HackSpace

TECHNOLOGY IN YOUR HANDS

BUILD THE

INTERNET OF THINGS

Homemade projects to connect your life

PINHOLE CAMERA

Inside the DSLR of the olden days

SHADOW CLOCK

Master time with a Raspberry Pi Pico

FLAT-PACK ROCKETRY

Build flying machines the IKEA way

TILES PLANTS KEYBOARDS LEDS

Welcome to HackSpace magazine

The Internet of Things is, in theory, full of promise. It can mean our devices talking to each other and creating a seamless user experience – your alarm clock and coffee maker working together, your heating and car's navigation system making sure your house is warm when you arrive home, your washing-machine and solar panels making sure you clean your clothes when there's free electricity. However, somehow it never quite ends up like this. At least, not with off-the-shelf equipment.

Never fear, though. We are makers, and if we can't buy what we want, we'll make it. In this issue, we're taking a look at some of the best, most useful, and most innovative DIY smart home gadgets and gizmos. They're here for you to take inspiration from to build your very own high-tech haven. After all, it's 2022. We may not have flying cars yet but we can, at least, make our appliances talk to each other.

> In this issue, we're taking a look at some of the best, most useful, and **most innovative DIY smart home gadgets and gizmos**

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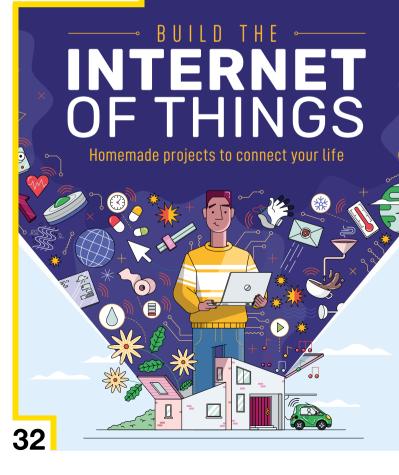
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LED Sphere

By **Tom Verbeure** 🖅 **github.com/tomverbeure**
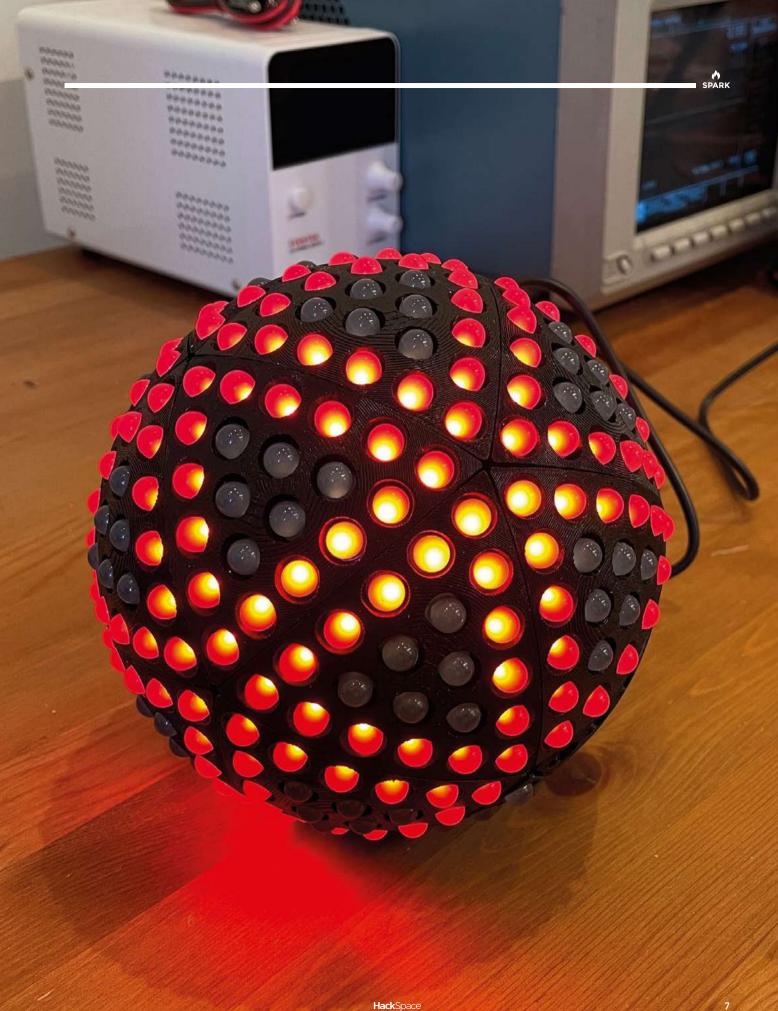
n our interview with Debra Ansell, on page 50, we briefly discuss some of the challenges of making an LED sphere. Debra solved this by arranging surface-mount LEDs on a flat plane, then diffusing the light through curved 3D-printed parts. Tom Verbeure has gone down a different route with this creation, using larger through-hole components placed into a 20-segment, 3D-printed sphere. There's always more than one way to do it, and no one way is better than any other, as this build shows. ◻

Right ◈
Tom's build is hollow in the middle, and is battery-powered
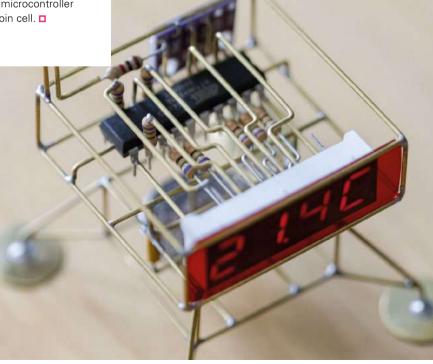
Free-form circuit structure

By **Mohit Bhoite**   bhoite.com

Individually cut brass rods must be a pain to work with.** Unlike copper sandwiched between layers of PCB substrate, copper wires aren't obliged to stay where you put them; just a single wobble, a single component out of place makes the whole thing look wrong.

Knowing that, and how hard it is to produce a free-form circuit sculpture, makes us appreciate Mohit Bhoite's work all the more. This tiny model lunar lander does nothing but display the temperature, but it does it with such panache that we've got to include it here. Components, as well as function, are minimal: he's used an ATtiny861A microcontroller and a BME280 sensor, powered by a CR2032 coin cell. ◻

Right ↗
Since building this sculpture, Mohit has made a version with a binary, rather than a seven-segment, display

Digital zoetrope
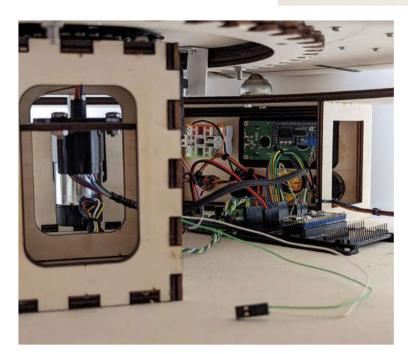
By **Brian Corteil**   twitter.com/CannonFodder

Before we invented television, humans were grasping at moving images for a while. One forerunner to the idiot box, which uses persistence of vision and a series of slightly different images to create the illusion of movement, is the zoetrope.

Prolific maker Brian Corteil has made this beautiful digital zoetrope, which uses 20 Pimoroni Badger E Ink® screens to display the images, a Raspberry Pi 4, and a beautiful body fabricated from laser-cut 3 mm and 5 mm plywood. ◘

Right ◈
Because it's digital, users can update the images with their own choice of animation

Ion Thruster

By **Jay Bowles** ⬈ **youtube.com/c/PlasmaChannel**

on thrusters are fascinating things, producing tiny amounts of thrust that are pretty much useless on Earth (with our inconvenient gravity). They're far more useful in space however, as they're smaller than rocket engines, and they don't need atmospheric oxygen like a jet engine.

Ion thrusters are old technology, having been used since the 1950s, and now Jay Bowles, of the fascinating YouTube channel Plasma Channel, has demonstrated a way to make it better: multiple stages. By varying the input voltages and spacing between stages, Jay's been able to experiment and produce a claimed exhaust velocity of 2.3 m per second. ◻

Right ◈
It still amazes us that one person working alone can create space-grade technology

Sawtooth organ

By **Blinkyparts**
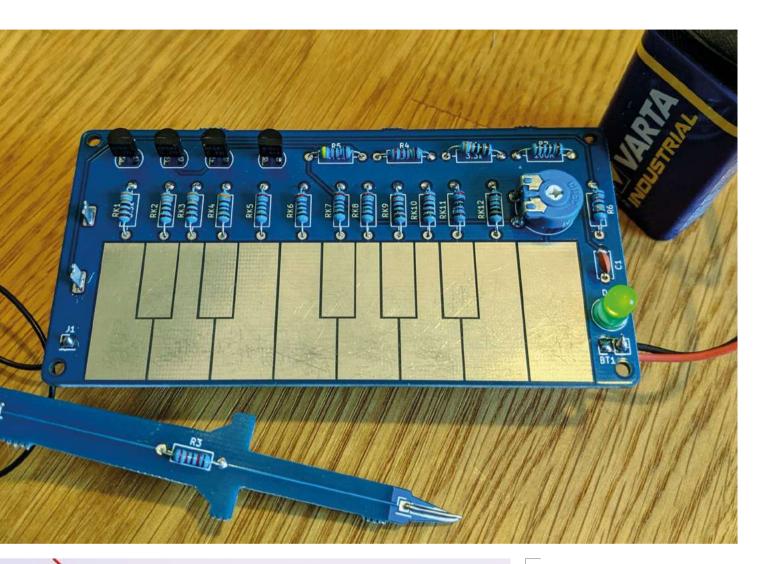
hsmag.cc/SawtoothOrgan
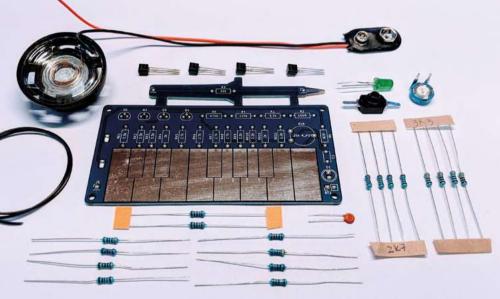
Electronic music is a fascinating hobby. You learn an awful lot, you spend a fortune on components and, in the end, you get a small box that makes a wobbly noise that's barely different from all the other circuits you've spent hours putting together.

Jokes aside, the learning curve for homemade analogue synths can be incredibly intimidating. So this circuit, which is priced at $9.99 on Tindie, is an inviting breath of fresh air. It's a sawtooth organ, which uses just a handful of components to make notes when the user presses a stylus onto a keyboard. That's it, and the simplicity means that anyone with a soldering iron will be able to put it together and bash out simple tunes.◻

Wind Tunnel

By **Jude Pullen**   **hsmag.cc/WindTunnel**

Designer extraordinaire Jude Pullen has designed this desktop wind tunnel to be built cheaply: it's made of card, wood offcuts, PVC piping, and some clear acrylic sheets for the sides, plus a set of digital scales. And it's cheap on purpose; this project was commissioned by The Design And Technology Association, which supports schools teaching design and technology. This subject has, in England and Wales, had its funding cut by over 70% since it was first introduced to the curriculum, so teachers need cheap ways to demonstrate the principles of design.

This is a minimal setup; all it measures is the force applied to the scales, from which the user can compare the lift generated by different wing designs. If you wanted to go deeper into engineering, you could add a manometer to measure pressure, an anemometer to measure wind speed, and a tachometer to measure fan speed. There's also scope to introduce some sort of vapour to visualise the airflow. ▫

Right ↗
Build your own aerospace engineering equipment for just £20
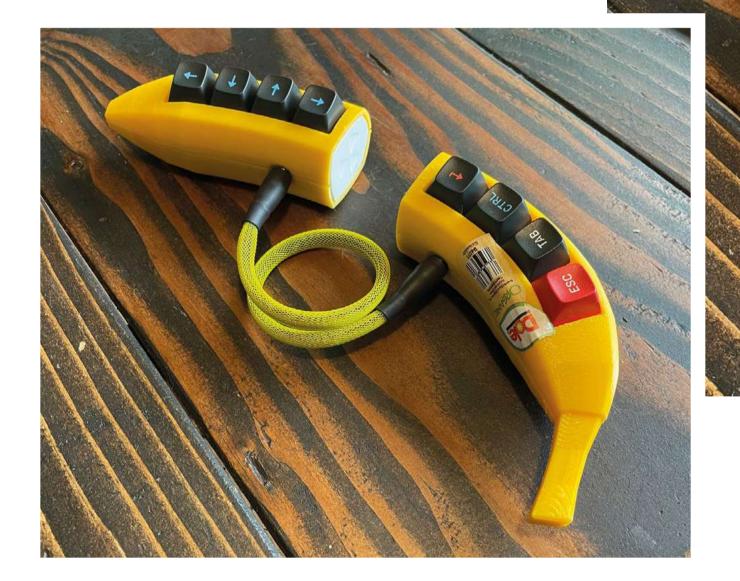
Objet 3d'art

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

If this build looks familiar, it's because its maker, Dan Bostian, has based it on his previous project, the **Banana Macropad.** That device comprised eight mechanical keyboard buttons and a wired USB connection, housed in the shape of the internet's favourite fruit, the banana. The Banana Split is all that and more: instead of a wired connection, this little keyboard uses Bluetooth, and it's split into two for more ergonomic banana usage. Yes, this device is silly, but it's bright yellow and we like it a lot. ◻

↗ **hsmag.cc/Banana**

Green ideas for the red planet

How would we live on Mars, and what can
this teach us about sustainable life on Earth?
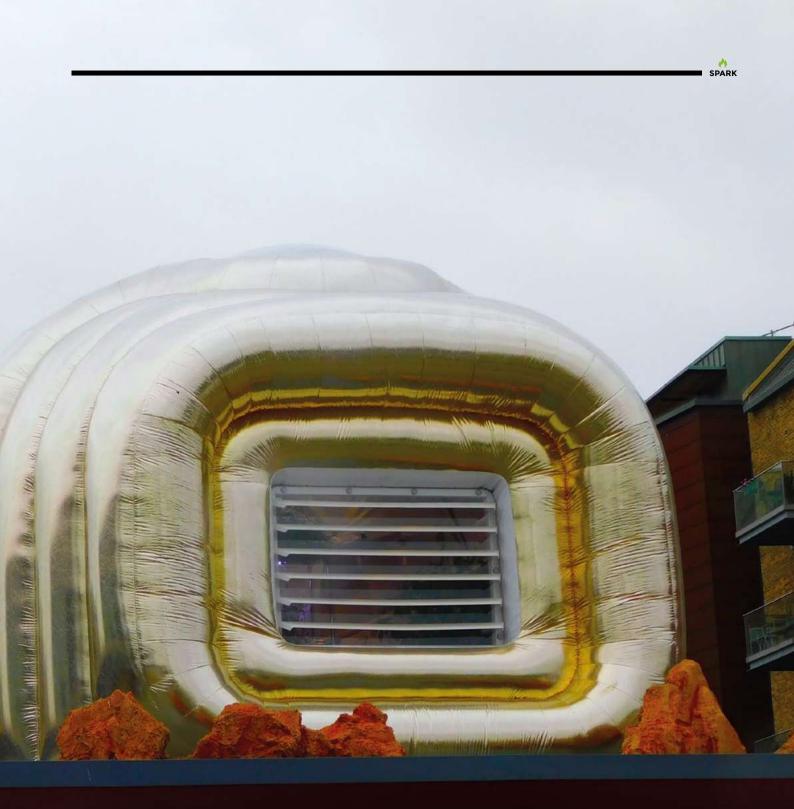
Sure, making stuff on Earth can be challenging, but what if you didn't have access to next-day delivery on kit and materials? What if you just didn't have access to a huge range of items at the click of a button? That's exactly what you'd have to do if you were a colonist living on Mars. It also happens that the same things – working with limited resources, thinking carefully about material choices, and reusing waste streams wherever possible – are also critical to sustainability here on our very own space rock, planet Earth.

Building A Martian House is a project by two artists – Ella Good and Nicki Kent – with collaboration from a large team of engineers, scientists, architects, and others, that aims to explore the challenges of living on Mars, while simultaneously exploring ways to not destroy Earth. →

Right ◈
**Is this what
our first extra-
terrestrial colony
will look like?**
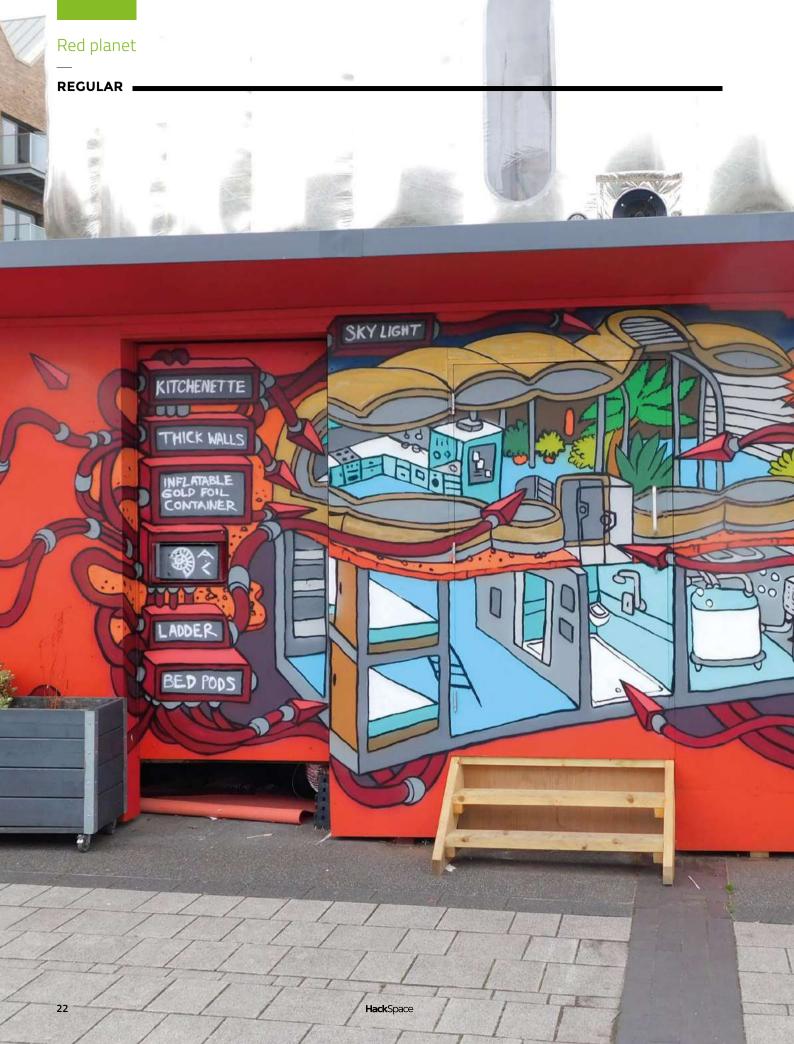
BUILDING A
MARTIAN HOUSE

An artwork by Ella Good and Nicki Kent,
in collaboration with Hugh Broughton Architects,
Pearce+ and the people of Bristol.
Presented in partnership with M Shed.

The building itself looks a bit like an inflated silver-foil tent – basically, it is. The reflective foil is designed to protect the inhabitants. On Mars, the foil would be packed with soil (which can potentially be hardened with bacteria), but here on Earth – under our protective blanket of atmosphere – it's been inflated with air to allow it to be taken down and re-used elsewhere once this exhibit finishes. The two floors of the house are both above ground here, but on Mars, the upper floor would be at ground level, and the lower floor would be underground.

> While much of the space is – out of necessity – very utilitarian, **there are some comforts**

While much of the space is – out of necessity – very utilitarian, there are some comforts. The window on the upper floor is to let the inhabitants take stock of their surroundings. However, the limited protection from solar storms would mean that sometimes inhabitants would have to retreat downstairs for protection. Part of the project is thinking about how to balance the harsh environment with some little touches that, while not strictly necessary, help make life a little more pleasant.

This idea of balancing the emotional and social needs of humans with the constraints of off-Earth life is a recurring theme in the Martian House project. Should humans ever make it to Mars, this may well →

Left ◆
Could you live with just these essentials?

prove to be a significant challenge as it's hard to analyse scientifically. There's no unit for relaxation, or equation to balance the joy of a sunset versus the pleasure of a hot bath. Push a person too far, and they'll crack, but if they require too much, then the mission may never get off the ground.

How much would you give for music? Would pre-recorded tunes be enough for you, or do you yearn to play or hear music live? How hard is it to turn scrap material into a working guitar? Using just 6g of his fictional four-monthly 20g allowance for guitar strings, Julian Parsons built a working electric guitar from scrap that could conceivably be found in a Martian colony (at least, for a price). The fretboard is made from wood inlaid with wire, the tuners are nuts and bolts, and the pickups are made from a broken electric motor.

Building instruments from cast-off materials is a process that's probably about as old as music, and there's no reason to think that it'll stop once we escape the confines of this green-and-blue orb. However, what form will Martian music take? Science fiction has led us to believe that electronic tunes will rule the airwaves of other planets, while Julian makes the case for a guitar. The reality will probably be dictated by the tastes and skills of the first settlers – will they be plucking strings or noodling with synthesizers?

Humans are fundamentally social animals, and one of the hardest parts of living on Mars might be the people you leave behind. Assuming there's not some

> **Science fiction has led us to believe that electronic tunes will rule the airwaves of other planets**

mass exodus, the chances are that at least some of your loved ones will stay behind, if not permanently, at least until the colony is set up.

While you can email, a handwritten note is a much more personal item, yet it's unlikely to be realistic to send paper backwards and forwards. Liz Lister explored the possibility of creating digital files from handwritten notes and then plotting them with pen remotely. Although this test didn't include sending it from space, it did create a more intimate connection than a UTF-8-encoded email.

You can read more about Julian's musical adventures, Liz's plotter tests, and other experiments around Martian life on the Martian House blog at **hsmag.cc/MartianHouse**.

While the Martian House was designed in consultation with scientists, engineers, architects, and people with a vast range of skills, the main benefits from the project – at least for us – aren't prototypes or specific bits of technology, but questions and frame of reference for asking them. In a way, it's perhaps a bit more like a live version of science fiction than part of the space program. □

Letters

PIXELS WITH PURPOSE

Thanks for the interview with Alpenglow's Carrie Sundra; I was aware that citizens in Washington DC can't vote for president, but I had no idea that US citizens in the overseas territories can't, and I like to think I'm pretty clued up when it comes to politics. Thanks to her for highlighting this.

David
Boston

Ben says: One of the many things we like about Alpenglow is that it has come out of one person's desire to make things, and if other people like them too, then fair enough. There's no market research team that would have come up with a light-up capacitive touch swear-word-emblazoned unicorn, but Carrie brought it into the world, and the world likes it. Also, voting is important.

VORON
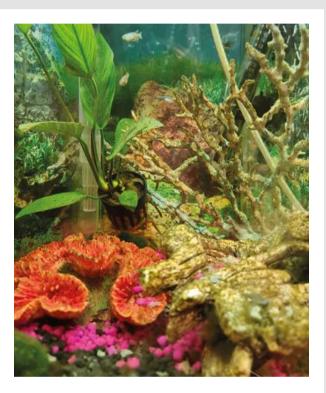
Voron reminds me of 3D printing before it got taken over by the buzzwords and hype of the MakerBot era. No, not every home is going to have one; no, a 3D printer cannot just magic you up any object you desire; it's not like the replicators in *Star Trek* or *Red Dwarf*.

What 3D printing is, or at least what it should be, is open, accessible, and accurate without being prohibitively expensive. I think the team behind Voron gets this, and I'm glad to see them getting some credit.

Brian
Kent

Ben says: **We agree, which is why we put Voron on the cover last issue. We'll be honest with you, it was a monumental task to print out all the components, but once we got it all put together, we can see why Voron is making waves: it's a leap forward in quality for the price. Of course, that's the financial price; the time it takes to print the parts should be considered as part of the total cost of ownership, but when you enjoy the process, it's all part of the fun.**

AQUAPONICS

I intend to follow your tutorial on aquaponics when I've cleared out an appropriate space in the garage. The variety of fresh salad leaves in the shops has taken a hit since Covid/Brexit/your supply shock of choice, and a fun, cheap, maker-friendly way of growing my own through the winter will be a great way to keep me fed. I don't know what I'm going to do with the fish, though…

Robert
Manchester

Ben says: **Five years ago, when we first discovered aquaponics, we were surprised by the addition of living animals to a traditional hydroponics setup (that's the key difference between the two). On a large scale, that makes sense, as with a decent amount of biomass in the system, you can grow fish large enough to eat. On a smaller scale, that's out of the question. Either way, we'd recommend the kitchen; you're effectively providing an environment for the fish, so it seems wrong to shut them away in the garage.**

CROWDFUNDING
NOW

Raven CNC

A CNC that fits in your workshop

From $2729 | hsmag.cc/Raven | **Delivery:** May 2023

C NC routers are great bits of kit – they can cut out **parts from wood with an accuracy that (we, at least) can only dream of.** Simply load up your wood, press a button, and drink your coffee while your robot assistant carves out your work. Then, when it's finished, remove the work and take credit for it. Perfect.
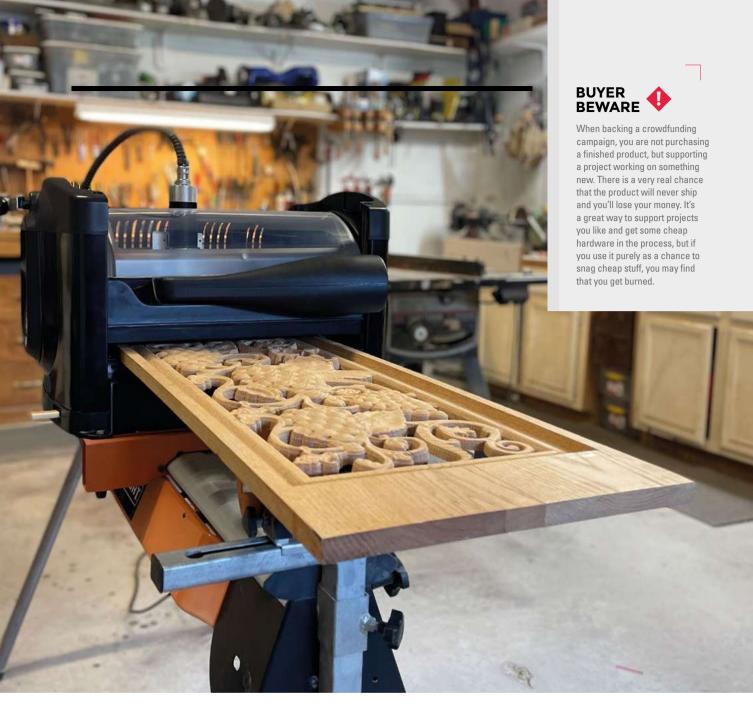
However, it's not quite perfect because CNCs come with one big caveat – they're huge. Unless you have a workshop like a YouTube wood influencer, you're probably going to struggle to fit in a CNC large enough to do serious woodwork (or if you do, it might end up being the entirety of the workshop).

Raven is an interesting solution to this problem. It's a 'feed-through' CNC, meaning that the cutting head moves across and the wood it's cutting moves through it, a bit like paper moves through a printer. While this does need a lot of space when it's working, it's a fairly small machine to tuck away when you're finished with it. The main downside of this approach is that you're limited to wood 39 cm wide (though it can be up to 365 cm long).

We've not tested this out, so don't know if it works as well as claimed, but we really want it to because it seems like a great solution to a very common problem. ◻

Above ▨
While 39 cm might seem narrow, you can fit a lot in

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Uncover the technology that's powering the future

AMAZING
IOT PROJECTS

Be inspired by these wide-ranging projects
to create your own **Internet of Things** devices,
whether useful or just for fun

BY PHIL KING

The Internet of Things (IoT) enables devices to 'talk to each other' by exchanging data over networks. Commercially available IoT devices include smart fridges, central heating thermostats, fitness trackers, and video doorbells. But, with a single-board computer or microcontroller, you can create your own DIY IoT device, as the makers of the wide range projects covered in this feature have done.

One of the most common uses of IoT is in home automation, such as for automating the drawing of blinds and curtains. Garage doors, fans, central heating zones, and pet feeders can all be controlled remotely from afar, whether by human interaction on the web or automated from sensor readings or timings.

To make your daily household tasks easier, homemade smart appliances include a smart fridge that monitors its contents, along with a smarter robot vacuum cleaner, washing machine, coffee maker, mailbox, and even a bin that tells you when to empty it.

Some IoT projects involve the visualisation of data from the web, such as the classic magic mirror that tells you the weather and news as you check your hair in the morning. Others supply live railway information, the weather forecast, and even bin collection alerts. Or you can play internet radio stations from around the world by spinning a physical globe.

IoT devices like a smart pill dispenser and pothole detector have a genuine use case and social benefits, while others are made just for fun, such as a jelly bean-pooping rainbow unicorn! Whatever you want to make, with IoT, your imagination can run free. →
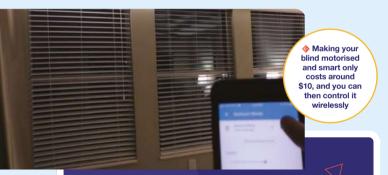
HOME AUTOMATION

Automate your home with the aid of **IoT** and you'll never need to draw the blinds again

↪ Making your blind motorised and smart only costs around $10, and you can then control it wirelessly

Motorised MQTT Blind

MQTT is a popular lightweight network protocol used in many IoT projects, enabling the sending of machine-to-machine messages using a broker and one or more client devices. For this project, The Hook Up YouTube channel demonstrates how to use it to control a DIY motorised blind via WiFi, from Alexa, Home Assistant, or SmartThings.

A standard Venetian blind was motorised with the addition of a stepper motor – a previous attempt using a servo was abandoned because it whined continually while adjusting its position. A cheap unipolar motor was converted to bipolar to provide the necessary torque to tilt the blind slats to the full extent. A 3D-printed adapter was made to fit the motor to the blind's tilt rod.

A NodeMCU microcontroller receives MQTT messages and controls the stepper motor. Code and STL files for various size adapters and a mount are in the GitHub repo. Alternatively, you could try automating your curtains: **hsmag.cc/mqttcurtains**.

➜ **hsmag.cc/MQTTBlind**

Smart Window Fan

Keep your home cool during summer with this smart window fan which turns on automatically whenever the outdoor temperature is lower than that inside. Rather than using an exterior temperature probe, this project receives the latest data from **Weather.com**, which maker Ishmael Vargas says is accurate enough. Interior temperature is monitored with a DHT22 sensor connected to a Raspberry Pi Zero W running a Python script.

To keep things simple, the fan is connected to a smart WiFi power plug rather than a relay switch. A dashboard running on Raspberry Pi using Pygame can be accessed from a smartphone with the VNC Viewer app, enabling you to view info and set the target temperature.

For a more ambitious project, you could even tint your window automatically according to the light level, and control it via an iOS app: **hsmag.cc/smartwindow**.

↪ A Raspberry Pi Zero is wired to a DHT22 sensor to monitor the room temperature; the external temperature is sourced from the web

➜ **hsmag.cc/WindowFan**

ThermOS

Smart thermostats are becoming ever more popular, enabling you to control your central heating system remotely, but commercial off-the-shelf models can be expensive and have limitations. A DIY option like Joe Truncale's ThermOS offers more flexibility for less outlay.

Needing a new smart thermostat to replace the six old thermostats controlling his complex and ageing home heating system, Joe opted to build his own solution powered by a Raspberry Pi 4. With Apple HomeKit integration, he can control his system's six heat zones for different rooms from his iPhone.

The Raspberry Pi is the brains of the operation, programmed in Python and making use of the HAP-Python HomeKit framework. It's connected to six relays to turn each heating zone on or off individually. DS18B20 temperature sensors, one for each room, are connected to the system using the existing thermostat wiring in the walls.

➔ **hsmag.cc/ThermOS**

⬥ Housed in a plastic case, the homemade ThermOS smart thermostat cost around $155 to build

Hands-Free Garage Door

The ultimate in convenience is a hands-free garage door that opens at the press of a button, so you can drive straight in – assuming your garage isn't full of junk like ours. When spilt coffee caused Andrew Pena's remote controller to fail, he looked into replacing it with a homemade version. As a newbie maker, he says he learned a lot during the seven months creating this IoT project.

Based around a Particle Spark Core board equipped with a high-power relay shield, it makes use of the IFTTT (If This Then That) service to open the garage door when an icon is pressed on a phone. To check the door's position, the original plan was to use a magnetic reed switch, but he eventually opted to use an old phone camera for visual confirmation.

Alternatively, you could use a Pico W to create a sensor to notify you of your garage door's position, as Jeff Geerling did, using ESPHome and Home Assistant: **hsmag.cc/PicoWGarage**.

➔ **hsmag.cc/GarageDoor**

⬥ Housed in a 3D-printed case, the device operates the LiftMaster door opener when triggered on a phone

"
WHEN ACTIVATED – BY A TIMER OR FROM A PHONE DASHBOARD – IT MAKES A BEEPING NOISE TO ATTRACT THE PET
"

Pet Feeder

As well as using smart home automation to control blinds, curtains, and other devices, why not extend it to your pets? This IoT food dispenser enables you to feed your dog or cat the smart way. When activated – by a timer or from a phone dashboard – it makes a beeping noise to attract the pet, which is detected by a PIR motion sensor; a servo is then triggered to rotate the dispenser (a Coke bottle with a 3D-printed top) to drop the food into the bowl.

Devised by the **circuit.io** team, the project runs on an Arduino Uno equipped with an ESP WiFi module to connect to the internet. The phone controller was created using Freeboard (**freeboard.io**), which makes it easy to design interactive IoT dashboards.

Other IoT pet projects include a cat-weighing litter tray (**hsmag.cc/LitterTray**) and GPS tracking vest (**hsmag.cc/IoTKitteh**). ➔

⬥ 3D-printed parts were made for the sensor, speaker, and server housings, along with the dispenser

➔ **hsmag.cc/IoTPetFeeder**

SMART
APPLIANCES

Make dumb household appliances smart with the addition of **IoT** connectivity

◈ Power is supplied by a portable phone charger; the list of items is read out on a Bluetooth speaker

Smart Fridge

Sure, you can buy commercial smart fridges these days, but where's the fun in that? This project enables you to turn any standard refrigerator into a smart IoT one with a camera view and machine learning to identify the contents.

A Raspberry Pi is placed inside the fridge and equipped with a Camera Module pointing at the interior, and a USB LED to provide light when the door is closed. The AWS Rekognition API is used to identify items and create a list of the fridge contents. With the use of a text-to-speech API, the list can also be read out as audio via a Bluetooth speaker. Maybe you could even add Alexa voice control?

Alternatively, you could build an IoT fridge/freezer monitor to send data to a web dashboard, with alerts, as the aptly named Rick Kuhlman did: **hsmag.cc/FridgeMonitor**.

➔ **hsmag.cc/SmartFridge**

Laundry Spy

Want to make your washing machine smarter and send you a notification when the laundry cycle is finished? It's fairly easy to do with a microcontroller and a sensor. For his Laundry Spy, Andrew Dupont used an ESP8266-based NodeMCU board, housed inside a small 3D-printed case, connected to two tiny accelerometers (also in cases) – each being mounted at the rear of his washing machine and dryer respectively, to sense the vibrations.

For IoT communication, Andrew used the MQTT protocol to send messages from the NodeMCU to a Raspberry Pi running a Node-RED home automation program. This, in turn, sends a notification to his phone via the Pushover service.

An alternative approach is to sense the washing machine's LEDs using a photoresistor – as done by 'bitluni', who also added a servo to press the start button: **hsmag.cc/SmartWash**.

◈ The Laundry Spy is attached to accelerometers on the rear of a washer and dryer, to sense when the cycle is finished

➔ **hsmag.cc/LaundrySpy**

"IT'S FAIRLY EASY TO DO WITH A MICROCONTROLLER AND A SENSOR"

> The transparent case is connected to the Roomba's bumper sensors, to detect if it catches the underside of furniture

PiRoomba

Robotic vacuum cleaners can navigate their way around a room, but some models aren't all that smart, taking a semi-random route that's likely to cover any given spot multiple times. Peter Wallis decided to modify his Roomba 530 to make it smarter.

To this end, he mounted a Raspberry Pi on the top and connected it to the Roomba's serial port to communicate. The Raspberry Pi is protected by a clear plastic bubble that's also connected to the Roomba's bumper sensors to detect if it catches the underside of furniture. To control the robot, Peter wrote a Java package to implement the Roomba Open Interface, making use of the RXTX library. In addition, he created a simple GUI with sensor levels and a virtual joystick to steer the Roomba from a remote computer on the network. Perhaps you could go one better by adding a camera for a vacuum's-eye view?

➔ hsmag.cc/PiRoomba

K-Fee

Boiling the kettle to pour your own hot drink is so last century. Created by four French engineering students, K-Fee is a smart connected coffee machine that lets you use a web interface to choose your strength and size of coffee and how many sugars you want in it – or select an existing recipe. There's also the option to make your drink at a specific time and date.

3D-printed components include a funnel each for coffee and sugar, with distance sensors in the lids to check the levels, and stepper motors attached to screws and discs to dispense the contents. A proximity sensor checks that a cup is in place. Sensors and motors are connected to an ESP32 board, which communicates via MQTT with a Raspberry Pi 3 that hosts the web server.

An alternative IoT hot drinks project, the Teasmade 2.0 is a modified vintage tea-making alarm clock that takes orders via Google Calendar: **hsmag.cc/Teasmade2**.

➔ hsmag.cc/KFee

> The K-Fee comprises numerous 3D-printed parts, including funnels to hold the coffee and sugar

Smart Waste Bin

Most bins are a bit rubbish compared to this one created by a team of students in Thailand with the aim of preventing public bins overflowing. To supervise the state of the trash placed in it, the smart bin incorporates several sensors linked to an Arduino board.

Crucially, an ultrasonic distance sensor in the lid detects how full the bin is. It also includes sensors for flames (in case something catches fire), temperature/humidity, and moisture (both indented for use in a composting bin), along with a microswitch to detect the bin opening.

To communicate the readings over a long range, a Sigfox gateway is used with a LoRa antenna. The MQTT messages are read by a Raspberry Pi 3 which functions as an application server using a Node-RED back-end, MariaDB database, and web application to show all the data.

A similar project is this IoT mailbox enabling you to check your mail remotely: **hsmag.cc/IoTMailbox**. ➔

➔ hsmag.cc/SmartBin

> The components are fitted into a 3D-printed case mounted near the top of the bin

DATA
VISUALISATION

IoT projects to bring data from the web into the physical world for your viewing or listening pleasure

◆ You could build a smaller magic mirror, such as this one with a 3D-printed case by GeekToolkit

Magic Mirror

Building a magic mirror is one of the most satisfying and achievable IoT projects for new makers. The basic build comprises a display, such as an old monitor or TV, and a sheet of special two-way mirror acrylic mounted together in a frame. Your magic mirror doesn't have to be full-size either: you could make a mini version using a small screen, such as this one: **hsmag.cc/MiniMirror**.

Magic mirrors are often powered by a Raspberry Pi, in which case you can use the ready-made MagicMirror² software (linked below) by Michael Teeuw, which offers all sorts of modules to show you the latest weather, sports, news, and much more. You can also embed video feeds, such as from YouTube, and connect your mirror to your own calendar. You can even link it up to Alexa, Google Home, and others to issue voice commands. The possibilities for customisation are almost endless.

➜ **magicmirror.builders**

Weather Tide Clock

A popular use of IoT is to hook up some sensors and send weather data to a web dashboard. One example is to build a Raspberry Pi weather station with a Weather HAT and external sensors connected to the Adafruit IO service (see your author's guide in The MagPi issue 119: **magpi.cc/119**).

Fiona Hopkins took a different approach with her Raspberry Pi-based Weather Tide Clock, which offers a unique physical representation of data from the Dark Sky API. Constructed largely from laser-cut parts, including numerous tiny gears, it features a large wheel with a pointer to show the general weather conditions, while coloured LEDs indicate temperature and impending rainfall.

Another row of LEDs on the bottom displays the 24-hour forecast. Above that, a moving bar with two pointers shows when the two daily low tides will occur, with a chime sound played for low and high tides.

◆ The Weather Tide Clock offers a physical representation of weather and tide data from the web

➜ **hsmag.cc/TideClock**

Live CTA Railway Map

Mini train departure boards – such as this one: **hsmag.cc/TrainBoard** – are a popular IoT project, showing arrivals and departures from a station. Jordan von Mulert has gone one step further by creating a complete map of Chicago's 'L' elevated railway, lit up with LEDs to show the positions of trains at stations in real time.

Mounted on a wooden board, the map features 191 LEDs – one for each station – wired individually to pins on eight 24-channel PWM LED driver boards controlled by a Raspberry Pi Zero W. A Python script pulls data from the CTA API every seven seconds; when it reads an 'approaching station' flag for a train, it lights the LED for the corresponding station on the map, which also features a zoomed-in view of 'The Loop', a busy 1.79-mile long circuit on the railway.

Rather than soldering the huge number of connections required on the rear of the map, Jordan opted to use wire wrapping, which he says is a lot quicker and super-secure.

→ **hsmag.cc/LiveCTAMap**

⬥ Pulling live data from the CTA railway API, the map shows the positions of trains by lighting up station LEDs

RadioGlobe

⬥ Spin the globe and position the reticule to find a nearby radio station and play it

You may have come across the excellent **radio.garden** website where you can listen to radio stations around the world. Accomplished maker Jude Pullen – who we interviewed about his Good Air Canary IoT project in HackSpace #58 (**hsmag.cc/issue58**) – was inspired to make a RadioGlobe that offers similar functionality in a physical device made with 3D-printed parts.

The award-winning project enables the user to spin the globe and move an arm to centre the reticule on a location; when a nearby radio station is found, the Raspberry Pi-based device plays it. Two rotary encoders are used to read the reticule's position, to determine the correct latitude and longitude. Station info is shown on an LCD screen in the base, with a speaker and rotary knob to control the volume.

→ **hsmag.cc/RadioGlobe**

"IRIS DISPLAYS SINUOUS SHAPES OF VARIOUS COLOURS TO SIGNAL THE ARRIVAL OF MESSAGES"

Iris

Smartphone notifications are handy, but can mean we're perpetually glued to our phones to check them all. It's an issue that Davide D'Alessandro is seeking to address with his light-up desktop device, Iris, which displays sinuous shapes of various colours to signal the arrival of messages. The idea is that these won't negatively affect your concentration as much as phone notifications.

Based around an Arduino Uno, the device is made from 3D-printed components and features two RGB LEDs along with single-colour ones, with their light diffused by a polypropylene window. Favourite contacts can be set and assigned a particular colour, with a rotary knob used to select and play back messages.

Another notable light-up IoT notifier project is the BinDayCator (**hsmag.cc/BinDayCator**) created by Darren Tarbard to indicate when it's bin collection day, based on data pulled from his local council's website. →

→ **hsmag.cc/IrisNotifier**

WEIRD
AND WONDERFUL

With a bit of imagination, you can create all kinds
of **IoT** projects – for practical use or just fun

Texting Pot Plant

Many people talk to their plants to encourage their growth, but how about a plant that sends you text messages? That's the concept behind Sandeep Mistry's project, which makes use of the new Pico W microcontroller with wireless connectivity.

The Pico W is combined with a Pimoroni Grow Kit to monitor the moisture level of the soil. If it's too dry, a text notification is sent – using the Twilio API with a free account – to the owner's phone to remind them to water it. For extra personality, Sandeep suggests adding random messages, along with a light sensor to detect sunrise/sunset and say 'good morning/night'.

Alternatively, the PyPortal IoT Planter (**hsmag.cc/PyPortalPlanter**) sends moisture and temperature level data to an Adafruit IO web dashboard, as well as showing it on the pot's mini LCD.

➜ **hsmag.cc/TextingPlant**

◈ This pot plant's Pico W will text your phone when it needs watering

◈ With a wave of the hand, the Smart AI Glove can operate IoT-connected devices

Smart AI Glove

You don't need to be a superhero, or a royal, to make things happen with a mere wave of your hand. Based around a Raspberry Pi Zero W, Ashok Fair's Smart AI Glove enables you to use hand gestures to control other IoT devices, such as a light, fan, and remote-control car.

Attached to a golf glove, a SmartEdge Agile IoT device works in conjunction with Brainium, a cloud-based tool for performing machine learning tasks. The Brainium app installed on Raspberry Pi sends MQTT messages based on data from a Rapid IoT Kit.

Another smart glove project, the Arduino-based Nero (**hsmag.cc/NeroGlove**) enables you to control inaccessible devices remotely from anywhere on Earth.

➜ **hsmag.cc/SmartAIGlove**

"
A RIDABLE ELECTRIC UNICORN THAT 'POOPS' JELLY BEANS WHEN YOU LIFT ITS TAIL
"

◈ Estefannie takes a ride on the rainbow unicorn, which is also a nifty electric vehicle

Pooping Unicorn

While many IoTs have serious, practical uses, this one is purely for fun. Created for the Kids Invent Stuff YouTube channel at the request of an eight-year-old child, it's a ridable electric unicorn that 'poops' jelly beans when you lift its tail.

Wanting to give it an IoT upgrade, the team enlisted the help of fellow YouTuber Estefannie. With the use of a Raspberry Pi W connected to a relay switch, it will now trigger whenever **@mythicalpoops** is mentioned on Twitter, at which point its tail lifts and jelly beans shoot out!

While you're cleaning up the poop, you might even want to make use of an IoT toilet roll holder (**hsmag.cc/IoTToiletRoll**) to monitor your sheet usage.

➜ **hsmag.cc/PoopingUnicorn**

Pothole Detector

Potholes in the road are the bane of motorists the world over – in the US alone, they cost drivers $3bn in vehicle damage every year. Many aren't fixed because the relevant highways authority doesn't know about their existence. That's where Justin Lutz's Pothole Detector comes in.

A Sony Spresense board is equipped with a camera to film the road, while an Edge Impulse machine learning model is used to detect potholes. When one is found, an MQTT message is sent to the AWS IoT Core service. Since the Spresense has built-in GPS, the exact location can be logged and plotted on a map.

➜ **hsmag.cc/PotholeDetector**

◈ Logging the GPS locations of detected potholes means they can be plotted in Google Maps

◈ When it's medication time, the patient presses a button on the touchscreen to dispense the pill into a cup

Smart Pill Dispenser

Remembering which medication to take and when can be confusing for patients. This Smart Pill Dispenser addresses the problem by enabling healthcare professionals to use a SmartPill web app to dispense pills and control the dosage remotely.

The dispensing device itself is built from 3D-printed parts, while the main electronics brain is an Arduino Mega. The latter is connected to servos, a real-time clock, and an IR barrier sensor to detect the pills. A Microchip AVR-IoT board is used to send and receive MQTT messages to and from the AWS Cloud.

Another, rather 'tongue in cheek', medical project is the IoT Pregnancy Test (**hsmag.cc/IoTPregnancy**), which instantly tweets the result! ▢

➜ **hsmag.cc/SmartPill**