching people walking past it, looking up and smiling.

HS Speaking of things that make people smile, I loved the pub in a hovercraft that you built. How did that come about?

MG That was for a video I made with Tom Scott [science/engineering broadcaster who goes to cool places and explains cool things].

So our mutual friend, Jonty Wareing, spotted something odd about the licensing for alcohol rules in the UK: you do not need a licence to sell alcohol if you are on a moving train, a plane, a boat, or a hovercraft. The boring reason behind that is alcohol licences are done by councils. So if you want to have a beer on your train, you'd have to get a million licences. And hovercraft are on that list because there used to be lots of hovercraft services across the channel and between Portsmouth and the Isle of Wight.

So we worked out that we wanted to serve beer and spirits – the two main things people buy in a pub.

For beer, it is funnier if it has a proper pump handle. If you see one of those, you think 'pub'.

The problem with the hovercraft we were using is that they're not exactly designed for multiple occupancy, or having a table, or doing anything other than driving it.

> "A lot of the things I've made are just a thing that I realised that I want, but it doesn't exist so I make it"

The hovercraft captain had a plank of wood at home, which he cut to be the right width to fit over the hovercraft, and came up with a way of attaching it using ratchet straps (it's made out of fibreglass, and it's not like we're going to drill into some bloke's hovercraft and ruin it).

So, he fashioned a wooden table and then, from that, we can attach everything to it – if you're going to be going around corners really fast, you need something to screw things onto.

On one side of Tom, we had a box with spirits and mixers in it. And on the other side was the beer. A hovercraft does actually kind of fly, so it needs to have its weight reasonably centred. As soon as it's leaning left, it wants to turn; a lot of driving a hovercraft is that you lean into the corner in the way you want to go, kind of like a plane flies round. If we hadn't weighted everything properly, it would be flying at an angle.

And then on top of that, we needed some other pub staples, so I got one of those big sheets of pork scratchings and attached that to the side of it. Tom had a contactless card reader.

And seeing as it was quite a small hovercraft, anyone coming up and getting beer on the hovercraft would be running alongside it, because the licensing law says that the hovercraft has to be on a journey. I still have the little chalkboard menu that we made with the price of the beverages.

HS Now that you're freelance, does that mean that you have more time for projects?

MG I have more energy for it. A lot of the things I've made are just a thing that I realised that I want, but it doesn't exist so I make it, or it's a stupid idea that's arisen from conversations with friends.

A good example is that I made a Wi-Fi adapter for my Game Boy Camera. I have had mine ever since it came out, and it is still my favourite digital camera. But, because it's from the 1990s, it's not designed for getting the photos off it onto a computer.

I found out that there's a big homebrew Game Boy development scene where people are still making games and programs and chiptune music on original 1990s Game Boys. Which means there are people who have made USB devices so you can plug your Game Boy cartridges into your computer. Using one of them, you can transfer your Game Boy Camera photos onto your computer, which is nice, but I want to be out and about taking a photo with it and I want to be able to get that on my phone and Instagram it or something. Short of taking a laptop and a USB dongle and everything with me, that's a bit of a faff. →

Above While it's in motion, this hovercraft is a perfectly legal place to buy alcohol

I thought, if I need a computer, the Raspberry Pi Zero is a computer, and the Raspberry Pi Zero W's got Wi-Fi in it. So maybe I could make a thing that just automatically takes the photos off the Game Boy and then shares it on a Wi-Fi network for you to get on your phone. And so I did: it's a thing I wanted, so I made it.

HS Is that a 3D print of your own teeth that I see on the shelf behind you?

MG One thing I learned many years ago is that any medical data about you, certainly in the UK and Europe, is yours. It's your data, you're entitled to it. So you can just ask for it. They use when you ask for it – I've had MRI scans and asked for the data and they go 'sorry, only a qualified person can analyse this. You can't diagnose yourself from it.' No, no, I want to do pretty things with it.

My dentist 3D-scanned my teeth, which as a clinical thing is very nice for him to be able to just point at bits of my mouth. I asked for digital files, and he sent them to me. And I was thinking 'what can I do with it?' When you've got 3D data of your body and a 3D printer, then the obvious thing to do is print it, but I needed a reason and that was around October. The teeth look bloody creepy when they're on their own – I thought I'd find out what they look like when they're in a pumpkin.

The hardest part of this was 3D-designing a pumpkin, because I've never done that before and I learned to use Blender.

HS Blimey. That's dedication.

MG That's the thing: I can't learn at all without a reason. I could follow a tutorial making a thing I don't care about, but if I don't care about it I would never finish it. It's the whole attention span thing: if I've got an end goal, I can learn how to do it. And I've got the audacity of trying to make a thing with no prior experience and just having a go and seeing how far I get.

And it comes back to what I said at the beginning: if you're having the thought, 'that's a cool idea, someone should do it', you've got to remember that you are someone, and you can be the one to make it. You might not know how to do it right this second, but there is nothing stopping you. There are so many resources on YouTube, of how to do a thing. You can combine different elements of it from different tutorials, or copying and pasting, and probably work something out yourself.

And the other thing is how do you find the time to do this kind of stuff? If you have time to sit doom-scrolling on Twitter, try and notice that and do something with it instead. If you have little ideas like this, write them down and come to them when you're bored, instead of watching *Love Island*. □

Right
Matt wanted a device that would add Wi-Fi capability to his Game Boy Camera, so he built one

Above You'll have to take our word for it that this space picture frame contains a Raspberry Pi Zero W

IN THE WORKSHOP: Tattered jacket

By Ben Everard

A new take on a traditional outfit

Above We went for leaves from a range of trees to increase the texture

An apple wassail is a tradition in the South West of England to bless an orchard. Like many things in the South West, the exact form of an apple wassail (wassail can also mean visiting houses, and singing songs for money or food in a manner similar to carol singing, but this is a completely separate tradition) varies a lot, and parts of it are lost to history.

I was asked to help revive this ancient tradition at a community orchard in Bristol, and as part of that, we had to decide how to marry the old and new. The wassail is led by someone representing the spirit of the orchard (which is thought to reside in the oldest tree in the orchard, although all the trees in this particular orchard are just two years old).

This person is often a morris dancer wearing a tattered jacket. I was tasked with recreating this. The tattered jacket is basically an old jacket adorned with strips ripped from old fabric. In times past, this was a cheap and effective way of making an outfit.

Personally, I believe that traditions have to constantly evolve or they die. Traditions aren't kept alive by simply mimicking the way they were performed in the past, but by understanding them and adapting the form to the current age, while keeping the spirit alive. With this in mind, what would a tattered jacket look like if made with modern tools and machinery?

I thought for a little while about the tools at my disposal. I considered using the technique of 3D-printing directly onto fabric, but this seemed a

Left A message left to the spirit of the apple trees

step too far. Instead, I decided to keep closer to the tradition of using scraps of fabric, but rather than simply tear strips as people used to do, I'd laser-cut them into the shape of leaves and sew them on. That seemed far more fitting for someone representing the spirit of the orchard.

I found a few leaf silhouette images online, and used Inkscape's trace bitmap tool to get an outline that could be laser-cut, then headed out to the local fabric store to see what scraps of green fabric I could get hold of.

Laser-cutting fabric works really well, especially fabric that has some polyester in it. The heat from the laser melts the polyester and seals the fabric so it doesn't fray. I got a few different shades of green and, very quickly, I had a pile of leaves ready to be sewn on.

Tradition dictates that outfits like this are made from old clothes, and it's one I'm happy to keep alive. The outfit will only be worn once a year, so there's no need to waste the Earth's resources on something new when I have a perfectly serviceable old Raspberry Pi hoodie with a broken zip. The final task was just sewing the leaves on. I opted to do this by hand because I haven't used a sewing machine in years and can't quite remember how to thread it up, and thought it'd be quicker to do it by hand than remember how to set up the machine. This might have been a mistake, because it took a long time to sew everything together.

I do also like to keep the old traditions alive

A TOAST

Traditionally, toast is hung in the tree, and we did this as well, but I also wanted to make something else to hang in the tree. Wassail poems are read out to encourage the tree, and I laser-cut an apple with a poem on it. Partly, this is so I didn't forget the poem I was reading out, but it also felt like something that could adorn the tree. Partly, this article might read like I just wanted to have a play with the laser cutter and was looking for any excuse. Perhaps there's some truth in that – I have been working on my laser cutter skills recently – but I do also like to keep the old traditions alive, even if that means modernising some parts of them.

After a savage summer of record-breaking heat and a cold winter, these apple trees need all the help they can get to bear fruit next year. Will a few laser-cut leaves help? I don't know, but it helped bring out the community to gather in a new green space for some cake and spiced apple juice, and that alone is a good thing. □

FEATURE

IN THE WORKSHOP: A guitar pickup

By Andrew Gregory

Music to our ears

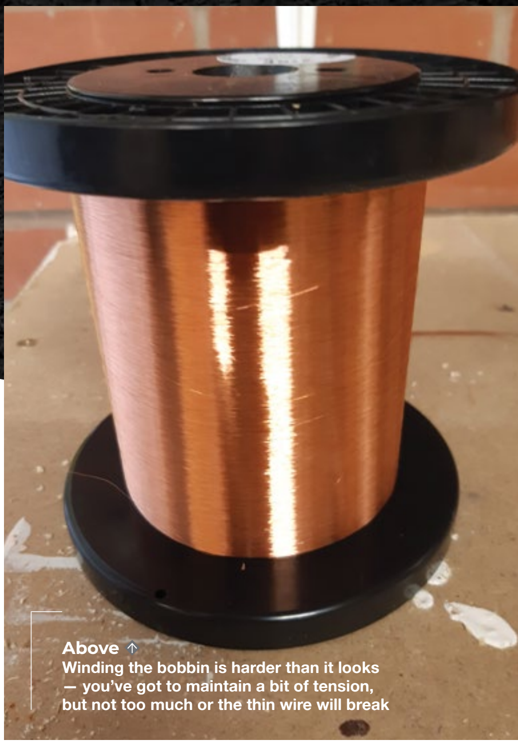
Above
We chose neodymium magnets, which are stronger than those used in the 1950s, and so will enable us to get away with using fewer turns of wire. Not this few though!

Electric guitars are simple at heart, but that simplicity, and the fact that they have been in existence more or less unchanged for 70-ish years, means that aficionados argue over their minutiae like Italians squabbling over pasta and tomato sauce. Every minor detail matters, and at the same time, it doesn't matter at all.

To keep things simple, we're going to make a single-coil pickup (as typically seen on a Fender Stratocaster), rather than a humbucker (which you'll find, again usually, on a Gibson Les Paul). A single-coil pickup is what it says it is: one long, continuous coil of wire, wrapped around one or more magnets that together pick up tiny fluctuations in electrical current when a guitar string is plucked nearby.

To give us room for error, we're making it a lot bigger than a standard Strat-sized pickup. We've copied our dimensions from the pickups on a Les Paul copy we have here, which measures 9 x 4.5 cm, including the plastic surround that mounts it to the guitar; we're using plywood because that's what we have, but you could use plastic, card, or anything that's easy to work with. We've drilled six holes, 1 cm apart, and pushed through six M6 bolts. Again, you could use nails, or smaller bolts – it doesn't matter as long as they're magnetic, so aluminium won't do.

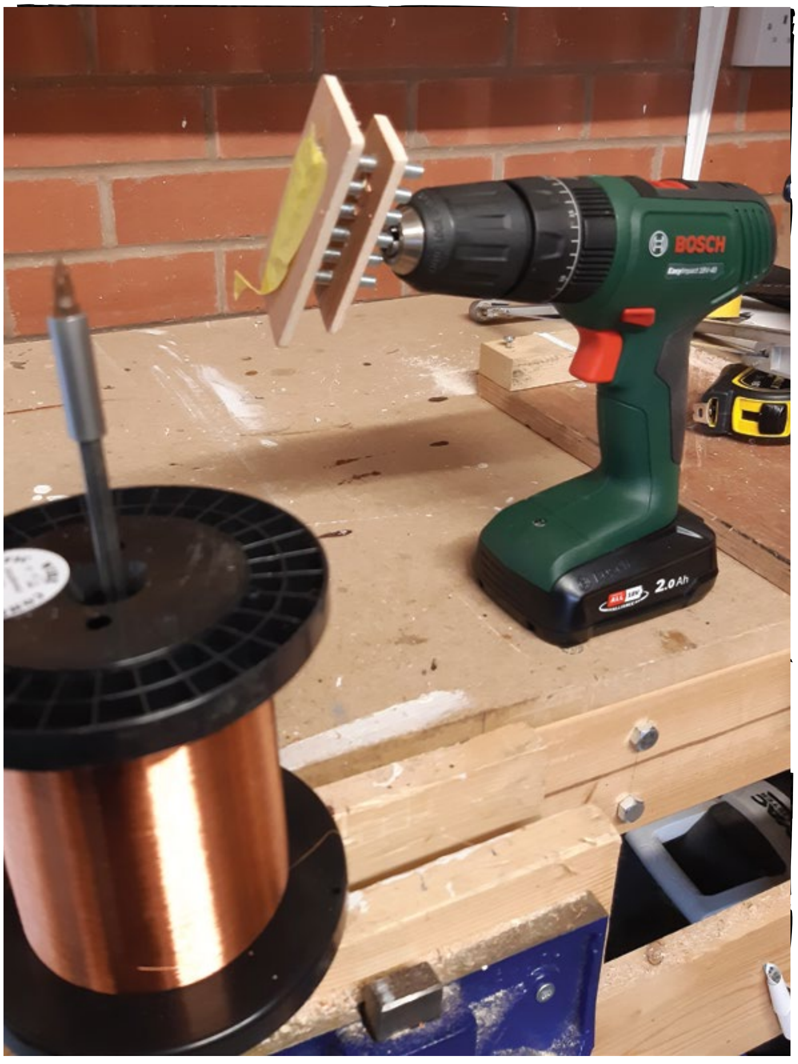
An identically drilled, slightly smaller piece of plywood fits onto the end of the bolts, and we've pushed it down because this is going to end up inside



Above
Winding the bobbin is harder than it looks — you've got to maintain a bit of tension, but not too much or the thin wire will break

Guitar pickups use very thin enamel wire

Below
More turns of wire gives you more resistance in the pickup, which in turn means you get more frequencies toward the middle of the harmonic range, and less of the top end



the pickup cavity of an existing guitar (we'll trim the bolts to length later, and glue magnets onto the ends to magnetise the bolts).

This is where we hit a snag. Guitar pickups use very thin enamel wire, wrapped many times around the structure that we've just made (it's called a bobbin, which will please anyone familiar with sewing terminology). The internet is full of brilliant solutions for winding pickups, but we thought we'd use an electric drill on its slowest possible speed setting. This is also why we haven't added the magnets, as we want the drill's chuck to be able to grip the threaded end of one of the bolts to spin the bobbin around.

Enamelled wire is typically sold by thickness, designated in American Wire Gauge (AWG). Pickups use wire between 41 and 44 gauge, so we plumped for 43 thickness and waited for it to arrive.

43 gauge wire is 0.056 mm thick. That's thinner than a human hair, so light you can't feel it on your skin, and so it's hard to see a single strand of it. So far, we've managed to wrap it around the bobbin 20 times before it snaps and we've had to undo our work and start again. That's nowhere near enough: the Gibson PAF (patent applied for) pickup invented in 1955 used two coils of 5000 windings each. We need to go back to the drawing board. □

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 58
LASER BOXES
Slice and dice your enclosures

PG 64
PICO W IOT
Why collect data if you're not going to make pretty graphs?

PG 68
GROW CRYSTALS
Turn household chemicals into beautiful objects

PG 72
RFID READER
Like contactless payment, only not contactless, and not payment

PG 56
SCHOOL OF MAKING
Start your journey to craftsmanship with these essential skills

56 Polypropylene printing

PG 78
DYEING PLASTIC
Colourful polymer creations

PG 82
ANALOGUE INPUT
Read voltages at precisely timed intervals

Printing with polypropylene

The filament has a bad reputation, but it doesn't have to be difficult to print

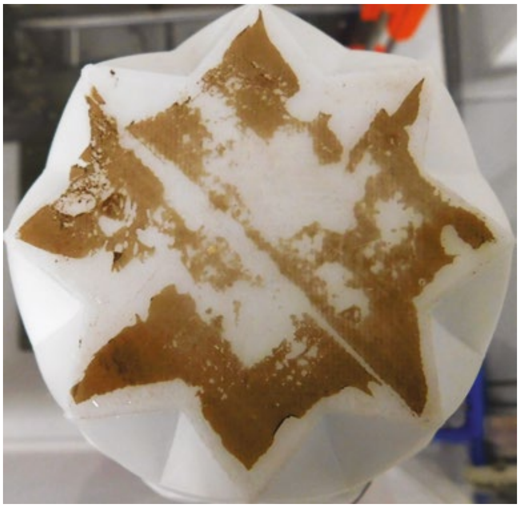
Ben Everard

@ben_everard

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

Polypropylene (or PP as it's known in the 3D printing world) has some excellent material properties. It's slightly flexible – so has excellent toughness. It's resistant to a wide range of chemicals. Prints can be watertight. However, it has one annoying flaw when it comes to 3D printing – polypropylene loves to stick to polypropylene, but it doesn't stick efficiently to anything else. Effectively printing polypropylene, then, is basically a process of finding a way to get it to stick to your print bed.

We tested out two methods: using packaging tape stuck to the print bed and using a painted-on primer. In both cases, we used Recreus's PP3D filament. We tested this out on a stock Prusa MK3S. The only modification is that it's in an enclosure because our workshop is unheated, and it's freezing here (this author is writing this wearing thermals, a T-shirt, a shirt, two jumpers, and a coat). It should print on just about any printer that can reach the printing temperature. We printed at 245 degrees and had great results.



Right Packaging tape helps PP filament stick to the bed, but it can leave a brown mess on the prints

Polypropylene has a reputation for being difficult to print, but we actually found working with it to be quite straightforward. We popped it in, used the recommended print settings, and it just worked. In all our testing, we only had one failed print, and that was where we hadn't covered enough of the bed with primer. The primer is a liquid that you paint onto the print bed and leave for a few minutes to dry. You can then print at a temperature of 45°C. The problem with polypropylene isn't just getting it to stick to the print bed, it's getting it to stop sticking to the print bed when you want it to. With the primer, you can heat it to 85°C and then it goes sort of goopy – you can then pry your print off. However, it still takes quite a bit of force, so delicate prints might be damaged by the process.

The primer lasts for two or three prints, and a new coat can be applied. If you want to print some other filament, you can clean the primer off with acetone. This does raise a slight issue, as not all print surfaces – particularly PEI (polyetherimide) surfaces – are safe for use with acetone. Prusa, for example, says that its textured surface will be damaged by acetone, but its smooth surface is OK as long as acetone isn't used very frequently. Recreus also recommends cleaning with Sanytol, but this isn't widely available in the UK, so we weren't able to test this out.

Above
There are many types of polypropylene filament, but this is the one we tested with

Packaging tape also worked very well. Again, the filament stuck to the tape incredibly well, and it was hard to remove. In fact, we found we needed a bit of sandpaper to fully remove the packaging tape from the print.

Conventional wisdom says that polypropylene is prone to warping, and may need a brim to help it stick properly to the print bed. We didn't have any issues with warping, but it's something to watch out for.

WHEN TO USE PP

Polypropylene fits into a midpoint between the common, more rigid plastics such as PLA and PETG, and fully flexible plastics like TPU. The prints bend quite a bit – particularly thin ones – without breaking.

> "One particularly useful feature of polypropylene is **that the layer adhesion is so good**"

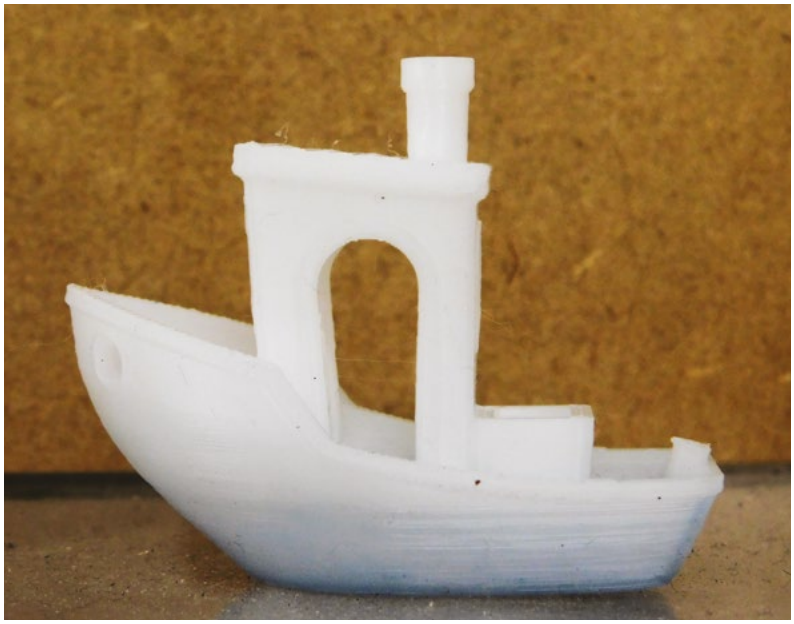
One particularly useful feature of polypropylene is that the layer adhesion is so good; prints can be fully waterproof straight off the print bed. Most filaments are almost (but not quite) waterproof and will leak drops through tiny cracks between layers.

We tested this by printing a vase in spiral vase mode – it held water without leaking for two days. We wouldn't really recommend this as a way of holding water because a vase full of water leaking everywhere isn't a pleasant experience, but if the risk of leaks is less catastrophic (say, for a plant pot or a project enclosure), then it could be a good option. You can make PLA (or other filament) prints waterproof by lining them with paint or some other sealant, but we don't know of another filament that can come off the print bed and be waterproof without treatment.

Some polypropylene filaments can be autoclaved, which would allow them to be used for fully sterile applications, but check with the specific filament you want to use, as not all are.

Since polypropylene has such strong layer adhesion, it could also be a good choice if you need parts that are strong in all three dimensions.

Overall, we found polypropylene easy to print despite its reputation, and we got great results. The parts are strong, slightly flexible, and look great. Bed preparation is a bit more of a hassle than with some, and it's not as environmentally friendly as PLA or a recycled filament, but it's a great addition to your 3D printer's armoury. ◻



Above
Overhangs and bridges printed almost perfectly

Left
We tested this single-skinned vase for two days, and it didn't leak at all

Laser-cut boxes

Create customised storage with an online generator

Ben Everard

@ben_everard

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

3D modelling is a tricky beast to learn. It's a useful maker skill, but it's one that takes time and effort to get right. Wouldn't it be much easier if someone created a tool to quickly and easily customise existing designs? Well, we have good news. The Boxes.py project does exactly this. You can choose from a huge range of existing designs, enter your own parameters, and get files that you can laser-cut.

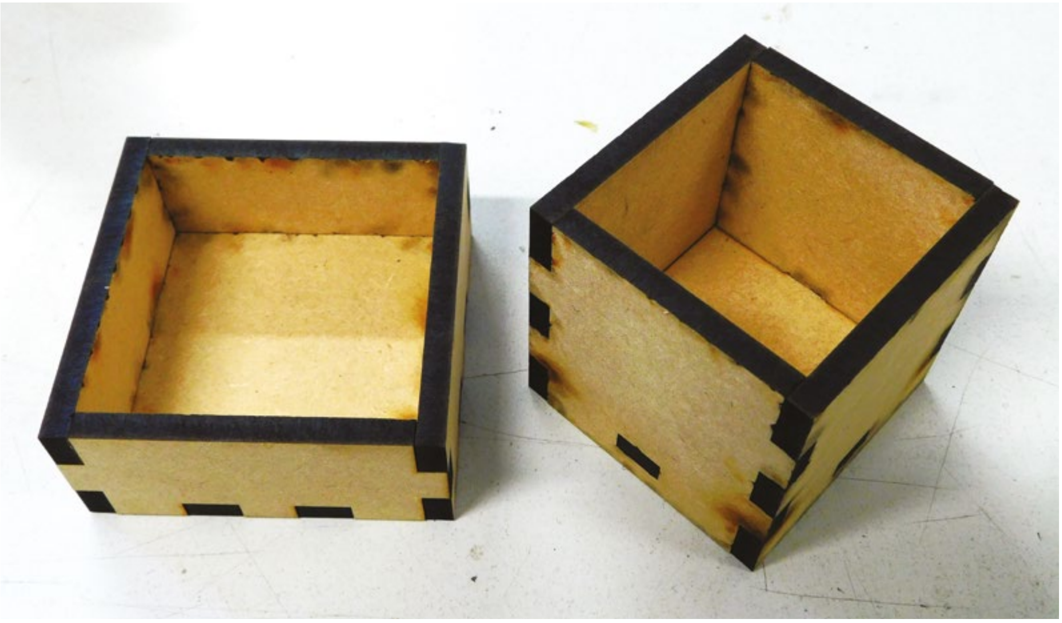
Before we start looking at the designs, we first need to get some calibration information for our cutter, specifically the kerf. This is the width of the cut that the laser makes. It varies from cutter to cutter, and even material to material.

In Boxes.py, the kerf is handled by the burn parameter, which is the distance from the edge that the laser will cut – in other words, the burn is half the width of the cut. Putting a larger value for burn will result in tighter fitting joints, and smaller values will give looser joints. This might sound counter-intuitive, but remember, the burn parameter doesn't control the kerf, it corrects for it. For some materials (such as wood), you might want very tight joints that hold together with just friction. For others, you might want slightly looser joints that leave some space for glue.

There's an included test to help you work out the burn parameter you need, which you can download from **hsmag.cc/burntest**.

You can leave all the settings at their defaults in most cases, though you might want to change the format depending on your laser cutter software. We usually use SVG or DXF, but use what works for you.

Cut out this test as you would any other laser-cut design, and try putting it together with the same



Right A lid is just a wider, shorter box turned upside down numbered edges against each other until you find the fit that you like. If none of them feel quite right, you can change the step and burn parameters to try a different range of sizes until you find settings that work for you.

Now we know the optimum value for the burn parameter, we can try our first box.

There are a lot of different box options, an almost bewildering range of box options when you first start. However, let's start in a simple place, the universal box. We're going to create a box that has a lid.

Head over to the universal box generator (**hsmag.cc/universalbox**) and enter the following, leaving the others as their defaults:

- **top_edge:** e Straight Edge
- **bottom_edge:** h Edge
- **x, y, h:** your sizes
- **thickness:** your material thickness
- **format:** the format you need
- **burn:** your calculated burn
- **lid:** flat

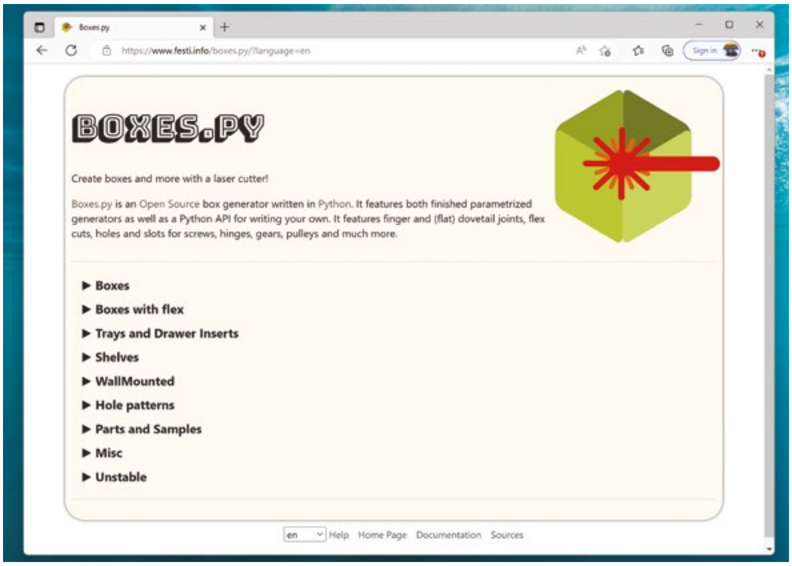
Whatever format you download it in, you should end up with a file with lines in three colours. The interior cuts are in blue, and these should be cut first. The exterior cuts are in grey, and these should be cut second, and the labels (if these are selected) are in red, and you don't need to cut or engrave these. We find it useful to include the labels in the download and design so that we have a reference as to which part is which, and simply turn off cutting for this colour; however, if you'd rather, you can deselect the checkbox to not include the labels in the file. Import the file into your laser cutting software, and cut it out.

Everything should fit together, though depending on how you set the burn parameter, you might need a bit of force. We printed ours to hold together without glue, and it needed a bit of tapping with a hammer to get everything in place.

The lid is made up of two squares, one internal and one external, and these need gluing together. You'll need to spread out some wood glue on the smaller square, then clamp it in place while it dries.

At the end of this, you should have a box with a lid.

> "If you cut thin strips into it, you can create **what's known as a 'living hinge' or flexure**"



Above
Boxes.py is the name of the software, not the web address

WIBBLE WOBBLE

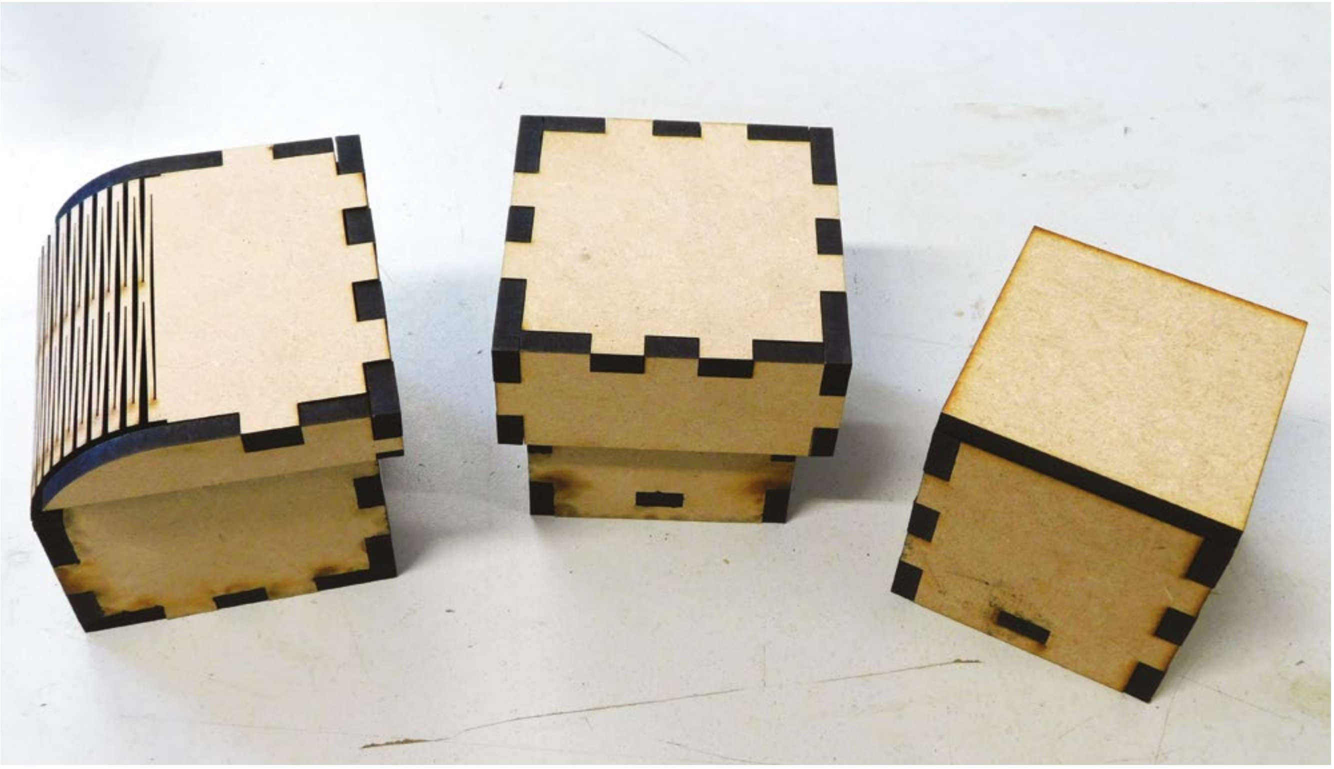
Let's take a look at another way of making a box with a lid, a flexbox. While sheets of engineered wood generally have a little flexibility (depending on their thickness), it's not usually enough to be useful. However, if you cut thin strips into it, you can create what's known as a 'living hinge' or flexure. These can be used in different ways, and there are a few different designs in Boxes.py that use them. The first thing, though, is to test out the material you have with a sample.

How well living hinges work depends entirely on the material you're cutting. Most engineered wood works well. Non-engineered wood is a bit prone to splitting, but can work as long as you don't need to bend it too many times. Acrylic doesn't work particularly well, but some other plastics might. In general, thinner materials work better than thicker ones. We did this test with 6.4 mm MDF and it worked fine.

There are a load of settings that you can tweak to alter the pattern that's cut to make the material flexible.

You can download the flex test from **hsmag.cc/flextest**. Unlike the burn test, this doesn't have multiple options in one file.

While the test pattern doesn't have any finger joints that are dependent on the thickness of the material, the flex parameters are given in proportions of the material thickness, so do make sure you enter this correctly. →

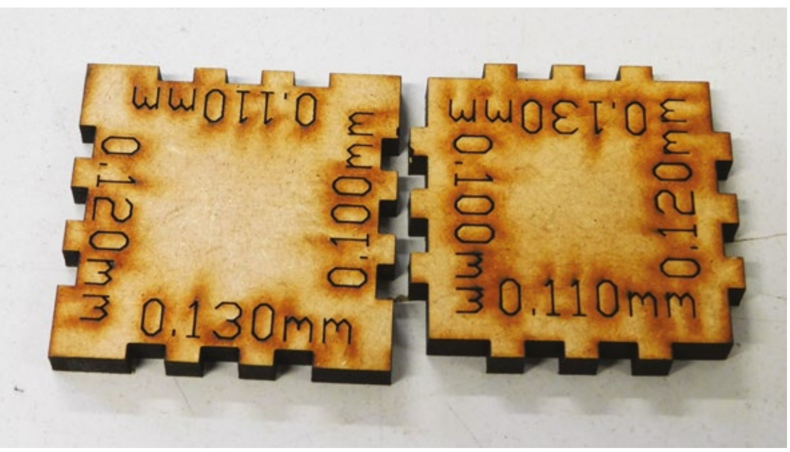


Above Three different styles of box

It might well be that the defaults for this are fine for your use. In our experience, the defaults work quite well for thinner material, but might need adjusting for thicker material. With 6.4 mm MDF, we adjusted the Settings For Flex > Distance parameter to 0.25.

Now we've experimented with the flex material, let's make a box. While there are lots of boxes that use living hinges, we're quite fond of the unglamorously named FlexBox3, which uses a living hinge to pivot the lid.

As well as the flex parameters you experimented with before, you can adjust the radius of the bend that the material will take. The default is 10 mm, which is a little tight. If your box is big enough to spare the space, we'd recommend increasing this. On our 100×100×100 mm box, we went with 30 mm, which is gentle and aesthetically pleasing. Again, you can download the files in any format you like and cut them as before.



Below Get the perfect fit with test cut

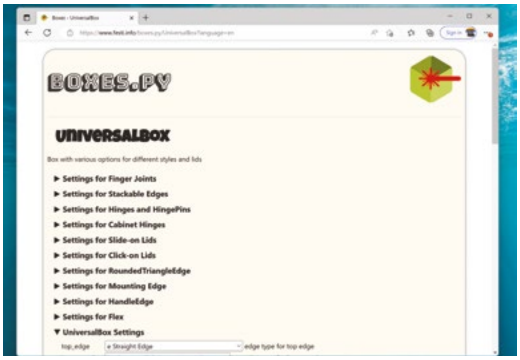
DOUBLE TROUBLE

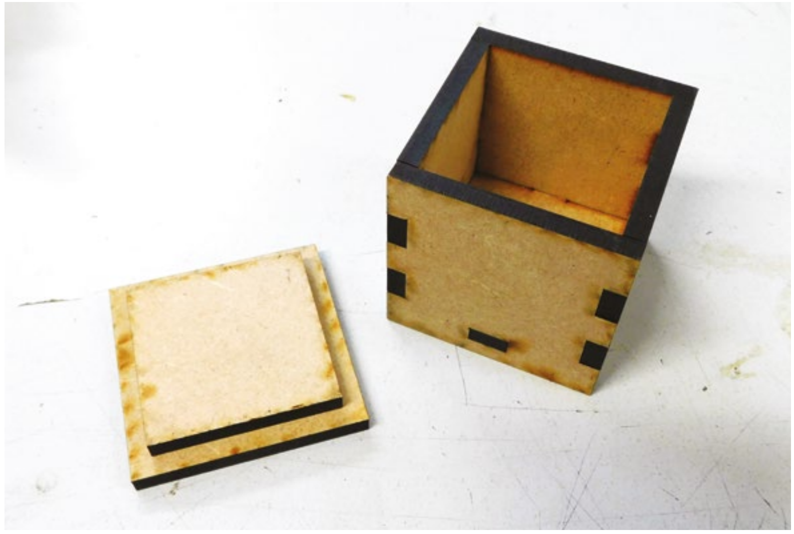
While Boxes.py does have a huge range of different boxes, as far as we can see, there's no simple box with what we would call a 'normal' lid. The sort of lid you'd find on a shoebox – that is a lid that's basically another box but slightly larger and a lot shorter that goes on top upside down. Fortunately, since this lid is essentially another box, you can create it using the universal box generator.

The first part of the box, you can make in the same way as our first box – in fact, you can use that if you like. To make the lid, you need to know the outside dimensions of the box. You could get this from the Boxes.py generator, but given that it needs to be quite accurate and it will depend a little on just how firmly you've pushed the joints together, we'd recommend actually measuring the box.

In the universal box generator, you can now create your lid-box with the following parameters:

- **top_edge:** e Straight Edge
- **bottom_edge:** f Edge
- **x, y:** the measured sizes of the main box plus 1 or 2 mm





Above A simple lid of two bits of MDF glued together

Left The universal box has a mind-boggling range of options, but you don't need to use them all

- **thickness:** your material thickness
- **format:** the format you need
- **burn:** your calculated burn
- **lid:** default (none)

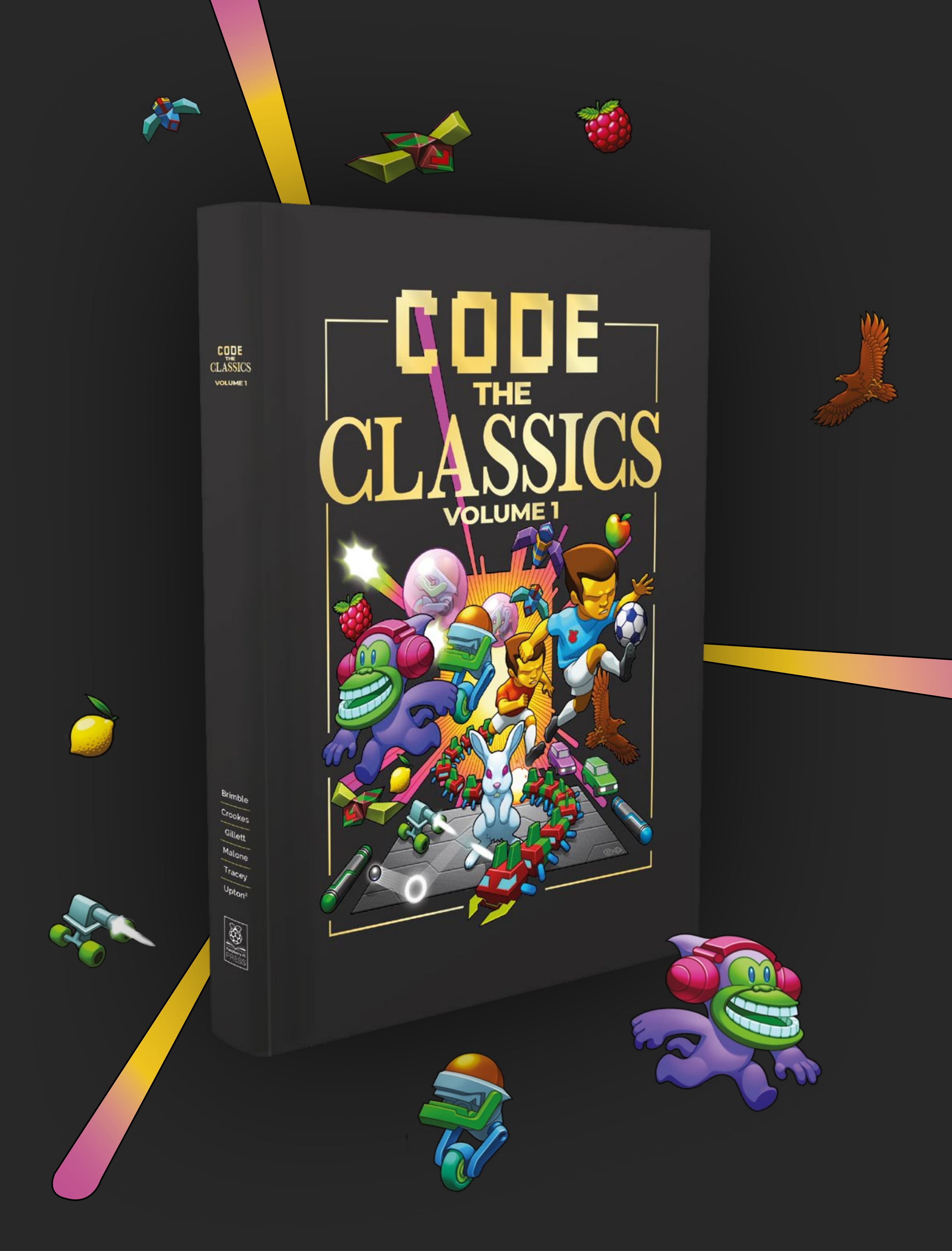
An important difference between this and the first box we made is the bottom edge. We used h-edges previously, which are stronger and better suited to the base. This is where the finger joint from the base pokes through a hole in the side. For this box, we've used an f-edge, which is where the bottom is flush with the bottom of the side. This isn't quite as strong, but the top of our box doesn't need to be very strong, so this should be fine.

You should now be able to download and cut this box, and it should fit snugly over the other box.

> "You should now be able to download and cut this box, **and it should fit snugly over the other box**"

We've looked at three examples of boxes you can make with Boxes.py, but there are loads more options available. Most of them have images to give you an idea of what's possible. Spending a little time clicking through the available options is time well spent, as you'll be able to pick the perfect enclosure for your next project.

Left We're always amazed by just how bendy MDF becomes


CODE
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CLASSICS
VOLUME 1
CODE THE CLASSICS
VOLUME 1
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Crookes
Gillett
Malone
Tracey
Upton²
PRESS

Part 03

Pico W IoT with Anvil: Plot sensor data

Store sensor data sent from Pico and plot graphs in an Anvil web app

MAKER

Phil King

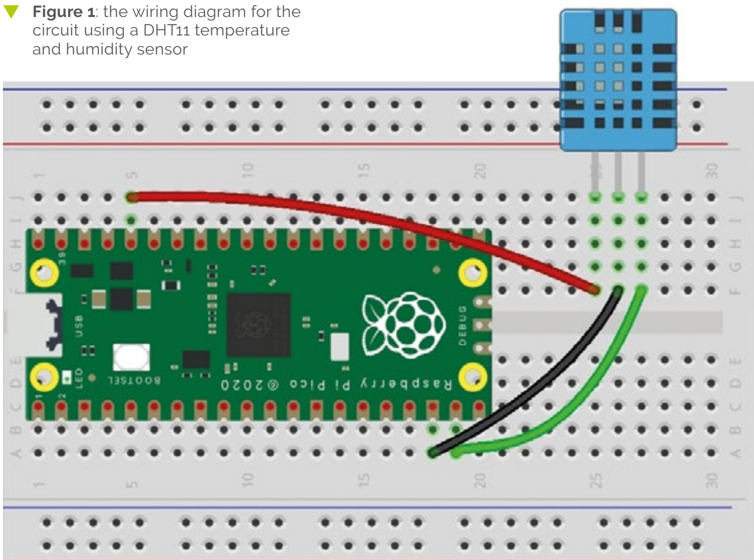
Long-time contributor to *The MagPi*, Phil is a freelance writer and editor with a focus on technology.

@philkingeditor

Anvil's Pico W IoT toolkit enables you to connect easily, and securely, to web apps you create. Using the Anvil UF2 firmware image, you can code programs on Pico W in MicroPython, with a few extra lines to connect to Anvil, then create a web app on the Anvil site which can send and receive data to/from your Pico W program.

Last issue, we sent DHT11 temperature and humidity sensor readings from Pico and displayed the readings in a web app dashboard. This time, we'll plot the data in graphs.

Figure 1: the wiring diagram for the circuit using a DHT11 temperature and humidity sensor



01 Install the firmware

If you already have a Pico W with the Anvil firmware installed and connected to your wireless network, you can skip the first two steps of this guide.

To link your Pico W to the Anvil framework, you'll need to use Anvil's special firmware file. Go to **magpi.cc/anviluf2** and download the latest 'complete' UF2 file. (If you want to avoid overwriting any existing files on Pico W, use the 'firmware-only' version.)

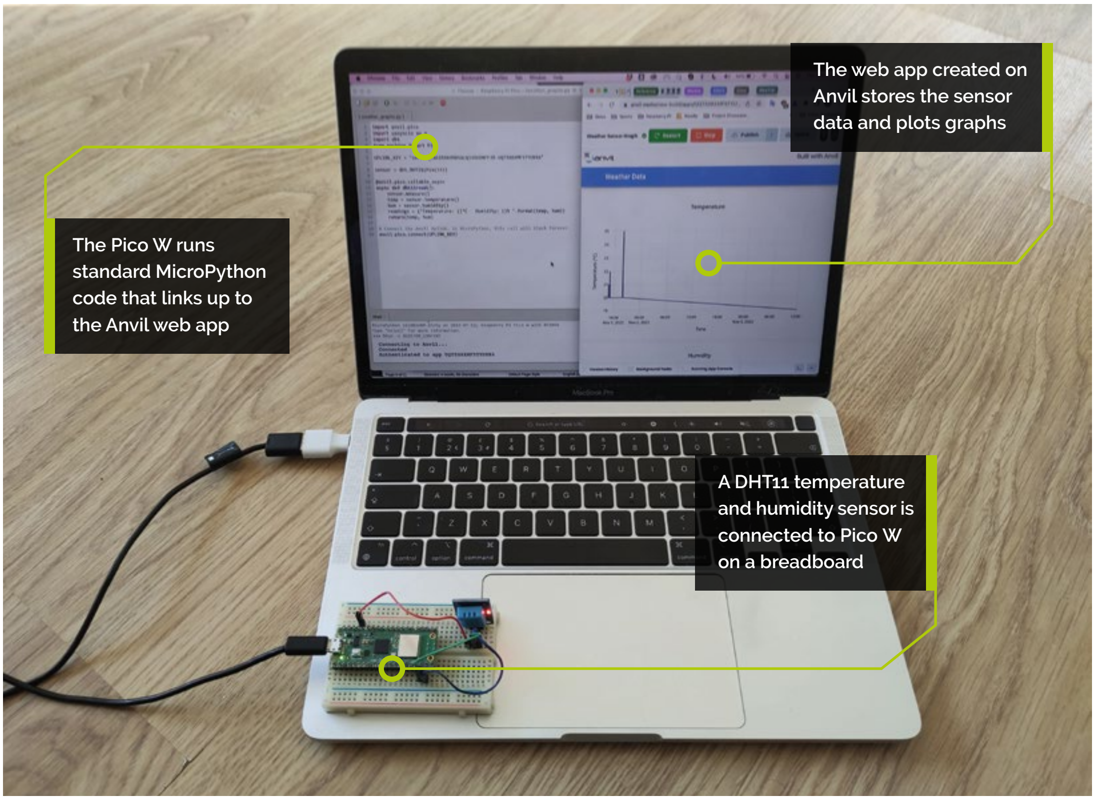
Hold Pico W's BOOTSEL button while connecting it to a computer via USB, then drag the UF2 file to the mounted 'RPI-RP2' volume. Once it's copied across, Pico W will automatically reboot and reappear as a volume called 'Pico W'.

02 Connect to Wi-Fi

With Pico W connected to your computer, open up the Thonny IDE and make sure the Python interpreter (shown at the bottom right) is set to 'MicroPython (Raspberry Pi Pico)'. The **main.py** file on Pico W will run automatically, so you will need to stop it by pressing the Stop icon. Open the **boot.py** file and enter your wireless router's SSID (name) and password at the top.

```
WIFI_SSID = "<put your network name here>"
WIFI_PASSWORD = "<put your wifi password here>"
```

Now when Pico W reboots, it'll automatically connect to your wireless network.



THE MAGPI

This tutorial is from in The MagPi, the official Raspberry Pi magazine. Each issue includes a huge variety of projects, tutorials, tips and tricks to help you get the most out of your Raspberry Pi. Find out more at **magpi.cc**

You'll Need

- Raspberry Pi Pico W
- Anvil account (free tier) **anvil.works**
- DHT11 sensor **magpi.cc/dht11**
- 3 × male-male jumper wires

03 Wire up the circuit

This is identical to the circuit we used in part two of this series. Place your Pico W on one end of a breadboard, as shown in **Figure 1**. With the power turned off, connect the DHT11 sensor to Pico W as in the diagram: power is supplied to its VCC by Pico W's 3V3 pin, GND is wired to GND, while the sensor's DOUT (digital out) pin is connected to GPIO 14 (you could use any GPIO pin).

04 Write the Pico code

Add the code from the **weather_graphs.py** listing and save it to Pico. Note that this is very similar to the code we used in part two of this series. Instead of sending a text string for the web app to display, however, we'll send the individual temperature and humidity readings with:

```
return(temp, hum)
```

As before, the `import anvil.pico` line enables Pico W to connect to Anvil's servers (using an uplink key for the web app), while `import uasyncio as a` sets up an asynchronous scheduler for running concurrent functions. Before defining our sensor-reading function, `dht11read`, we add a decorator line and an 'async' prefix to make it callable from the Anvil web app.

```
@anvil.pico.callable_async
async def dht11read():
```

05 Design the web app

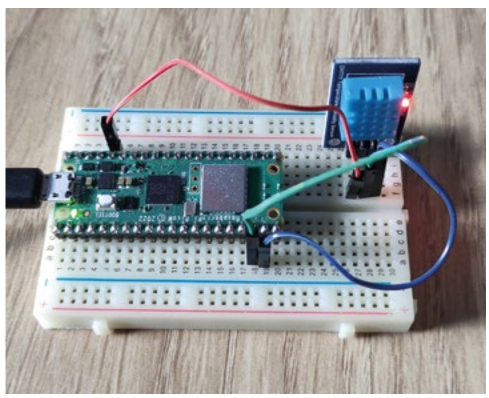
If you haven't done so already, visit **anvil.works** and sign up for a free account. Create a new blank app and select a theme – as previously, we're using the legacy Material Design.

Let's give our web app a title. From the right-hand Toolbox panel, drag a 'Display label – text' component over to the 'Drop title here' field at the top left of the blue bar in the main app panel. In the text field under Properties, enter 'Weather Data' or something similar.

06 Add two graphs

Next, we'll create two graphs: one for temperature, the other for humidity. Drag a Plot component from the Toolbox into the main app panel. Drag another one underneath it. Under Properties,

The DHT11 sensor measures both temperature and relative humidity



When the Pico W code is running, the web app graphs will be updated with live data

rename them 'plot_temp' and 'plot_hum'; the names will automatically have a 'self.' prefix added.

To add labels for the graphs and labels for their x and y axes, we'll need to add some code. Click on the Code tab and, under '# Any code you write here will run when the form opens', add the following code, making sure it's indented to the same level:

```
    self.plot_temp.layout.title =
'Temperature'
    self.plot_hum.layout.title = 'Humidity'
    self.plot_temp.layout.xaxis.title = 'Time'
    self.plot_hum.layout.xaxis.title = 'Time'
    self.plot_temp.layout.yaxis.title =
'Temperature (°C)'
    self.plot_hum.layout.yaxis.title =
'Humidity (%()'
```

If you try running the web app now, you'll see that the graphs have labels. Now stop it running.

Top Tip

Schema conflict

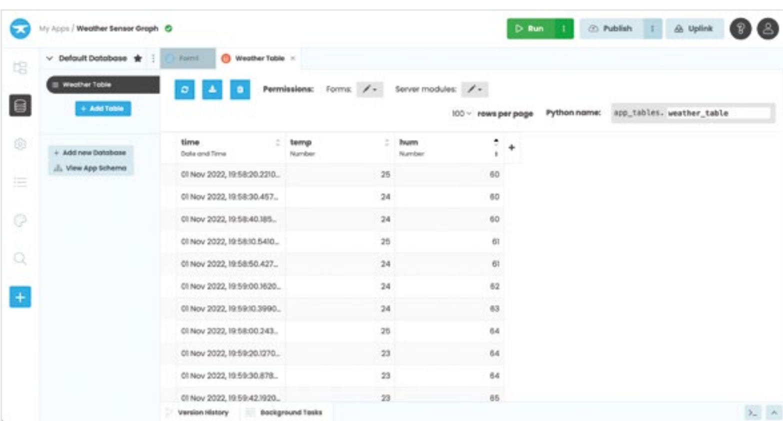
While editing your data table or app, you may see an error message saying that the default database schema doesn't match your app. Just click on the correct schema option to resolve it.

07 Create a data table

To plot data on our graphs, we will need to create a data table with three columns: for the date/time, temperature, and humidity. Select Data from the left sidebar and then '+ Add Table'. In the 'Python name' field on the right, change its name to 'weather_table'.

Click '+ New Column' and choose 'Data and time column'; we'll name it 'time'. Click the '+' button to the right of it and select 'Number column'; name it 'temp'. Click the '+' button to the right of that, select 'Number column' again, and name it 'hum'.

We now have our data table, into which we'll later write data sent from our DHT11 sensor connected to Pico. To make sure it can do that, set the table's 'Forms' Permissions to 'Can search, edit and delete' – otherwise you'll get a 'permission denied' error when running the web app.



You'll need to create a data table in Anvil to store the sensor data that will be plotted

08 Send table data to plots

The next step is to link our new data table to the graphs in our web app, so that they will plot the data from it – once there is any sent from Pico. Click the 'Form1' tab to return to the web app design, then click the Code tab.

We'll create an `update_graph` function to read each row of each the data and plot it in each graph. Add the following lines, indented by two spaces to match that of `def __init__`.

```
  def update_graph(self):
    with server.no_loading_indicator:
      data = app_tables.weather_table.
search()
      self.plot_temp.data = go.Scatter(
        x=[r['time'] for r in data],
        y=[r['temp'] for r in data],
      )
      self.plot_hum.data = go.Scatter(
        x=[r['time'] for r in data],
        y=[r['hum'] for r in data],
      )
```

To run this function and draw the graphs upon starting the web app, we need to add a line to the end of the `__init__` function (under `self.plot_hum.layout.yaxis.title = 'Humidity (%()'`), to call it:

```
    self.update_graph()
```

09 Add a timer

As in part two of this series, we'll add a timer function to tell Pico W to run a function to send the DHT11 sensor data. Click the Form tab. In the Toolbox panel, click ‘See more components’ and then drag a Timer component below the graphs. This is an invisible component, so won’t show on the finished dashboard. In the Properties panel, change the timer’s Interval value to 10 (seconds).

Double-click the Timer component to show its default function in the code in Split view. Before `pass`, add the following code (indented to the same level):

```
    data = anvil.server.call_s("dht11read")
    app_tables.weather_table.add_row(
        time=datetime.now(),
        temp=data[0],
        hum=data[1]
    )
    self.update_graph()
```

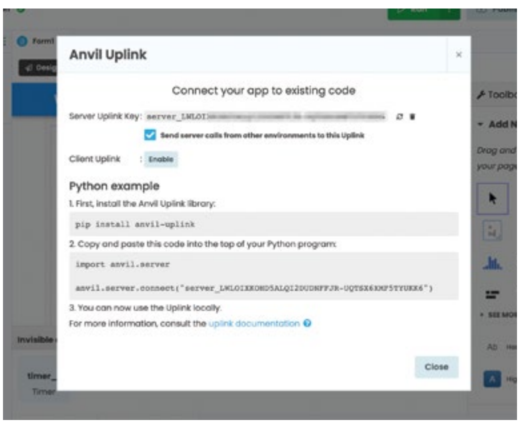
The first line calls the `dht11read` function in our Pico W code, causing it to take a sensor reading and send the data. The next part adds a row of data with the timestamp and the temperature and humidity readings sent from Pico (to match the order in which we return them in the MicroPython code). To use the `datetime` method, we’ll need to import it; in Code view, scroll to the top and add the following line (under `from anvil.tables import app_tables`):

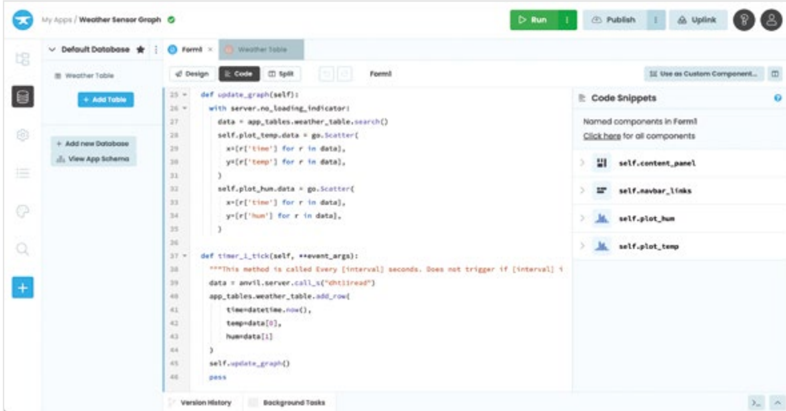
```
from datetime import datetime
```

10 Enable server uplink

To link the web app to the Pico W program, click the ‘+’ button at the bottom left and select Uplink, then click Enable Server Uplink. This will

Enable Server Uplink for your web app and then copy the key to paste into your Pico W program





generate a Server Uplink Key for the app which you should paste into line 6 of your **weather_graphs.py** MicroPython code on Pico W so it can connect to it.

The web app code include functions to read the data table and call the Pico sensor-reading function at regular intervals

11 Run both apps

First, run your Pico W program in Thonny. You’ll see messages in the Shell pane to show it connecting. Once it has, run your Anvil web app (in maximised mode). You should now see the two graphs and it will start plotting data.

To extend or adapt the project, you could add different sensors to your Pico circuit and plot their data in graphs.

weather_graphs.py

Language: **MicroPython**

DOWNLOAD THE FULL CODE: magpi.cc/github

```
001.  import anvil.pico
002.  import uasyncio as a
003.  import dht
004.  from machine import Pin
005.
006.  UPLINK_KEY = "<put your Uplink key here>"
007.
008.  sensor = dht.DHT11(Pin(14))
009.
010.  @anvil.pico.callable_async
011.  async def dht11read():
012.      sensor.measure()
013.      temp = sensor.temperature()
014.      hum = sensor.humidity()
015.      return(temp, hum)
016.
017.  # Connect the Anvil Uplink. In MicroPython, this call will
      block forever.
018.  anvil.pico.connect(UPLINK_KEY)
```

Grow amazing crystals

Mike Bedford guides you on a voyage of discovery, turning ordinary household substances into astonishing crystals

Mike Bedford

Despite loving all things digital, Mike admits to being a bit of a Luddite, vinyl records and all.

Surprising, you might think, in a magazine dedicated to making stuff, that we're not going to be showing you how to make anything here. Admittedly, we're looking at growing crystals, but the fact is that many chemical substances form themselves into crystals without any human assistance whatsoever. What's more, some of those crystals are works of beauty, as you can clearly see from the photo of a mineral sample below.

The chances are those particular crystals grew deep in the ground, at high temperatures, perhaps over thousands of years. However, crystals can grow much more quickly, and in more benign conditions. And while that process will take place unaided, by providing ideal conditions, we can assist the process, and so ensure that those crystals are larger and more impressive than they might otherwise have been. Most naturally occurring mineral samples won't dissolve in water. After all, if they were soluble, as soon as they'd become exposed to the Earth's surface, they'd have been washed away in the rain. However, although they wouldn't stand up to the rigours of the weather, crystals can form in an aqueous solution, and because that's the easiest way to grow crystals, that's our theme here. And it gets better. With just the odd exception, our crystals are made from substances that you can buy from high street stores, and are non-toxic. In fact, you'll almost certainly have one of them in a kitchen cupboard already. So, as long as your kids can safely heat some water in a microwave oven, they can safely make most of our crystals without constant supervision. Not that this project is only for kids. The fact that chemicals can form themselves into such a wide variety of attractive crystals is surely mind-blowing, however old you are.

Above These crystals of vanadinite on barite probably grew underground many millennia ago

Photo: Masha Milshina

WHY DO CRYSTALS GROW?

A simple experiment provides us with just the slightest inkling of why crystals form in their various characteristic shapes. To try this out yourself, you need some spheres, such as marbles, and a base board onto which you've glued or pinned four pieces of wood to make a square frame. That frame should be about half the diameter of the marbles tall, and the internal dimensions should be just enough to hold a 4×4 matrix of marbles. Now, carefully pour the marbles into the square, repeatedly if some marbles overflow the frame, and 16 marbles will form the first layer. As you keep on pouring the marbles, unless they disrupt a lower layer, another nine will form a second layer, then a further four will form the third layer and, eventually, a final lone marble will sit on the top. In other words, we'll have a pyramid.

Now imagine that, instead of marbles a few millimetres across, we have molecules of a chemical less than a millionth of a metre across, and instead of just 30 marbles, we have countless billions of molecules. No longer would we see

Above
As long as the bottom row can't move, pouring marbles on top of each other illustrates how spheres can automatically form themselves in a pyramidal shape

individual marbles in an approximately pyramidal shape, but we'd see an almost perfect pyramid. In our experiment, the force that holds the marbles together is that of gravity, but in crystals, there are forces of attraction which pull them together. Despite that difference, we can get some idea of how the attraction between loads of tiny molecules can produce the much larger geometrical shapes that we call crystals. We've only seen one shape, but because the attraction between the molecules is greater than the force of gravity, we can get further shapes, and those shapes differ with the molecular properties of the particular chemical substance.

Now, we're going to get practical, and there are three aspects to helping you to grow crystals. First, we'll describe the basic method that applies for all our types of crystal. Then we'll suggest some particular chemicals that'll grow into crystals. And, finally, we'll provide some hints and tips.

> **All our crystals are grown from solutions in water,** and the general method has three steps

THE BASIC METHOD

All our crystals are grown from solutions in water, and the general method has three steps. First, you need to create a small amount of a supersaturated solution of the chemical substance. To do that, heat a few tens of millilitres of water (in a Pyrex jug, or in a microwave oven) to a suitable temperature – see Hints and Tips overleaf for guidance on the temperature. Now, stir in the chemical, a bit at a time, until it stops dissolving and you see solid particles remaining on the bottom of the jug. Stir well for several minutes, reheating the solution as necessary.

Above
The attraction between minuscule molecules of chemicals is greater than that due to gravity, so other shapes, like this octahedral crystal of fluorite, can form

Next, pour some of that solution into a shallow container, being careful not to transfer any of the undissolved material. Cover the container with kitchen paper to prevent it being contaminated with dust, and leave it undisturbed. Exactly how long you leave it depends on the chemical, and it could range from hours to days, or weeks. As you leave it, crystals will start to form, and these will get larger over time. That's a good start, but we can do better.

When you've got some decent-sized crystals, carefully remove one and place it on some kitchen paper to dry. We're going to use that crystal as a seed, to grow a larger crystal. First of all, attach it to a piece of very fine nylon thread, of the type used as fishing-line. Don't use ordinary thread like cotton, because crystals will start to grow on its rough surface, while we only want material to accumulate around the seed crystal. Tying the thread to the crystal could be tricky, so an alternative is to use a tiny amount of superglue, but even that's not easy. Now, prepare a larger amount of supersaturated solution of your chemical, in the same way that you made some earlier. Pour it into a small glass container, perhaps 100 ml to 200 ml, again being careful not to transfer any undissolved chemical, and leave it to cool down. Now, tape the free end of the nylon thread to a stick and place the stick across the top of the glass container, so the seed crystal hangs somewhere in the middle without touching the bottom or the sides. Cover it with kitchen paper, and leave it somewhere it won't be disturbed. The seed crystal will get →

Above Step 1 – Create a super-saturated solution of your chosen chemical

Above Step 2 – Pour it into a shallow container and wait for seed crystals to grow

progressively bigger – remove it when you're satisfied with it, and cut off the nylon thread.

The final bit of general advice concerns deciding how much of the various chemicals you need to buy. This depends on how much solution you intend to make, bearing in mind our 100 ml to 200 ml suggestion for growing a single crystal, and the solubility of the chemical. You can find solubility values online, but note that they vary with temperatures, with some substances being much more soluble at higher temperatures.

CHOICE OF CHEMICALS

Different chemicals produce different shaped crystals, so you'll probably want to grow crystals from several substances, and here are some recommendations.

Right Practice makes perfect so, with sufficient patience, you should be able to grow octahedral, or truncated octahedral, alum crystals like this one

Photo: Ude

First of all, we suggest alum, because it allows you to grow large crystals fairly quickly, so you can get a feel for the process while having to wait only a day or two, rather than many days or weeks for some chemicals. Alum – and specifically potassium alum, which is the most common type – is potassium aluminium sulphate, $KAl(SO_4)_2$. It's not widely available in local stores, although it is sometimes used in pickling, and we found some in a Pakistani supermarket. A perfect alum crystal, as you might get if you grow it suspended in solution, is an octahedron, but it might be a truncated octahedron or another shape, especially if it grows on the bottom of a container.

Next, how about growing crystals from Epsom salts, the chemical name of which is magnesium sulphate, $MgSO_4$? It's sold as an additive to bath water, so you should be able to find it in pharmacies. Epsom salt crystals are typically monoclinic prisms, although needle-like is a more understandable description. You could use a seed crystal to grow a single larger crystal, although Epsom salt crystals look good as clusters, so you might choose to miss out the seed crystal stage and, instead, allow a cluster to form by simply pouring the supersaturated solution into a larger glass container.

Salt, by which we mean common salt, or table salt, is sodium chloride, NaCl, and is our next recommendation. Perfect salt crystals are cubes. In fact, you'll see that if you look at salt with a magnifying glass but, of course, you'll be hoping to grow much larger ones.

We've seen three different substances which result in differently shaped crystals, but they're all colourless. It's possible to add food colouring if you want to grow coloured crystals but, if you're a purist, you might prefer to grow crystals from something that's naturally coloured. If so, our suggestion is copper sulphate, $CuSo_4$. Copper sulphate is used as a pesticide, so you might be able to find it at a gardening store, but you'll probably have to buy it online. Unlike all our other chemicals so far, it's toxic. So, wear gloves, don't allow younger kids to use it unsupervised, and don't use any of your containers for culinary purposes afterwards.

HINTS AND TIPS

We glossed over how hot the water needs to be to make a supersaturated solution, because it depends on what chemical you're dissolving. Some chemicals, like common salt, increase in solubility by a modest amount with temperature, so you'll probably need to heat the water to almost boiling point. Epsom salts do somewhat better, so a lower temperature will work.

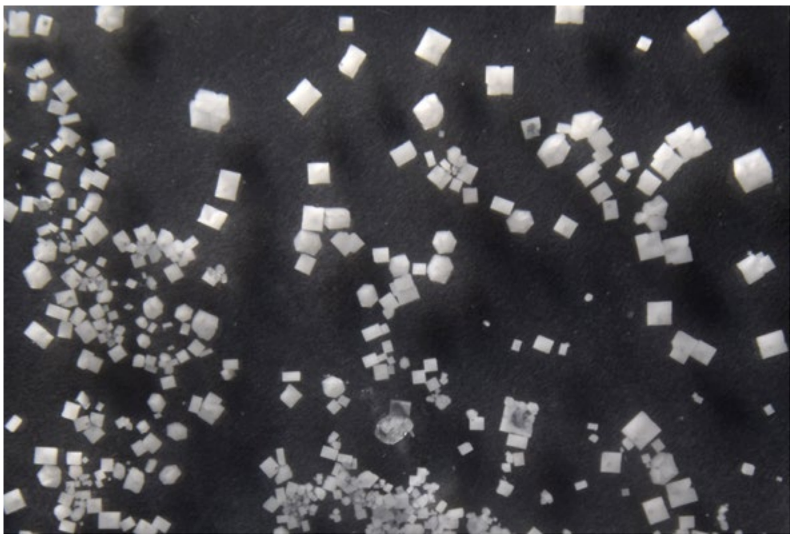
Be sure not to dissolve too much of the chemical in the water, as we did initially with alum, which becomes vastly more soluble with temperature. If you do dissolve too much, the material will start to crystallise as soon as the solution cools down, and rapid crystallisation results in a mass of very tiny crystals instead of just a few larger crystals. Getting the concentration of the solution right, which partially involves choosing an appropriate temperature, is a trial and error process, and probably the main factor that'll dictate how successful you are.

"Bear in mind that different chemicals will take different **times to start crystallising from the solution**"

Bear in mind that different chemicals will take different times to start crystallising from the solution. With some chemicals, such as alum, you'll see small crystals start to appear very quickly, and Epsom salts is a quick mover too. Common salt is a lot slower, and it could be many hours before you see any crystals appear in your shallow container, so do be patient. However, if crystals stubbornly refuse to appear, try sprinkling in a very small amount of the chemical you're growing, crushed up into tiny pieces. All being well, these will act as seeds to grow your larger seed crystals.

And, finally, a word about water. If the water has impurities in it, it's likely that any crystals you grow from it won't be the perfect shapes that you were hoping for. So, if you live in an area with hard water – which means it contains lots of dissolved minerals – it would be a good idea to use distilled or deionised water.

Growing crystals is very much an experimental project, and it'll probably take you some time to fine-tune the process to grow large and perfectly shaped crystals. Even so, if our experience is typical, your first attempt will probably result in good enough crystals to encourage you to persevere. Except for our initial abortive attempt with a much too saturated solution, our first alum crystal was reasonably large and nicely shaped, although it was marred by other crystals sticking to it. Turning to Epsom salts, we managed to grow some good clusters of needle-shaped crystals in just a day or so. And it would have been good to tell you that we'd made good progress with common salt too, but these crystals can't be hurried, and all we can say so far, after several days, is that we have some pretty perfect-looking cubic crystals, even though they're still tiny. □



Above Common salt crystals don't like to be rushed. Some of our crystals are pretty much perfect cubes, and we rather hope some of them might even have reached a decent size by the time you read this

Left Step 3 – Hang your seed in a larger jar of solution, and watch it get larger

RFID spells fun

Make a fun card-matching game using RFID readers and a Pimoroni Pico LiPo

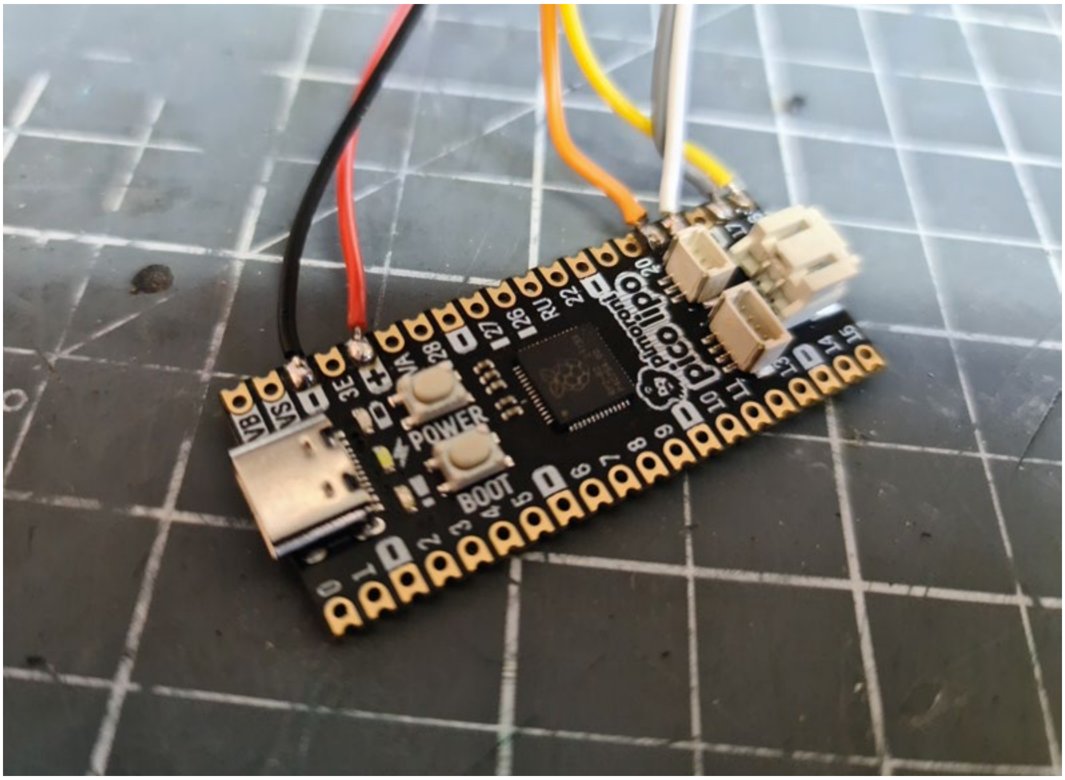
Dr Andrew Lewis

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

Kids love to play and learn, but playing games to practice new skills like reading, mathematics, or even simple baking is something that parents associate with either one-on-one interaction or with tablet computers. It doesn't have to be that way, and while computers do have their place, it's nice to present a child with a more tactile interactive experience. In this project, you'll see how to assemble a simple game board with radio frequency identification (RFID) readers to make a spelling game for young children. The game uses letter cards and picture cards. Using the letter cards to spell the word that matches the picture makes the board play a simple tune (see Beep Boop box, overleaf). You can also use the game to program new picture cards by activating a hidden reed switch on the board.

RFID systems are everywhere. They're in your phone, on the packaging for your parcels, on the food in supermarkets, in your debit card, and maybe even on the door to your office or gym. Looking at its list of applications in modern society, it's easy to see the technology as a very 'suited and booted' security and business-rooted phenomenon. It's a technology for stock control, security, and access control. But with origins that lead back to the theremin, it's a technology that deserves to be seen in projects with a lighter, less business-focused theme.

Making a simple game board isn't rocket science. You'll just need a shallow box that you can use as a board, and some creative inspiration to decorate it. You could hand-cut a box from thin plywood or cardboard, laser-cut one in acrylic, or even reuse an old pizza box. The important part of this project is the electronics, and getting the position of the RFID readers inside your game board correct. →



Left The Pimoroni Pico LiPo board is a little more expensive than the vanilla Raspberry Pi Pico, but it comes with some additional LiPo battery management and extra memory

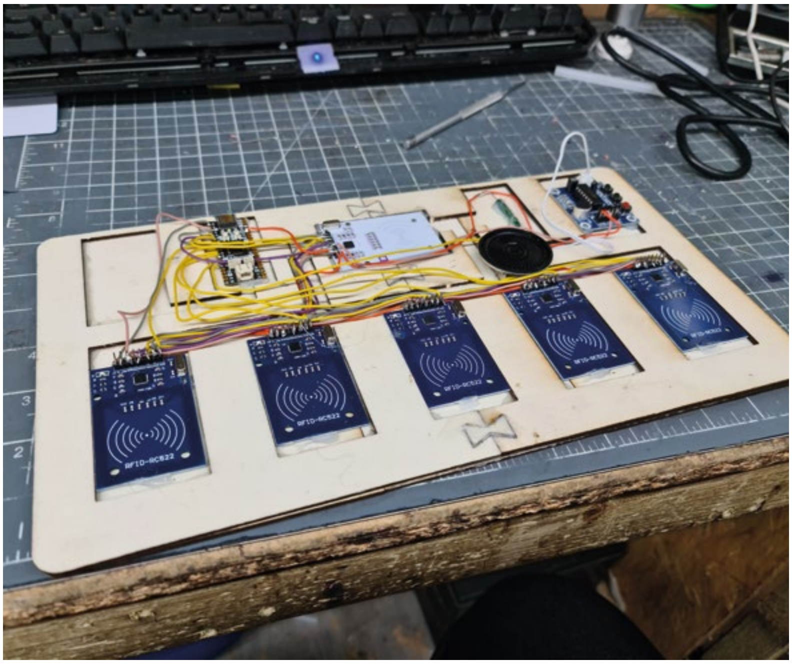
YOU'LL NEED

- **Pimoroni Pico LiPo** (shop.pimoroni.com/products/pimoroni-pico-lipo)
- **1 × LiPo battery pack** (shop.pimoroni.com/products/lipo-battery-pack)
- **6 × RC522 13.56MHz RFID/NFC module** (amazon.co.uk/AOICRIE-RFID-Kit-Compatible-Raspberry/dp/B09H6PLM1C/)
- **40 × 13.56MHz RFID/NFC cards, with 1kB of memory (also called MIFARE cards)** (shop.pimoroni.com/products/rfid-card-10-pcs)
- **ISD1820 audio record module with mic and speaker** (amazon.co.uk/HALJIA-ISD1820-Recording-Playback-Loudspeaker/dp/B06XD96N4J/ref=asc_df_B06XD96N4J)
- **A reed switch** (Normally open type)
- **A shallow box, or a piece of wood or card to use as a game board**

DATA LOADING

There has been a lot of talk here about reading and writing RFID cards, but very little about what that actually means. RFID cards come in a variety of different standards, using a number of different frequencies and protocols. This project uses an RC522 reader, which works at a frequency of 13.56MHz and is used with classic MIFARE-type cards that have 1kB of memory. These are the sort of cards that you find used as travel passes or printer/photocopier credit cards. The memory is arranged into 16 sectors, each of which contains four blocks of 16 bytes. The first three blocks are data blocks that are used for storage, but the fourth block is an access control block, which defines how the information in that sector can be accessed. Writing to this block incorrectly can permanently break the card. In addition to the writeable areas, there is a 4-byte long read-only ID burned into the card. This ID cannot be changed, and it lets you identify a particular tag if you need to. In order to read or write information on a MIFARE card, the card must be authenticated using one of two keys. The multiple keys can be programmed to allow different access levels to the information stored on the card. As an example, Key A could allow read-only access, while B would allow write access. By default, these cards are usually delivered with the access keys set to hex FFFF. Some card sectors are safe to edit, others sectors are protected. If you try to mess around with these blocks and sectors and don't know what you are doing, you can trigger security features that will ruin a card permanently. The datasheet for MIFARE Classic 1K cards (**hsmag.cc/MIFARE_Classic1K**) gives you the full breakdown on exactly how this works and which areas are safe to work with, but for now, you just need to understand that the areas used in the project files are 'safe' to use, and if you want to start messing around with other areas, you should read around the subject a little bit before you experiment.

One other thing to note is that the configuration of the MIFARE card's memory as 16 sectors containing four blocks each is not actually reflected in the MicroPython code. In the Python examples, the code is represented more simply as 64 sectors of 16 bytes. This means that the access control blocks are actually every fourth sector. The sectors begin numbering at 0, so sectors 3, 7, 11, 15, 19…63 are all control blocks, and writing to them accidentally would most likely wreck the card.



Above
While this project looks pretty simple as a schematic, it's actually quite a workout to solder quite so many wires in one go unless you're used to doing it professionally. You might also find that you're going to be reusing the same wire colour for different purposes in the same circuit, which is never ideal. If you're feeling the strain, split the job into several sessions, and keep track of which wires you've already soldered by marking your schematic at the end of each session

SERIAL PERIPHERAL INTERFACE

The RC522 RFID reader modules use the SPI interface to communicate with the Raspberry Pi Pico. SPI is a popular and well-established protocol that lets you connect multiple devices together on a single bus to reduce the overall number of lines used to communicate with the processor. Although some devices can be daisy-chained to reduce the number of connections going to the master device, many (including the RC522 modules used in this project) are independently wired, with each connection being connected to the same pin on the next board. The SPI interface needs several connections to function properly, some of which are shared between boards. These are usually labelled MISO, MOSI, and SCLK. MISO stands for Master In Slave Out, and is the connection that sends information from the slave device (our RC522) to the master device (the Raspberry Pi Pico). MOSI is the reverse of this, standing for Master Out Slave In, sending information from the master device to the slave). As you might have already guessed, SCLK is a clock signal that keeps everything in sync. In addition to these shared pins, you also need a dedicated pin to indicate which board should be active, and this is usually labelled SS or CS for Slave Select or Chip Select. On Some RC522 boards, this pin might be labelled SDA. This pin goes straight to the master and does not get shared with the other slave boards, which means that you'll need one free pin on your Raspberry Pi Pico for each device on your SPI interface. Although the RC522 board has several other pins, these are the only pins that relate to the SPI interface directly. The remaining pins deal with power (3.3V and GND), a device reset pin (RST), and an IRQ pin, which triggers when the slave detects a card. While it would be possible to use this pin to trigger the Raspberry Pi Pico, it provides no significant advantage over simply polling each reader in sequence, and would require several extra wires to be connected to the board.

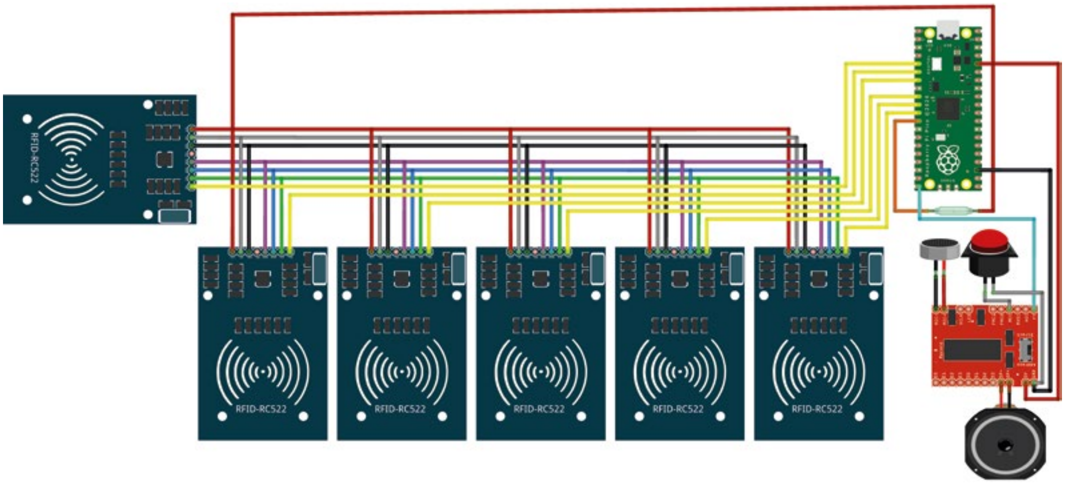
BEEP BOOP

Detecting cards is part of the game, but so is creating some meaningful feedback for the user. LED lights and buzzers are one option, but you can also use a sound module like the ISD1820 or ISD1932 to make the game more distinctive. These modules allow you to record sounds using a microphone, and play them back in part, or in full, by triggering a pin high. The exact recording time and number of different sounds stored will depend on the version of the chip and the configuration that you're using, but you can easily record several sounds to reward your players. One consideration with these modules is that they aren't very loud, so you will need an amplifier if you want big sounds for your game.

Some RFID modules (particularly the cheapest of the 'buy 20 for the price of a coffee' varieties) don't have the best range, and will only work if your card or tag is a couple of centimetres away from the reader in open air. Different materials will reduce this range by different amounts, and anything that can interfere with electromagnetic waves (like iron) will probably stop the signal completely. Getting your players to place their cards in the right place is key to making your game work well. Most RFID modules use similar circuits and control chips, and it is possible to adjust the gain of most readers to increase their effective range. However, increasing the range too far could mean that multiple cards interfere with each other and give unexpected readings – it's unlikely, but possible, that this could cause a problem for your board game if the card readers are placed too close together.

The game you are creating will use RFID readers to read letter cards and picture cards, so you will need at least four RFID readers to spell simple three-letter words (three letters, one picture). The readers connect to a Raspberry Pi 2040-based board. In the board game shown in this article, a Pimoroni Pico LiPo has been used because the board has a LiPo battery charging circuit built in. If you want to use AA batteries with your project or power the project straight from USB, you could easily use a Raspberry Pi Pico or Raspberry Pico W instead.

To interface the RC522 devices with the Raspberry Pi Pico, you are going to use MicroPython, and Dan J. Perron's micropython-mfrc522 library, which you can find here: **hsmag.cc/DanJPerron**. If you've never used MicroPython on the Raspberry Pi Pico before, you can follow the instructions at **hsmag.cc/Get_Started_Pico** to get started.



Left The RC522 RFID modules use the SPI interface, sharing several wires between each board. GPIO pin 15 serves as a trigger that starts a recorded celebratory tune playing

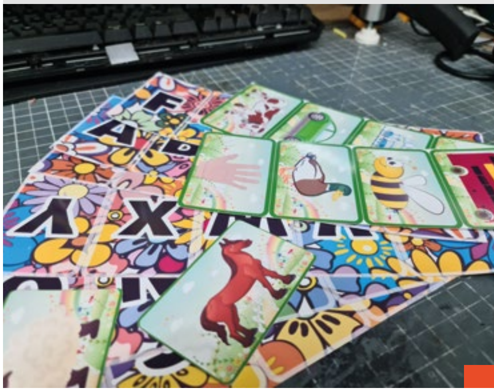
Download the library and copy the **mrfc522.py** file onto your Raspberry Pi Pico. You will also need to copy the project's **main.py** file onto the Raspberry Pi Pico when you are ready to run the game, but first there is some work to do setting up the cards for the game. At the moment, your game cards have not been programmed. They have no data stored on them beyond that which came from the factory. Ideally, you want to make at least one full set of letters A–Z, and extras to deal with words that have double letters (sheep, pool, egg, etc….), and you'll also need to make several picture cards that are programmed with the word represented by the picture on their face. Letters and words are

> "You want to make at least one full set of letters A–Z, **and extras to deal with words that have double letters**"

written to the cards at the same location in the card using ASCII. To write the information to the cards, the project uses two Python files: **Pico Alphabet Program.py** and **Pico Word Program.py**. The first of these files lets you program the entire alphabet A–Z automatically one card after another. Each card scanned gets the next letter of the alphabet written to it. The second program allows you to write a whole word or a single letter to the card, by typing the word into the console in Thonny and then pressing the **RETURN** key. □

STICK HERE

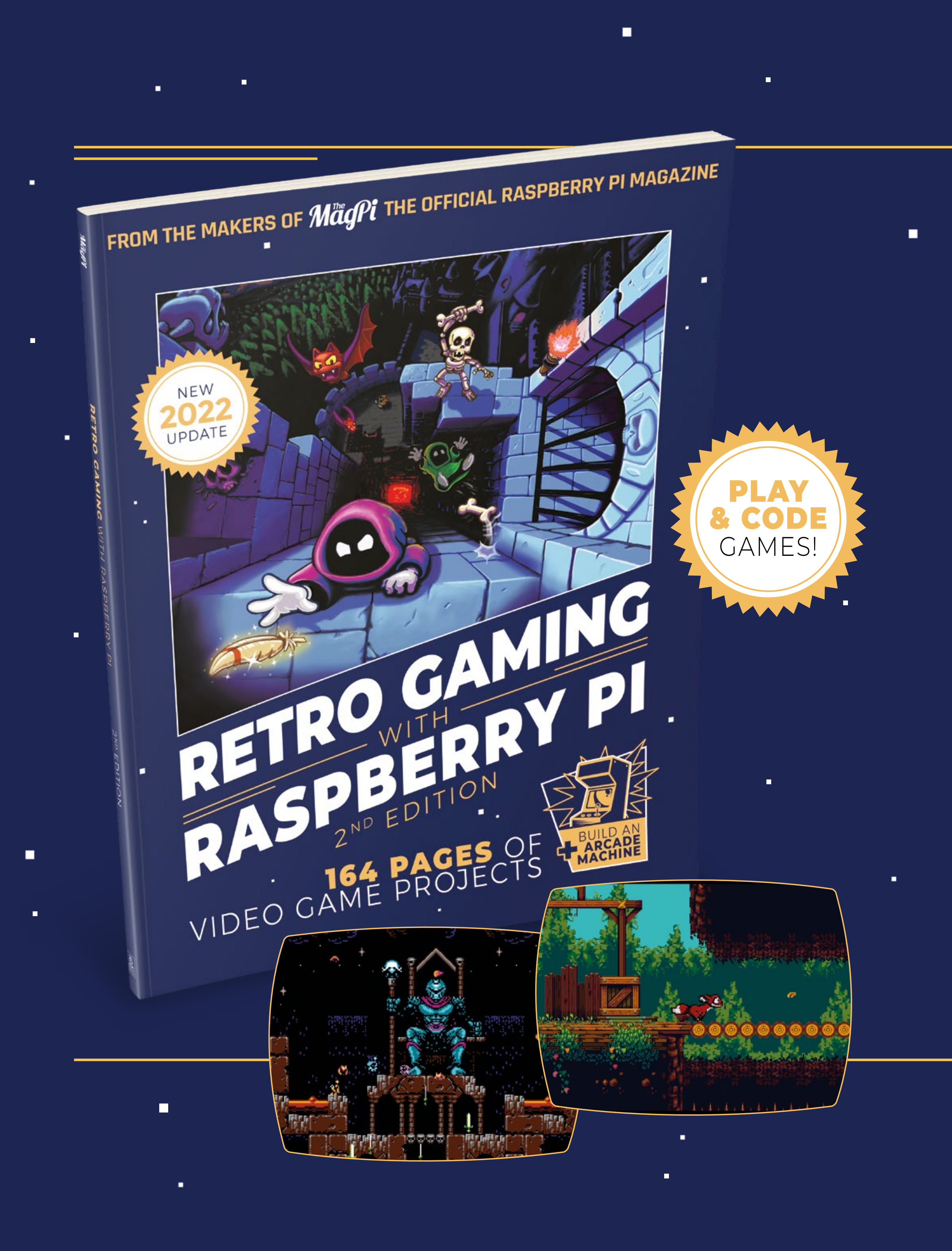
Decorating your RFID cards is a little bit trickier than you might expect. Normal RFID cards are made from PVC or similar materials that give off toxic fumes if they are burnt, and do not absorb ink from regular inkjet printers. Dedicated card printers use a sublimation dye that transfers onto the card using heat, but these printers and their consumables are usually very expensive. You can dye the cards with synthetic fabric dye and acetone, or use dedicated PVC paints, but these aren't particularly easy or forgiving techniques to work with. You could choose to use RFID stickers instead of cards, and attach them to cards of your own creation, or you could print designs onto sticky-backed inkjet paper and trim them to the exact shape of the cards once they are stuck in place. This method might sound quite amateurish, but it's a low-cost solution, and the results are actually quite respectable. It also makes it easier to peel off damaged designs and refresh the cards in future. You can also experiment with alternatives to paper, like synthetic felt or EVA foam.



QUICK TIP

If you're having problems with the position of the cards not triggering an RFID reader, you could create a slight recess in the board so that your cards fit in exactly the right place.

Left The most time-consuming part of this project is making all of the cards. The quickest way is to print on paper and glue onto cards. If you can afford to spend a little bit extra on parts, you could use RFID stickers instead of cards and save a little bit of time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Dyeing for art

Dye your own sheets of acrylic using synthetic fabric dye

Dr Andrew Lewis

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

Coloured acrylic (aka Perspex) sheets make a huge difference to the aesthetics of a project, but you don't always have the right colour for the job. In this article, you will learn how to apply your own tint to a plastic sheet, and create different effects.

This project requires some preparation work before you dive in and start throwing chemicals together. First, change into some clothes that you don't mind ruining with dye, and then prepare a clean, disposable, work surface in a well-ventilated area. An outdoor table with plastic and card protection is a good choice. Plastic sheeting will help protect the surface of the table, and cardboard will help absorb any spilled chemicals. Protect your hands with two pairs of nitrile gloves.

Right Many 3D printers have a heated bed. If you don't have a dedicated hotplate, you can use the bed of a 3D printer to keep a few jars warm. Protect the bed with some cling film, and make sure that the motors are disabled – you don't want an accidental printer move to sweep your jars onto the floor

DYE HARD... PLASTIC EDITION

Turn on your hotplate, and set the temperature to about 70°C. You'll be using the hotplate to keep your mixture warm for longer, rather than to bring the mixture up to temperature, so it doesn't need to be very hot.

DO NOT BE ON FIRE

Fill your container a quarter of the way with boiling water, then add a roughly equal amount of fabric dye. Adding more dye will create a deeper colour, while less dye will be a lighter colour. Place the jar on the hotplate and set it to one side. Prepare your plastic object. Remove any protective film, wash it with a degreaser, then rinse in water. Take your object and tie it onto a length of string, coated wire,

QUICK TIP

It's usually easier to dye acrylic once it's been cut to its final size, because large sheets of plastic need a big dye bath.

Left
This is one project where preparation is everything. Have everything ready before you start so that you don't have to look around in a panic to find something you'd forgotten

or fishing-line and then tie the other end of the string to a lollipop stick, so that you can dangle the acrylic in the container of dye.

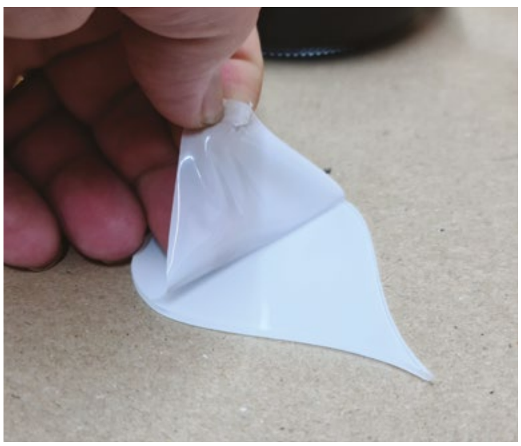
The next step in the project is potentially dangerous, and you should take extra care. Dipping an acrylic object into the dye mixture at this point would result in a very washed-out and faded-looking plastic tint (or possibly no tint at all, depending on the dye). To get vibrant colours, you need to soften up the plastic slightly so that it will properly absorb the dye. Acetone will melt acrylic plastic, and adding acetone to your dye mix will soften the plastic enough to accept the dye. Add about a quarter of the volume of your container (one third of the volume of the water-dye mixture) of acetone to the mixture, stir for a couple of seconds, and then immediately suspend the acrylic item in the dye mixture for between 5 and 15 minutes. The effect of the dye will vary depending on the type of acrylic sheet you're using, and the colour of the dye. Cast acrylic will accept dye less readily than extruded acrylic, and dyes don't always react as readily as you expect. Blue dye seems to take longer than yellow dye to absorb, while purple seems to take very quickly.

EXPERIMENTATION REQUIRED

Once you remove the object from the dye, rinse it with clean water and hang it up to dry. Repeat this process for all of your acrylic objects, then turn off the hotplate. When the remaining dye mixture has cooled, you can store it in a sealed container in a dark place until you need it again. Just reheat it, add a little more acetone, and dip more objects. You →

STAY SAFE

This project uses dangerous chemicals at high temperatures. Acetone and isopropyl alcohol are both extremely flammable as a liquid or as vapour, and can cause eye irritation, drowsiness, and dizziness. Fabric dye can also cause eye irritation and other effects. You must work in a very well-ventilated area, away from sparks, flames, and other possible sources of ignition. Read and understand the MSDS and other safety information for all of the chemicals that you use in this project. If you do not understand how to proceed safely, then do something less dangerous instead.



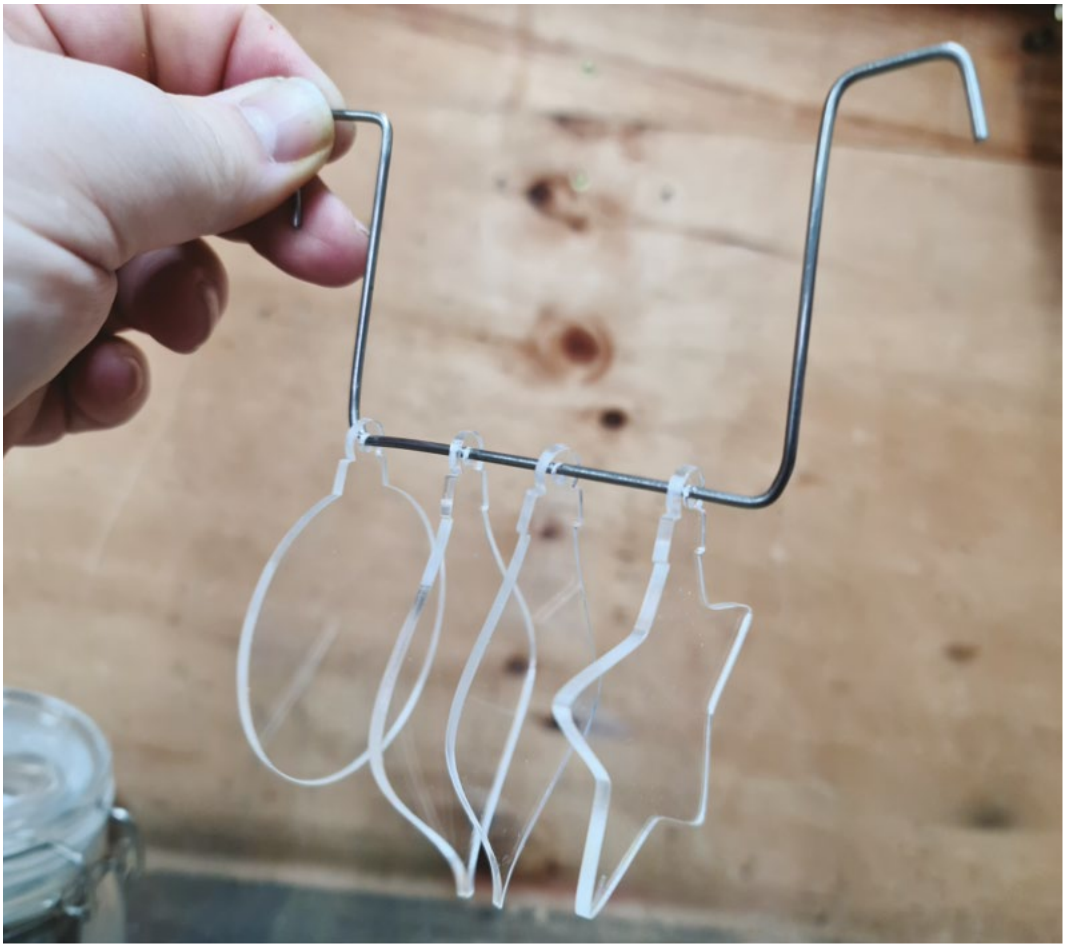
Above
Any residue on the surface of the plastic will affect the absorption of the dye, so you want it to be as clean as possible. Leave the protective film on until the last moment

YOU'LL NEED

- **Rit DyeMore Synthetic Fiber Dye** (NOT Rit All-Purpose Dye)
- **Acetone or isopropyl alcohol**
- **Hot water**
- **An electric hotplate**
- **Thermometer**
- **A heat-safe container large enough to submerge your acrylic objects** (a Kilner jar will work)
- **Acrylic plastic objects to dye**
- **Lollipop sticks, skewers,** or rigid wire to hang your objects in the dye
- **Forceps or tweezers** (to fish your objects out of the dye when they inevitably fall in)

QUICK TIP

Most nitrile gloves aren't completely waterproof. Double-gloving will give you a few extra seconds grace, but won't guarantee that you won't end up with technicolour fingers.



Right It's OK to dip multiple items at once, as long as they're not going to touch each other. If the pieces touch, it may affect the finish of the plastic and lead to an uneven dye

Below Hanging the dyed pieces up to dry is important as the plastic may still be slightly softened by the solvents, and any mechanical force could affect the finish of the plastic

> "You can vary the intensity of the dye on an object by removing the item from the dye bath slowly"

might find that the process takes longer and results in a lighter colour as the dye gets used up, but a single mixture should be able to dye many objects.

As you get used to the dyeing process and are comfortable working safely with the materials, you can start to experiment with techniques to get different effects. You can vary the intensity of the dye on an object by removing the item from the dye bath slowly, over a period of several minutes. The areas that have been in the dye the longest will have a more intense colour, while those that have been in for the shortest time will have a very faint tint.

Above
You can get a huge range of different tint effects, from solid colour to almost no tint. Here, you can see a selection of different colours and effects, including gradients and split-dipping

Left
This piece was removed very slowly and smoothly from the dye over a period of about five minutes. You can see the smooth transition from dark to light

Below
Tinted plastic is great for ornaments, jewellery, and cosplay features

You can partially submerge an item to dye only one portion of it, and then reposition it in a different bath to dye another portion a different colour. It's also possible to completely dye an object one colour, then add a different (usually darker) colour on top. The key to success with this process is experimentation. It won't work for every colour combination because the tint of the dye will be affected by the underlying colour of the plastic, but it can be used to create mixed gradients or hard contrasts with a darker colour. This is a technique that's great for creating decorations or costume pieces, as the variations in colour can add a more organic, handmade feel than single colours. □

MIXOLOGY

You can mix dyes together to get different colours. Dye maker Rit has a handy guide at **hsmag.cc/RitFormula** that should provide you with a starting point for getting the exact colour that you are looking for.

As there are so many possible variables, it's very likely that you will need to do some experimentation with scrap pieces of acrylic, if you do need to match a colour exactly.

Fast analogue input with Raspberry Pi Pico

Get perfectly timed snapshots using CircuitPython

Ben Everard

@ben_everard

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

CircuitPython is great for getting started with microcontroller programming, but it can have a few shortfalls. One of which is very accurate timing. The CircuitPython interpreter does quite a bit in the background, and this means that the execution of the program pauses occasionally. These pauses are short and don't generally cause any problems, unless you need something to be very accurate time-wise.

One thing you might need accurate timing for is reading an analogue signal. If you want to understand what the signal is doing, you need to know exactly when the readings are taken.

Thankfully, in CircuitPython 8 on Raspberry Pi Pico, there's a solution – analogbufio. This lets you read values from the analogue-to-digital converter (ADC) directly into a Python data structure. It's only available on Pico and other RP2040-based hardware at the moment, but may be expanded to other platforms in the future.

To use this, you'll need to install CircuitPython 8 which, at the time of writing, is in beta. You can get it from **circuitpython.org**. Take a look at the 'Getting Started' box if you've not used CircuitPython before.

Let's start by taking a look at the example code from the module:

GETTING STARTED

If you've never used CircuitPython before, it's a version of the Python programming language for microcontrollers, with a specific focus on making it a great experience for new users.

You can find out how to get started with it using this link: **hsmag.cc/AdafruitCP**.

```
import board
import analogbufio
import array

length = 10
mybuffer = array.array("H", [0x0000] * length)
rate = 500000
adcbuf = analogbufio.BufferedIn(board.GP26,
sample_rate=rate)
adcbuf.readinto(mybuffer)
adcbuf.deinit()
for i in range(length):
    print(i, mybuffer[i])
```

This reads in ten values at a rate of 500,000 readings per second, then prints them onto the serial console.

One of the key parts of this code is the array, `mybuffer`. You might think that CircuitPython uses lists rather than arrays, but this isn't quite the case. CircuitPython has both lists and arrays. The difference being that, while lists can be a series of almost anything, arrays are tied much more closely to the hardware. An array is a specific piece of memory that's dedicated to storing multiples of different bits of a single type of data. The specific type of data is controlled by the typecode – in this case 'H', which is an unsigned sort.

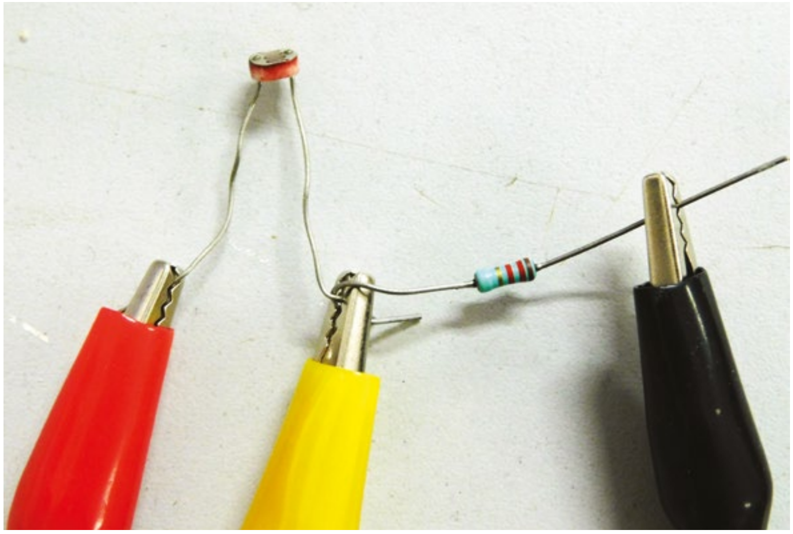
On Pico, that's a 16-bit positive number. The reason we sometimes need to use arrays, rather than lists, is that in some cases the underlying hardware requires it. With analogbufio, we can stream data directly from the analogue input to the block of memory and, to do that, we need a contiguous block of memory to stream it into. For this to work, it has to be an array.

The ADC on Pico is 12 bits, so we're wasting four bits every time we read in data. However, arrays can only be certain data types, and 12-bit numbers aren't

PIO

As the name suggests, analogbufio only works with analogue inputs – but fear not, users of digital I/O. You can get the same features using programmable I/O (PIO). This gives you a huge amount of control over the format and timing of digital input and output on RP2040-based boards like Pico.

You can find out how to get started with PIO in CircuitPython at **hsmag.cc/circuitpythonpio**.



supported. If you don't need this level of accuracy, you can use the typecode B to read in 8-bit numbers and save 50% of the RAM.

REGULAR READINGS

A big advantage of analogbufio is that the timing of the samples is controlled by the underlying hardware, so they should be very accurately spaced. This means you can recreate the underlying signal with far more accuracy than you could if you did a MicroPython loop, reading in data each time. Let's take a look at how we can do this in practice.

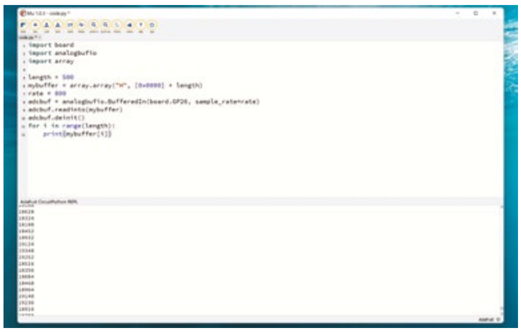
The **sample_rate** parameter is the number of samples per second captured, and we're limited to between 732 and 500,000.

As a simple test, we decided to investigate the buzz in our lighting. Mains electricity here in the UK cycles at 50Hz, and our lights flicker at about this rate. We wired 3.3V to a light-dependent resistor (LDR), and the other end of the LDR we connected to both GPIO 26 and a 1kΩ resistor. The other end of the resistor we connected to ground. This makes a simple voltage divider circuit that lets us sense the light level.

We tweaked the code to:

```
import board
import analogbufio
import array

length = 500
mybuffer = array.array("H", [0x0000] * length)
rate = 800
adcbuf = analogbufio.BufferedIn(board.GP26,
sample_rate=rate)
adcbuf.readinto(mybuffer)
adcbuf.deinit()
for i in range(length):
    print(mybuffer[i])
```



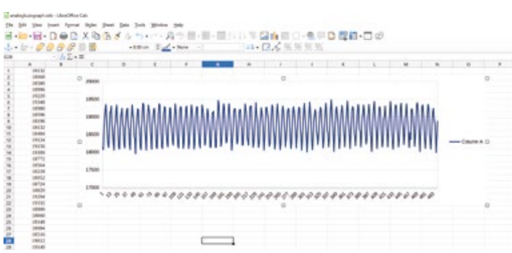
Above Our circuit is a simple resistor divider with half of it being a light-dependent resistor

Left The analogbufio module gives you an easy way of capturing data at a regular interval

> "A big advantage of analogbufio is that the timing of the **samples is controlled by the underlying hardware**"

This reads in the voltage 800 times a second and then, once the values are all read in, prints them out. Unfortunately, Mu's plotter doesn't like getting huge dumps of data like this, so we copy-pasted the results into LibreOffice Calc and plotted a graph. There, as if by magic, is a 50Hz cycle!

This is a really powerful technique for getting data onto Pico. You could use it to analyse audio, analyse circuits, or much more.



Left The alternating current on the mains cycle is clearly visible on the received data

FIELD TEST

HACK | MAKE | BUILD | CREATE

Hacker gear poked, prodded, taken apart, and investigated

PG 92

INKY FRAME

A display that sips from batteries

PG 94

CAMERA MODULE V3

Upgrade your robot eyes

PG 96

CROWDFUNDING

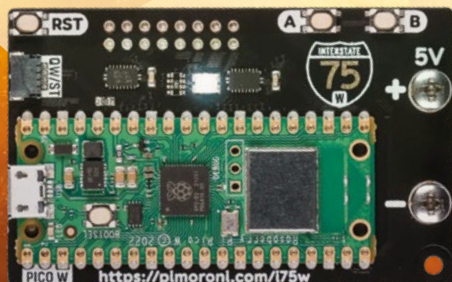
MAKE 100

A gentle start to the maker calendar

PG 86

BEST OF BREED

Exceptional electronics equipment



ONLY THE BEST

The latest in DIY electronic kits

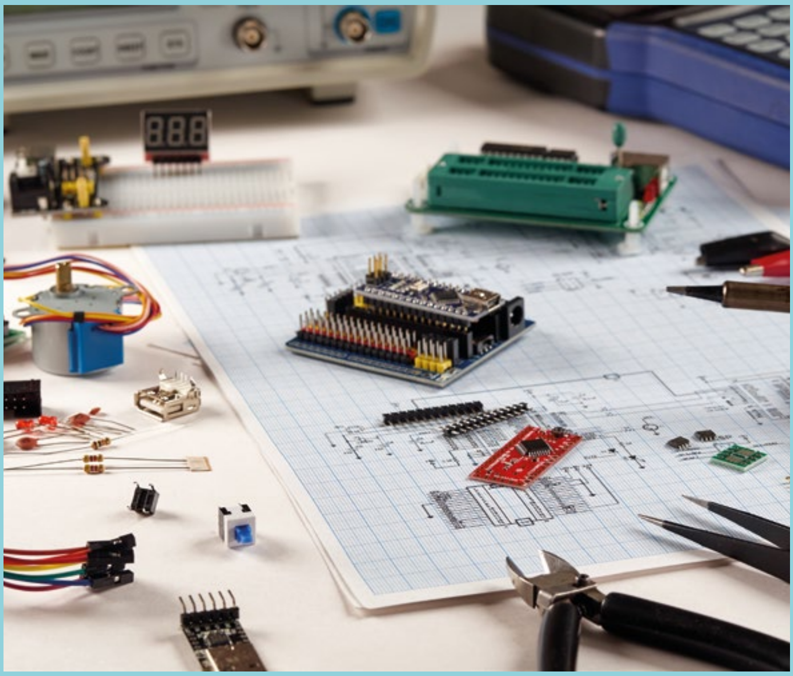
A collection of new, or at least newer, DIY electronic parts and accessories

By **Marc de Vinck** @devinck

It's been a wild ride for anyone manufacturing electronic kits or accessories over the past few years, myself included. I've had some parts on order for over 100 weeks, and with no end in sight. Fortunately, the supply chain disaster of the last few years is looking better for 2023. But still, sourcing some parts, especially microcontrollers, is still near impossible. Let's hope they start showing up soon!

And yet some manufacturers have been able to continually roll out new products. They may have switched their focus to more basic offerings like DIY keyboard accessories and components, or cranking out new variations of LED-related products and accessories as they seem to still be readily available, albeit usually at higher price points.

In this Best of Breed, I'll be looking at a collection of new offerings from various manufacturers that should be of interest to anyone creating electronic projects. And, thanks to Raspberry Pi and the readily available RP2040, you'll even see a few new products that have an integrated microcontroller.



PicoBricks Base Kit vs Arduino Make Your UNO Kit

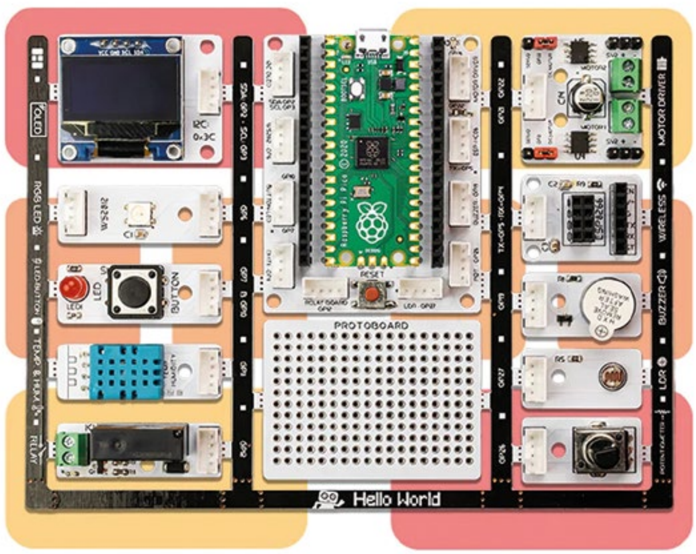
PICOBRICKS ◆ $50 | picobricks.com

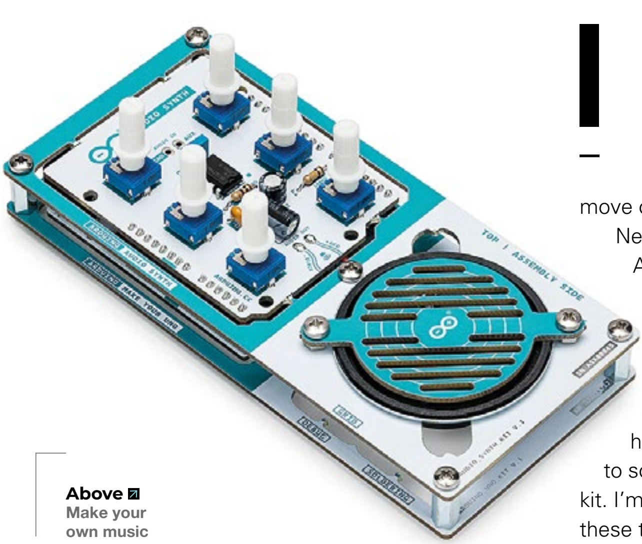
ARDUINO ◆ $59 | arduino.cc

Below Plug your project together

The PicoBricks Base Kit (available at Pimoroni) is a building block system designed to be used in the educational market, but certainly works well at home, too, especially if you have some younger makers interested in electronics, since it does not require any soldering. The kit features a Raspberry Pi Pico, making for a powerful and well-documented set of electronics. You can program it with the Bricks IDE, MicroBlocks, Thonny, the Arduino IDE, or MicroPython.

The kit includes a variety of PicoBrick pieces, such as the common button, LEDs, and LCD screen. But it also includes a few other more interesting components like a temperature and humidity sensor and motor driver board. You should be able to make some fun interactive projects with the variety of components included.





Above Make your own music

I really enjoy kits that are fun to build but are also fun to use, and the Arduino Make You UNO Kit is a great example of that type of kit. You start by learning the basics of building an Arduino UNO. Once completed, and you understand basic programming, you move on to another fun project.

Next up, it's time to build a synth! Building an Arduino is fun – I've done it dozens of times, but once you are done, it usually sits there, but not with this kit. Through the help of a well-documented online guide, and 3D interactive viewer, you are guided through the process of building a simple synthesizer. Now you have something fun to play with after you learn to solder and code. This is a beautiful and complete kit. I'm hoping Arduino continues to design more of these types of kits in the near future. →

VERDICT

PicoBricks Base Kit

A good place to start for beginners.

8/10

Arduino Make Your UNO

Fun to build and fun to use.

10/10

BEST OF BREED

Inky Frame 4.0 with Pico W

PIMORONI ◆ $71 | pimoroni.com

Pimoroni has made yet another great-looking product, and with great specs, too. The Inky Frame 4.0 is an e-ink display with an integrated Raspberry Pi Pico W. And that alone sounds great, as we all love the Pico, but unlike most e-ink displays, this one is much larger and features seven colours. Yes, seven!

On the front of the 4" display are five user buttons, and on the back, you will find a Pico W featuring a Dual Arm Cortex-M0+ running at up to 133MHz with 264kB of SRAM, 2MB of QSPI flash, and on-board 2.4GHz wireless communications. Coupling Wi-Fi and an e-ink display opens up a world of possibilities. Build a home automation dashboard, a mini low-res photo display, or grab some data from online, such as stocks, weather, or social stats, and share it at work or home. Just keep in mind, it's low-power, but it's also low-resolution and it takes some time to refresh the display.

Below ◆
For an in-depth review, head to page 92

VERDICT

Inky Frame 4.0 with Pico W

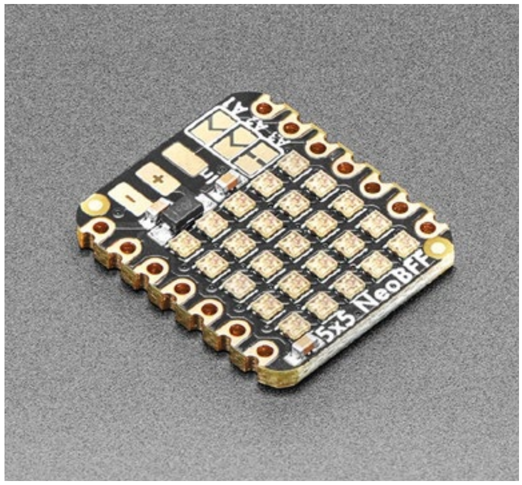
Awesome if you like e-ink.

9/10

Adafruit 5×5 NeoPixel Grid BFF Add-On for QT Py and Xiao

ADAFRUIT $10 adafruit.com

I really like the QT Py board from Adafruit, and if you have one, this is a must-have accessory. The NeoPixel Grid BFF Add-On for QT Py and Xiao adds a grid of 5×5 individually addressable RGB LEDs. It's the perfect form factor for the QT Py or XIAO, and the LEDs are bright and perfectly placed on the PCB. You need to see the demo video on the Adafruit product page to appreciate how fun a 5×5 RGB matrix looks. If you love LEDs and tiny PCBs, then you need to pick up this inexpensive BFF for the QT Py or XIAO microcontroller.



Left Teeny-tiny blinky lights

VERDICT

Adafruit 5×5 NeoPixel Grid BFF Add-On for QT Py and Xiao

A great companion to the QT Py or XIAO.

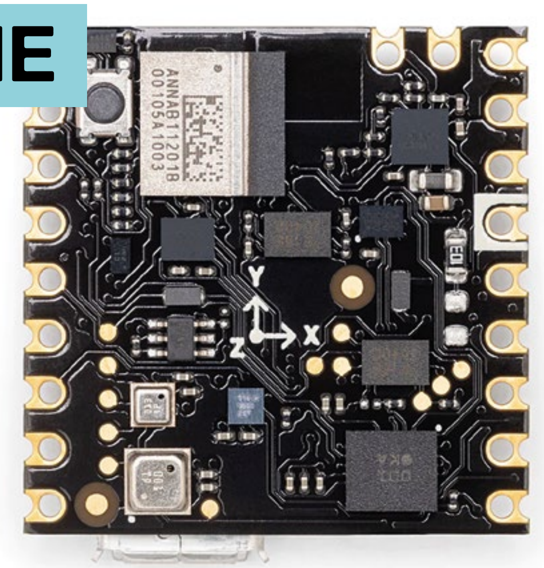
9/10

Nicla Sense ME

ARDUINO $83 store-usa.arduino.cc

Admittedly this is not a new board, but somehow I missed it, so it's new to me! The Nicla Sense ME is a small form factor, low-power board that is used for intelligent sensing projects. The Arduino ecosystem makes for a simple platform and, coupled with four state-of-the-art sensors designed by Bosch Sensortec, you have a powerful, yet easy-to-use and robust sensing ecosystem.

The Nicla Sense ME features a BHI260AP motion sensor system with integrated artificial intelligence, a magnetometer, pressure sensor, and a four-in-one gas sensor also featuring integrated AI, pressure, humidity, and temperature sensors. The PCB also includes an integrated accelerometer and gyroscope.



That's a lot of useful and smart sensors. And you can even connect to the board via BlueTooth Low Energy (BLE). There is so much packed into this little board that you really should head over to the product page to learn more.

Left Lots of power in a tiny area

VERDICT

Nicla Sense ME

Tiny and powerful.

9/10

Interstate 75 W with Pico W

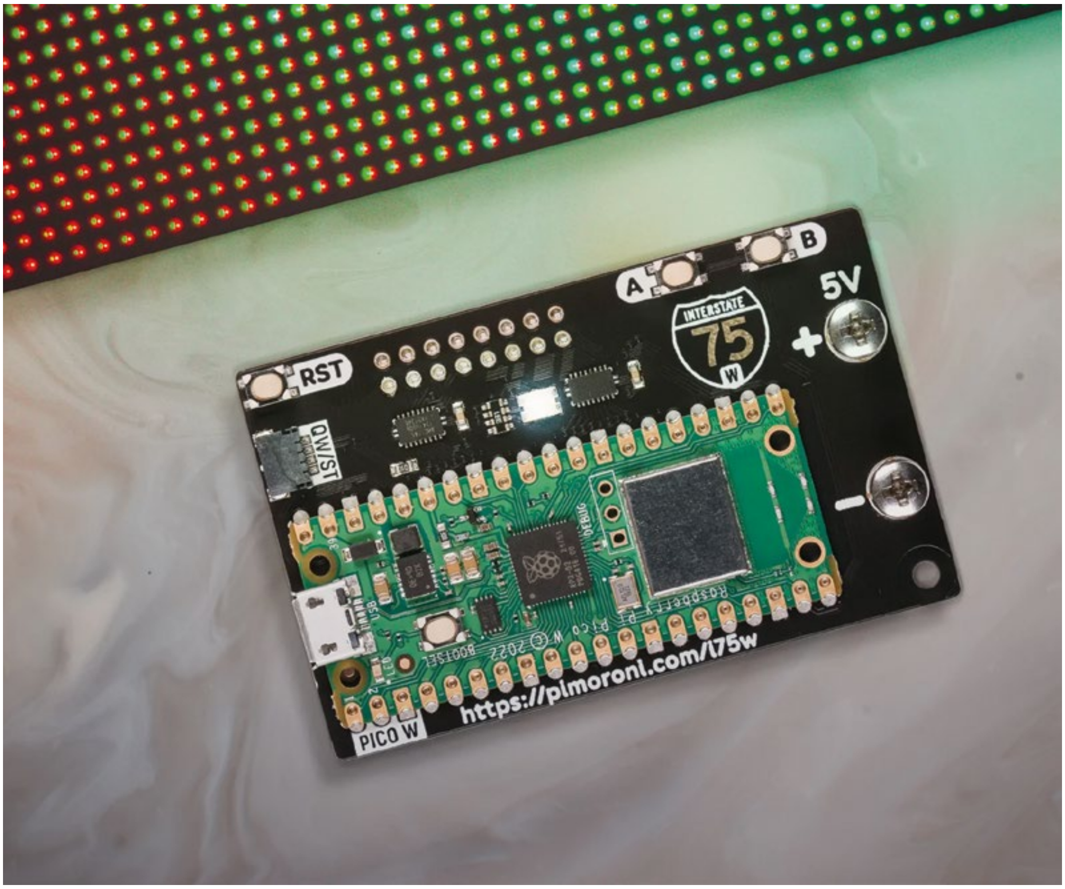
PIMORONI $20 | pimoroni.com

I love LEDs, especially LED matrices, so I am adding this little Pico-powered board to the list of things I want to buy. The Interstate 75 W, powered by a Raspberry Pi Pico W, is a dedicated controller for HUB75 LED matrix panels. Pimoroni designed the PCB to easily plug right into the back of an LED panel without any additional wires or mess.

It provides an easy solution for creating an animated LED sign, artwork, or whatever you might want to display on a HUB75 LED matrix. Just be aware, an LED matrix is not included. But the Pico W is!

Pimoroni also included a Qw/ST connector on the PCB breakout, so adding additional sensors is as simple as plug and play with any Qwiic or STEMMA QT sensors.

There is a lot more information about how to use this board on the Pimoroni website, including how to draw on a matrix using the PicoGraphics library, and many other code examples, including MicroPython and C/C++. So, head on over to the website and learn more about the Interstate 75 W with Pico W. And don't forget to pick up a HUB75 LED matrix!



Left Light up your life

VERDICT

Interstate 75 W with Pico W

Got LEDs? Then get this board!

10/10

Inky Frame 4.0

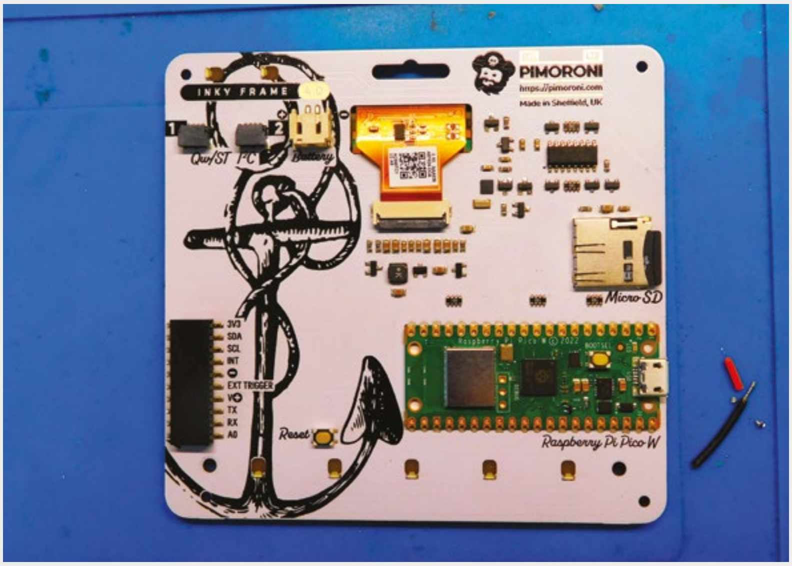
Putting a maker-friendly e-ink screen to the test

PIMORONI ◈ **from £69.90** | **hsmag.cc/inkyframe4**

By Ben Everard @ben_everard

E-ink displays have an almost magical property – they keep displaying an image without using any power. They're not just low-power – they're zero-power. You can take the battery out, pop the display in a box, and come back to it days or weeks later and it'll still display the same image. Black and white e-ink displays are becoming more common (and affordable). However, colour screens are still a bit of a rarity. This month, we've been testing the latest offering from Pimoroni: the Inky Frame 4.0.

Below ◈
As well as a battery connection, there are two STEMMA QT/ Qwiic connectors and a header with six GPIOs



The '4.0' refers to its diagonal size in inches (just over 10 cm). That's the actual screen part of the 640×400 pixel display – there's also a pinkish-purple surround. It is the second in the series and joins the original 5.7-inch display in Pimoroni's line-up.

E-ink displays don't create colours in quite the same way as most electronic displays. This screen has seven inks (black, white, red, green, blue, yellow, and orange). Each pixel can only be one of these colours, but you can mix them slightly by making adjacent pixels different colours – a process known as dithering. The results aren't crisp images, but do have a certain charm. There's an element of 8-bit era computer graphics about them (but they're much higher spatial resolution). False contours are a particular feature, especially around skin tones. Blocky, cartoon-like images will display better than photos, but that's not to say photos look bad.

You can't really judge e-ink screens in the same way you judge other screens, though. Absolute image quality is important, but so is surface finish (in this case, very slightly glossy), and how well it looks in daylight (in this case, excellent).

The e-ink display is controlled by a Raspberry Pi Pico W, and has associated gubbins to help this run, including an SD card slot for storing images on and five buttons.

LOW POWER

The ability to run a display for long periods without changing or charging the batteries is a major selling point of e-ink displays. It lets you hang a piece of

Left We've left this image unedited so that you can see the screen as our camera sees it

art on the wall and leave it to itself to display new images periodically.

The Inky Frame can run for long periods on very little power because it has an external real-time clock. This hardware can turn off the Pico W entirely and wake it up at a particular point. When Pico W wakes up, it will start again as though it's just been powered on, so you have to design your code accordingly. You can also wake it up via a button press or an external trigger.

> It's conceivable that you can make a photo frame that updates daily **and runs for a year on a single set of batteries**

This deep sleep is only accessible from the battery JST connector (not when powering from the USB port). You can power this using three AA batteries or a LiPo (there is no battery protection or charging support in Inky Frame, though you could add a Pimoroni LiPo Amigo if needed).

We ran some tests and found that you can wake up Pico W, open an image from the SD card, and display it on the screen, then go back into deep sleep using just 0.16mAh from a 5 V battery (or slightly more at 4 V). It consumes between 20 uA and 40 uA while in deep sleep mode (depending on voltage, with 20 uA at 2.8 V and 38 uA and 5 V).

The actual amount of time batteries last will depend on how often you wake up the screen, the particular batteries you have, and the temperature you're running them in. It's conceivable that you can make a photo frame that updates daily and runs for a year on a single set of batteries, but we haven't had time to fully test this yet.

SOFTWARE

Pimoroni maintains its own blend of MicroPython, which comes preloaded on the Inky Frame. This includes the ability to decode and display JPEG images with just a couple of lines of code. There are also drawing functions and the ability to download images from the internet. Putting the Inky Frame in a timed deep sleep mode so that it wakes up at a predetermined point in the future is also done with just a single line.

We're very impressed with the Inky Frame – both the hardware and the software are well thought-out and implemented. Pimoroni has taken a great colour e-ink screen and made it easy to use. The MicroPython support is excellent, and this makes it a truly accessible piece of kit for anyone with a bit of programming experience. It's ideal for displaying art or information. Well, whatever you like, really.

VERDICT

Looks great and is easy to use.

10/10

Raspberry Pi Camera Module 3

The most popular maker camera gets an overhaul

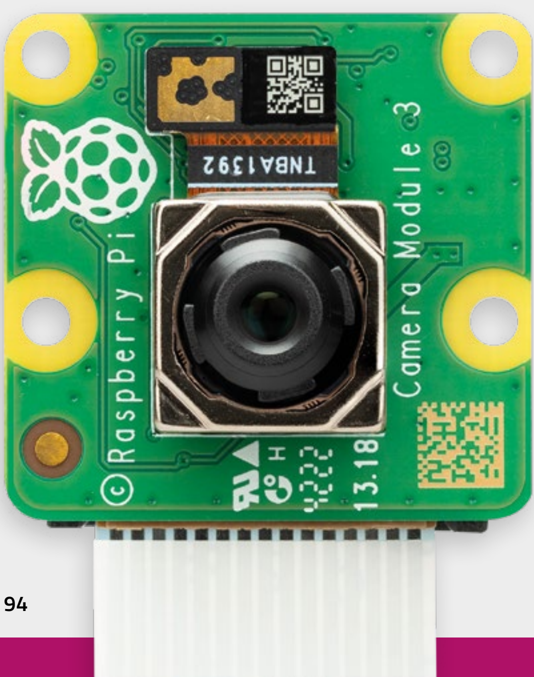
RASPBERRY PI LTD $25 | raspberrypi.com

By Ben Everard @ben_everard

The headline feature of almost any digital camera is the number of pixels, and all versions of the Raspberry Pi Camera Module 3 have 12-megapixel sensors – a 50% increase from the 8MP sensor on the Camera Module 2.

While most cameras are designed to take pictures for humans to look at, that's not always the case with Raspberry Pi cameras. They're just as likely to take photos that are analysed by AI, and there are different things that computers and humans take from images. For example, our jelly-filled-skull-holes might appreciate the crispness of an extra 50% of pixels, but to the cold silicon of an artificial intelligence, that means 50% more information to process. Feeding the full 12 million data points would choke all but the most powerful machine learning brains, but it does mean you can zoom into smaller areas than you could with the previous cameras. In this case, more pixels means more range.

Below The Camera Module V3 has the same mounting points as the V2, but the camera itself is a slightly different shape, so won't fit into all enclosures designed for the previous version



While the extra pixels are a nice bonus, they're – for us at least – not the most exciting things about the Camera Module V3. The two new features that we're most interested in are the high dynamic range (HDR) support and autofocus.

When taking a photo, you have to expose the sensor for a certain amount of time. This, combined with the aperture (size of the opening that light passes through), determines how bright or dark the image is. The sensor has particular limits, so that if not enough light hits a pixel, it's completely black. If too much hits it, it's completely white. This causes a problem if part of the scene you want to capture is light and the other part is dark. If you set the exposure correctly for the light part, the dark part ends up being black (or very dark). If you set the exposure correctly for the dark part, the opposite happens.

HDR lets you apply different exposure settings to different parts of the image. Once upon a time, photographers would take multiple images, each with different settings, and then manually combine them to create one image. However, modern hardware – including the new Raspberry Pi Camera – can do this automatically. This mode is limited to 3 megapixels, but the results are typically much better-looking images than 12MP non-HDR images, especially in environments that aren't specifically lit for photography. In our experiments, for anything other than cases where you needed the full resolution (such as print-ready images), HDR gives an easy visual boost to most images.

The new Camera Module brings in autofocus, which means that you can now capture images of things as close as 10 cm, or as far away as you like, without any problems.

Obviously, if only part of the image is in focus, this begs the question – what part? By default, the camera

Right
When St. Etheldreda built a church in 672 AD on the East Anglian plains, she couldn't have imagined that the buildings would survive through hordes of Vikings, Normans, and now camera testers

will attempt to keep the centre of the image in focus, but you can adjust this in your code. Whichever area you select, the camera will use phase detection to find the optimum lens position to keep it crisp and in focus. While shooting video, it can adjust as the subjects in the frame move.

One of the problems of reviewing the Raspberry Pi Camera Modules is the sheer range of uses that they can be used for. Some people use them to build cameras. Some people use them for AI robots. Some people use them as webcams. To help keep the camera as relevant as possible to as many people as possible, it comes in a few options. All of them have HDR and autofocus, but they have different lenses and filters.

WIDE SHOT

The Camera Module V3 comes in normal and NoIR formats – the latter having the infrared filter removed, which means it captures more light and can be used with 'invisible' IR illumination to create a night-vision-like effect.

Both normal and NoIR have regular and wide-angle lens options. Wide-angle means that the camera captures a wider arc of the world in its image (120 degrees, rather than the standard 75). The flip side of this is that more of the world is spread across the available pixels.

Things like security cameras, and possibly robot cameras, will benefit from the wider field of vision, whereas, if you're more interested in the things right in front of you, the standard lens will work better.

All these are the same size and connect in the same way, and they can all be controlled from software. However, the results are quite different, and which one is best for you depends a lot on what you want to do with it. Together, they offer a fantastic range of possibilities for embedded computing projects.

The Camera Module V3 is a huge improvement over the V2 in just about all areas of image quality, while still retaining the programmable control that makes it such a useful platform.

Below
The NoIR versions have a black PCB, but otherwise look identical to the standard versions

VERDICT

HDR and autofocus bring big image quality improvements to this maker camera.

10/10

CROWDFUNDING NOW

Make 100

Start the new year with something new

Usually, we look at a crowdfunding project each month, but this issue, we'll do something a little different. January is Kickstarter's Make 100 month. The idea behind this is to encourage creators to start the year with a smaller project. It can be in any area, but the rewards must be limited to 100 of whatever it is you are producing. This, unsurprisingly, is particularly popular with people making things by hand, so there are plenty of interesting things in the fields of textiles and art.

There are loads to choose from, but here are a few of our favourites:

- Some gorgeous hand-painted, biological-inspired plates. The black-on-white designs feel particularly appropriate for this time of year: **hsmag.cc/plates**

- Yarn is the 3D printer filament of the textiles world, and just like 3D printer filament, the colour can be as important as the material itself. In this case, it's not just the colour, but a range of colours that blend together, one after the other: **hsmag.cc/m100yarn**

Left
Each project has just 100 available

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.

- Colour is added to glass using rods of glass with very concentrated colour. When bits of these rods are added to clear glass, they change its colour. However, it will come as no surprise that glass is brittle and can break. This can leave little bits of coloured rod that are too small for many uses. To prevent wasting these, Big Eddy Glass Works is creating 100 Colour Bomb Wonder Cups, with little pops of colour: **hsmag.cc/colourbomb**

- Last issue, we looked at needle felting, a technique for essentially tangling fibres together to make 3D sculptures. Jennifer Harris is using this method to create a series of 'Tiny Worlds', each one captured inside a glass jar: **hsmag.cc/feltworlds**

These are just a few that captured our eye. You can see everything at **hsmag.cc/make100**.

We'd love to see some short-run electronics in future years, but we couldn't find any in this year's range. There are a few bandwagon-jumpers who are running larger campaigns and just adding in a single reward tier which is limited to 100. This is within the rules of Make 100, but to us at least, it feels against the spirit.

Make 100 campaigns can run for up to 60 days (although Kickstarter recommends 30 days), and must launch in January. For many artisan makers, the start of the year can be a lean time after a busy November and December. The Make 100 project feels like a great way of supporting small makers, while also getting yourself a unique, limited-edition item.

> **"For many artisan makers, the start of the year can** be a lean time after a busy November and December"

Right There's no need to waste spare colour

next month

230322 ×05

issue #65

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