55 PROJECTS: Arduino, Raspberry Pi, 3D Printing

Make:

HALLOWEEN HACKS: CREEPY COSTUMES, PROPS, DRINKS!

We're All MacGyvers Now

ARE YOU READY?

A Maker's survival guide to emergency prep and response

- DIY Power, Radio, Food & Water
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LIGHT THE NIGHT: 3D print this solar bottle lamp

- **Wireless LED Kaleidoscope**
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- Skill Builder: Faster 3D Prints

THE FLOWER QUEEN
REINA WALLER

By ANNE-MARIE PRITCHETT

SOME OF THE GREATEST ARTISTS stumbled into their niche by chance. While Reina has always been in the artistic realm in one way or another, she discovered her passion for creating botanical mixed media art a couple of years ago. “I forage almost all of my materials directly from nature—wildflowers, leaves, even insects! I hand-pick, press, arrange, and glue all of the elements onto fabric or wood; I also utilize my graphic design and photography background to turn my designs into art prints and apparel. It brings me true joy to connect with and honor the Earth in this way, giving it new life through my art,” said Reina.

During the 2020 pandemic, she turned to nature to find joy and peace during uncertain times. “I started picking flowers because it made me happy. I was bringing home fistfuls of wildflowers, and I instinctually started tucking them away in books, which my mom and I used to do. She’s an avid gardener, and we were always outside growing up, so the act of pressing flowers reconnected me to simpler joys in life,” she said. “A few weeks later, I had this enormous collection of flowers, and on a whim, I thought to myself, ‘I really should create something with all of this!’”

Seeing natural elements intertwined with Reina’s love of art sparked something in her soul. “The root of my inspiration is my upbringing and lifelong connection with nature. I was always getting lost in the garden as a kid, studying the flora and fauna that surrounded me. But I never married my love for nature and my artistic background until 2020. It was just a literal epiphany. It saved me in some ways because I truly found myself through that process."

Reina's favorite work is her flower uterus piece that she made in March during Women's History Month. "I had this idea to do the female reproductive system in pressed flowers for a while. It makes me feel deeply connected not only to myself but to women as a whole. It's my way of creating a platform for women to speak about their personal experiences as a woman. Female empowerment and women's rights are important to me, and that piece is, by far, my most powerful creation."

Her ultimate life goal is to be a full-time artist, creating on a larger scale, hosting workshops and markets, and, one day, forming an art collective within her community. "Art is a gift everyone should have the opportunity to connect with. If I could help others to do so along the way, that would be the ultimate prize."

Reina would like to thank her supportive family, friends, and partner, who always lift her up and remind her of the magic she has within.

Find Reina's work at Rise and Earthshine on Etsy, in small businesses in the DFW area such as Bewitched Denton, The Dime Store, and Salted Sanctuary, and at the community market in Denton, TX. @riseandearthshine

American Lung Association.

Not only did the DIY Hero Competition bring together thousands of designers, makers, and crafters to form a community of like-minded artists, but it set out to raise awareness for the American Lung Association. The ALA saves lives by improving lung health and preventing lung disease. Founded over 115 years ago, the organization continues to pursue its mission to help the world breathe better through education, advocacy, and research. DIY Hero, LLC is proud to support this cause by donating a portion of the net proceeds from the competition to American Lung Association.

Although Reina took the crown, there were three other finalists who deserve some recognition, as well. See their works on the coordinating DIY Hero page.

DIY HERO

PROPS TO THE FINALISTS

3 TALENTED ARTISANS SHARE THEIR RESPECTIVE CRAFTS

KELLEY NAYLOR

An art jeweler for most of her life, Kelley finds inspiration from stones/gems and usually starts with them as the basis for creating only one-of-a-kind pieces. She began learning silver and goldsmithing from her father. Next up: a high-end couture gender-free design house.

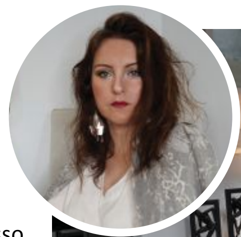
Favorite stone: American Turquoise
Advice: practice / fail a lot
Biggest supporter: Holly Green
@Kelley L. Naylor / SoulXDesigns.com / Zarks Gallery in Eureka Springs, AR

MICHAEL BRONCO

Charleston-based woodworker and bladesmith, Michael teaches his craft to kids for a living. Next up: a tobacco cabinet for his wife.

Advice: dig in and don't stop
First projects: a copy of the Inglourious Basterds knife + a go-cart at age 8
Inspiration: great grandfather, grandfather, father
@mountainmanworkshop
@broncoblades

KAROLINA KRUKOWSKA



She designs pieces of unique furniture, art, and luxury spaces that enclose all of her creations. Next up: a baby + the Luxembourg Art Prize
Favorite quote: "Art is theft" – Picasso
Advice: try different mediums
Inspiration: her mother
Recent: Tracing Book for Kids + an NFT collection called Queens
krukowskadesignstudio.com

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"To my mind, what defines the modern maker is if you're willing to share. For me that's where the frontier is." *—Cesar Jung-Harada, inventor and teacher*

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Make: Community

Support for the publication of *Make:* magazine is made possible in part by the members of Make: Community. Join us at make.co.

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What's the best MacGyver-style fix you've seen or done yourself?

Lee Zlotoff
Santa Fe, New Mexico
(We Are All MacGyvers Now)
I figured out how to MacGyver my mind to solve any problem. And then wrote a book about it.

Debasish Dutta
Baripada, Odisha, India
(DIY Solar Bottle Lamp)
Making a tripod for a smartphone by using a piece of MDF sheet.

David J. Groom
Ann Arbor, Michigan
(Cyber Prep & Custom Fabrics)
Has to be the time at my grandparents' and my dad needed a longer ladder to reach their chimney, so he took two shorter ladders and joined them as one insanely dangerous, long ladder using a giant heavy bench vise!

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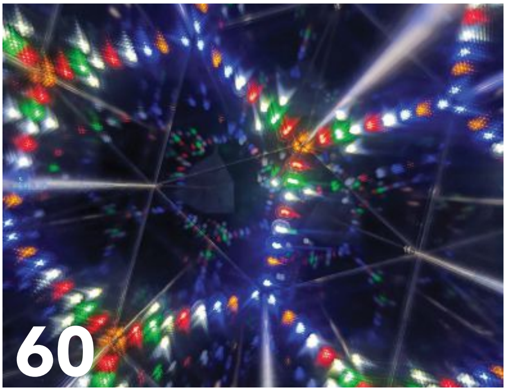
ON THE COVER: Shradha Piri delights in the light of the Solar Bottle Lamp, in Baripada, Odisha, India. Build it on page 44. Photo and project by her uncle, Debasish Dutta. Additional photos by Mike Warren and Adobe Stock-Lumos sp.



Adobe - top vectors, André Morin, Andrew Lamb, Paul Smith, Debra Ansell, Douglas Arensberg, Mike Warren, Bryan Harper

HALLOWEEN HACKS

SKILL BUILDER

TOOLBOX

THE LAST WORD

FROM THE EDITOR'S DESK

SCIENCE FAIR ACCOLADES

Congratulations to **Caleb Kodama**, who wrote last issue ("Sick Sniffer," *Make:* Volume 81) about adapting **Benjamin Cabé**'s AI-powered artificial nose ("Second Sense," Volume 77) for a school science fair project to detect fungal pneumonia. At press time, Kodama had placed 2nd at the county level and his pneumonia detector was headed for the state competition. Well, the results are in:

"I just won First Place in the 71st annual California Science & Engineering Fair. There were 854 participants from 343 schools throughout the state who presented 720 projects in competition."

MAKER FAIRE FORETOLD

Hired in 1967 to create an educational technology fair at the San Mateo County fairgrounds, ***Stewart Brand*** *spent six months trying to raise money before giving up the project. [His biographer]* ***John Markoff*** *notes that the funding proposal reads like it is describing the Maker Faire that happened 40 years later in the same location.* —Computer History Museum blog

A CELLPHONE FOR ACTUALLY MAKING CALLS

Justine Haupt has turned her open-source"Rotary Cellphone" (Volume 73) into a convenient kit! Preorder the LTE-ready Rotary Un-Smartphone (in beige, atomic hotline red, and seafoam green, no less) at skysedge.com/unsmartphones/RUSP/index.html.

HIGH-ALTITUDE GPS CHUTE

Yohan Hadji ("Auto-Return Parachute," Volume 80) writes: "The first high-altitude demonstration was a full success. R2Home rose up to 3,500m (11,400ft) under a weather balloon and autonomously detached before opening its paraglider wing and flying back to land within 5 meters of the launch point — and it returned an RS41 radiosonde sensor package, used for atmospheric soundings all over the world. Next step: 20–30km (100,000ft). Serious game starts now."

READER INPUT

TIMELY ROBOT COMBAT

I just received Volume 81, so happy. My son is helping to set up a university robot wars team, obviously fantastic information. Let me know when I need to renew my subscription. Printed words delivered to my mailbox makes me very happy and elated. It's like someone cares about the future. —*Jeremy Whitehurst*

GREAT TO SEE A GREAT MAGAZINE IS BACK

I love getting *Make:* in print. It's important to have something so positive in these rugged times. Fantastic issue! —*Mike Winter*

SHOW AND TELL US!

Send your tips, maker moments, project pics, or thoughts on *Make:* to editor@makezine.com, subject "Reader Input." If we select your note, we'll send you a *Make:* hat!

Who You Gonna Call?

by Dale Dougherty, President of Make: Community

The local police department just had to get it off their chest. After a recent storm caused a power outage and fallen trees, the department was inundated with so many 911 calls, they couldn't handle the volume. So they posted a message on Facebook about how *not* to use 911:

- We don't know why the power is off, how it got turned off, or when it is getting turned back on.
- We do not have the number to a plumber or gutter company.
- We don't know if the freeways are open or not; and there isn't a freeway in this town.
- We can't do anything about a tree that fell in an empty lot.
- We're sorry the horses, cows, sheep, and other livestock look like they are having a miserable time standing in the rain. But they live outside, and they'll be OK.
- We don't know if it's going to flood, when it's going to flood, or where it's going to flood.

The police wanted people to know that 911 was not an information hotline. It should be used to report crimes and other life-threatening emergencies. They couldn't answer every question. This too-pointed message, once posted, wasn't well received by city officials.

Yet 911 calls highlight a core problem in an emergency of any kind. A lot of people need help and they don't know how to get it. They feel helpless so they need to talk to someone. What do you do in a flood, fire, blizzard, storm surge, drought, earthquake, hurricane, or tornado? How about a pandemic, which we didn't see coming?

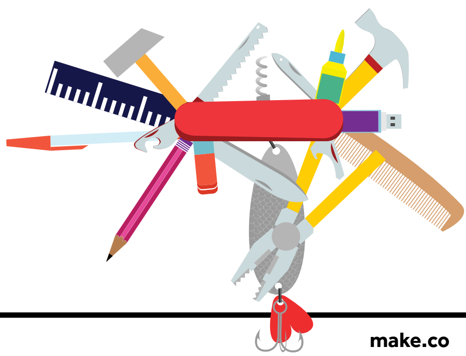
How might we prepare for all those situations? One type of person considers himself a "prepper," a superhero of survival. They anticipate food, power, and water shortages. They have a backup plan for their backup plan. Their garage or shed is full of specialty off-the-grid gear. They are determined to save themselves and their family.

But what about all those other people calling 911 and worrying about what's happening to them?

The area where I live has experienced wildfires and floods in recent years, such that emergencies are no longer unexpected events. There are now local efforts to prepare for handling a wide range of unforeseen problems. The basic idea is mutual aid — how do we help each other get through an emergency, knowing it might be a while before police and fire departments are able to respond?

Our town's program is called Map Your Neighborhood, based on a model developed in Washington state. It could be summed up as "Get to Know Your Neighbors." Get together and talk with each other. (On the tail end of Covid, this is admittedly awkward.) Get to know what skills and capabilities your neighbors have and what they care about. Get to know who the most vulnerable are in your neighborhood and how to help them. An elderly person who doesn't drive might need help in an evacuation or have medication that requires refrigeration during a power outage. Who has a reliable generator or solar battery backup? Who has experience as a plumber, electrician, or arborist?

Our fire department is working with citizens to build a local radio communications network (using FRS, GMRS, and ham radios) so that a community without internet or landlines can still pass messages back and forth. People can ask for help and get an answer. It's calling on neighbors to help neighbors. By combining the power of DIY and DIT (Do-It-Together), we can MacGyver the capabilities of the community for the benefit of all.



Adobe Stock - Oleksandr Miedviedie

MADE ON EARTH

Backyard builds from around the globe

Found a project that would be perfect for Made on Earth?
Let us know: *editor@makezine.com*

SURREAL SCULPTURES BRANCHING THROUGH THE NATURAL AND MODERN WORLD

HENRIQUEOLIVEIRA.COM

Henrique Oliveira never knows exactly how his sprawling sculptures will take shape, which is, perhaps, a contributing factor to their organic look and feel, bridging the natural world with the modern, resulting in the surreal exhibitions and installations he's been creating around the world for over a decade.

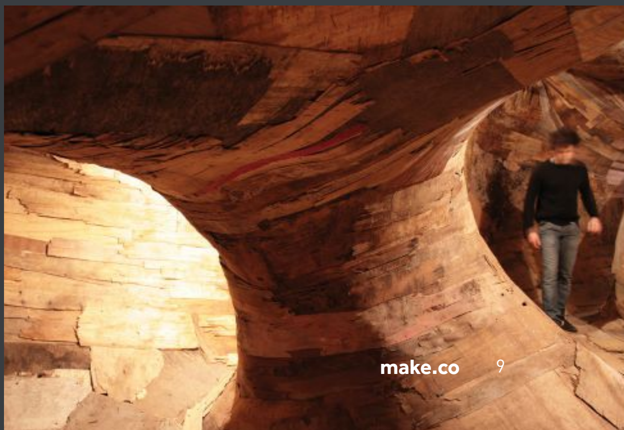
"It was not something planned, like had an inspiration to do; it was something that came naturally with the development of the work," Oliveira tells *Make:*. "At some point, instead of painting, I just started to patch two pieces of old plywood together, and started getting interested in the surfaces."

The Brazilian native, who now lives in London, spends several months on location at galleries or museums to create epic pieces like *Baitogogo*, a mesmerizing knot of branches appearing to grow out of white plywood columns, constructed in 2013 inside the Palais de Tokyo, a contemporary art museum in Paris, France. Or *The Origin of the Third World*, an immersive sculpture spectators could walk through at the 2010 São Paulo Art Biennial. Materials for each project vary — bricks, wood, PVC pipe, tree branches, mud, mattresses, rubber, metal scrap — but he tells *Make:* his most important tools include a pneumatic stapler gun, which he uses to attach pieces of second-hand bender board together, and a drill to connect the skeleton PVC structure that supports the branches.

In 2021, Oliveira's sculpted limbs joined Mother Nature's, outdoors at Belgium's contemporary art celebration Triennial Bruges, and he just finished another outdoor piece that will be displayed in the gardens of La Seine Musicale in Paris this summer.

So, what's the message behind these branches? "They're open to interpretations," he says. "I went to art school, so we learned art is not useful, so actually the world doesn't need it. But we need to make it, and then people might enjoy it." —*Greg Gilman*

André Morin



When Geeks Craft

TO THE STARS

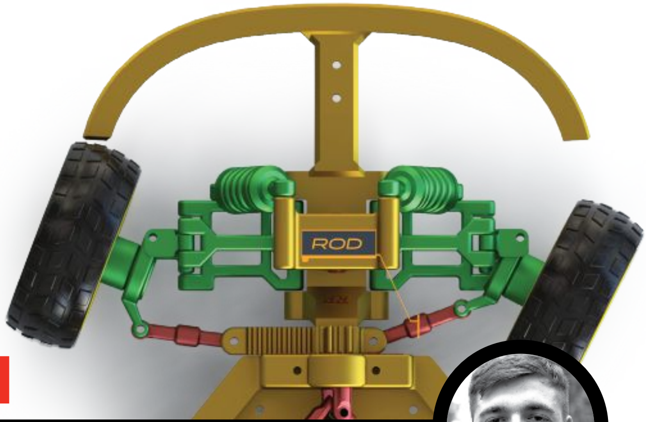
YOUTUBE.COM/WHENGEEKSCRAFT

Space. For most, it is the final frontier. For others, it remains a distant galaxy far, far away. But for some, like the creative team of Nicole and Thure of **When Geeks Craft**, it is a destination already reached. Their stained-glass, fully-lit replica of the space shuttle *Discovery* demonstrates a passion for making that's truly otherworldly.

The two makers behind the quirky YouTube channel spent almost a month and a half working on this project. While Nicole built the shuttle and booster tanks out of glass, her partner Thure modeled the base in Fusion 360, laser-cut the pieces, and added lighting for effect. Although Nicole has worked with glass before on When Geeks Craft, she says it's not an easy material to get the hang of. She used a paper model kit version of the *Discovery* as a starting point, which gave her a stronger understanding for this build; "If you can start a project with some sort of reference," she says, "it will always make your life easier."

Cutting and grinding around 150 individual glass pieces into shape by hand took several days of hard work. Although it was difficult without the use of a waterjet machine or another precision cutter, Nicole remarks that having a basic crafting knowledge made working with glass pretty simple, especially when it came time to apply copper tape onto the pieces and solder them together. When asked if she had any advice for those inspired to try working with glass, she says that "if you are able to understand basic crafting functions like soldering and using a template, picking up a new skill like glass becomes a lot easier."

The amazing teamwork between Nicole and Thure shines through the tutorial videos they make for all their projects. They think it's awesome being makers and content creators, although figuring out how to make and film something simultaneously can be complex at times. Above all, though, they love the support they receive from their YouTube commenters and Patreon members. "Our community is full of very active makers that inspire us to keep creating." Nicole and Thure have many future projects preparing for lift-off, and you can keep up with them at When Geeks Craft on YouTube, Instagram, and TikTok. —*Marshall Piros*



REFLECTING IMAGINATION

3DEXPERIENCE SOLIDWORKS for Makers empowers Ridvan Polat to create and share from anywhere

Ridvan Polat wants to share his love of CAD with the world. As a child, Ridvan was fascinated with the inner workings of cars and would draw various mechanisms with paper and pencil. He was first exposed to SOLIDWORKS as a high schooler, and discovered a new way to manifest the objects that would form in his mind, or as he so eloquently puts it: "SOLIDWORKS is a reflection of my imagination!"

While at University, Ridvan had an idea to help solve the lubrication challenges associated with Wankel rotary engines. This led him to prototyping using 3D printers, and he ended up winning a 3D printer for his idea that allowed him to first realize his ideas in **3D**EXPERIENCE SOLIDWORKS for Makers and make them tangible.

Ridvan soon got to know the **3D**EXPERIENCE toolbox from Dassault Systemes SOLIDWORKS, including xDesign, which empowers him to create any time inspiration strikes using browser-based tools. A growing interest in education, coupled with his engineering background, pushed Ridvan to share his projects and techniques on his YouTube channel, where his fascination with **3D**EXPERIENCE SOLIDWORKS for Makers could reach a wider audience.

A great example of Ridvan's desire to educate can be seen in the form of his R/C car project. Besides gears made with the **3D**EXPERIENCE toolbox, ready-made wheels and DC motors, and electronics from a childhood toy, the entire design was from scratch. Ridvan opted for a DC motor rather than an R/C servo for his rack-and-pinion steering to maximize realism, and developed a print-in-place fisheye tie-rod system to allow the steering to function correctly during suspension compression.

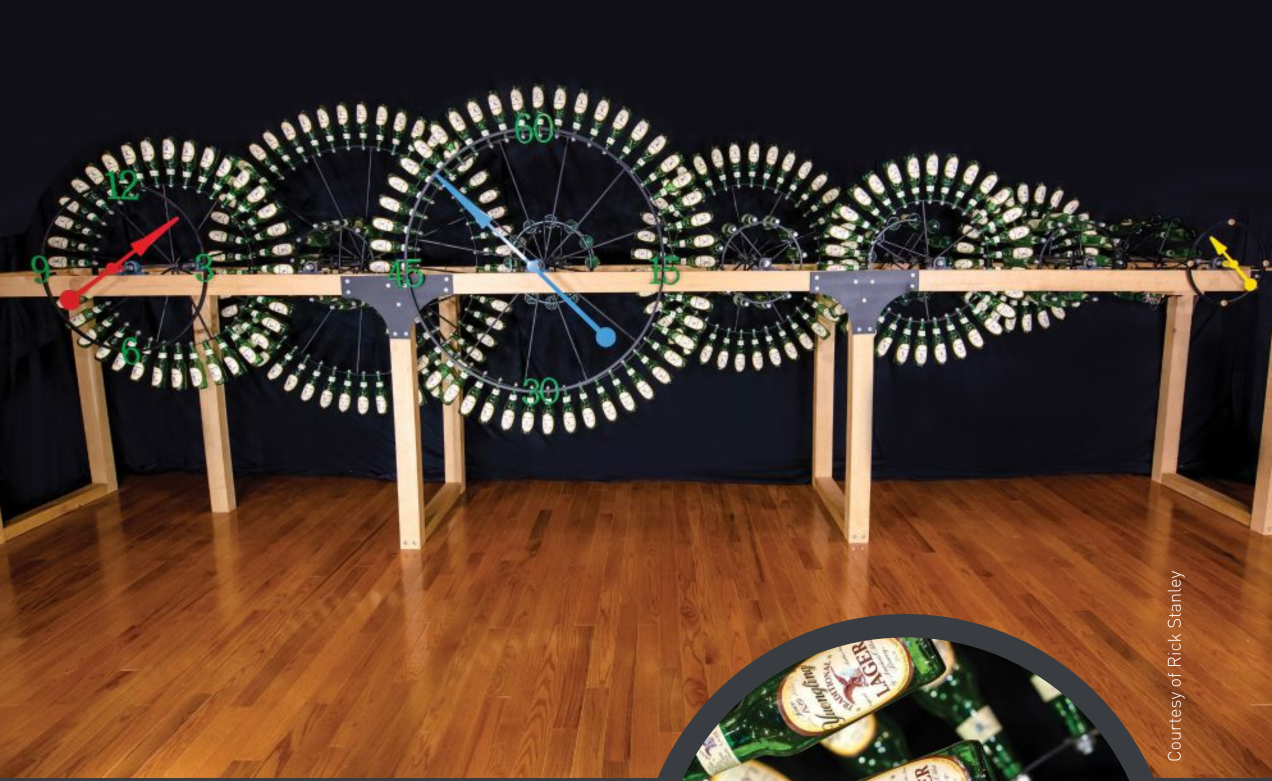
Ridvan's plans include a new go kart/buggy hybrid, and step-by-step tutorials for the current R/C car. And when those tutorials are ready, you will find them on his YouTube channel, youtube.com/user/automotive58 — where you can also find all of Ridvan's SOLIDWORKS projects and tutorials! You can also check out Ridvan's R/C car in 3D/AR at rpolat58.github.io/RC_Car.

3DEXPERIENCE SOLIDWORKS for Makers is available for your hobbies and personal projects. For just US $99/year or US $9.99/month you'll get the same intuitive cloud-connected CAD modeling tools that the professionals use, along with:

- Fully online design solutions you can access from any web browser.
- An online community that lets you connect with worldwide makers from fab labs, makerspaces, and influencers, all ready to share their designs, ideas, and expertise.
- Access to an expanded professional ecosystem to rapid prototype your parts, or receive engineering services via the **3D**EXPERIENCE Marketplace.
- Support to help you get the most out of **3D**EXPERIENCE SOLIDWORKS for Makers.

SOLIDWORKS

Learn more at:
discover.solidworks.com/makers



Courtesy of Rick Stanley

CELEBRATING TIME

STANLEY-CLOCKWORKS.COM

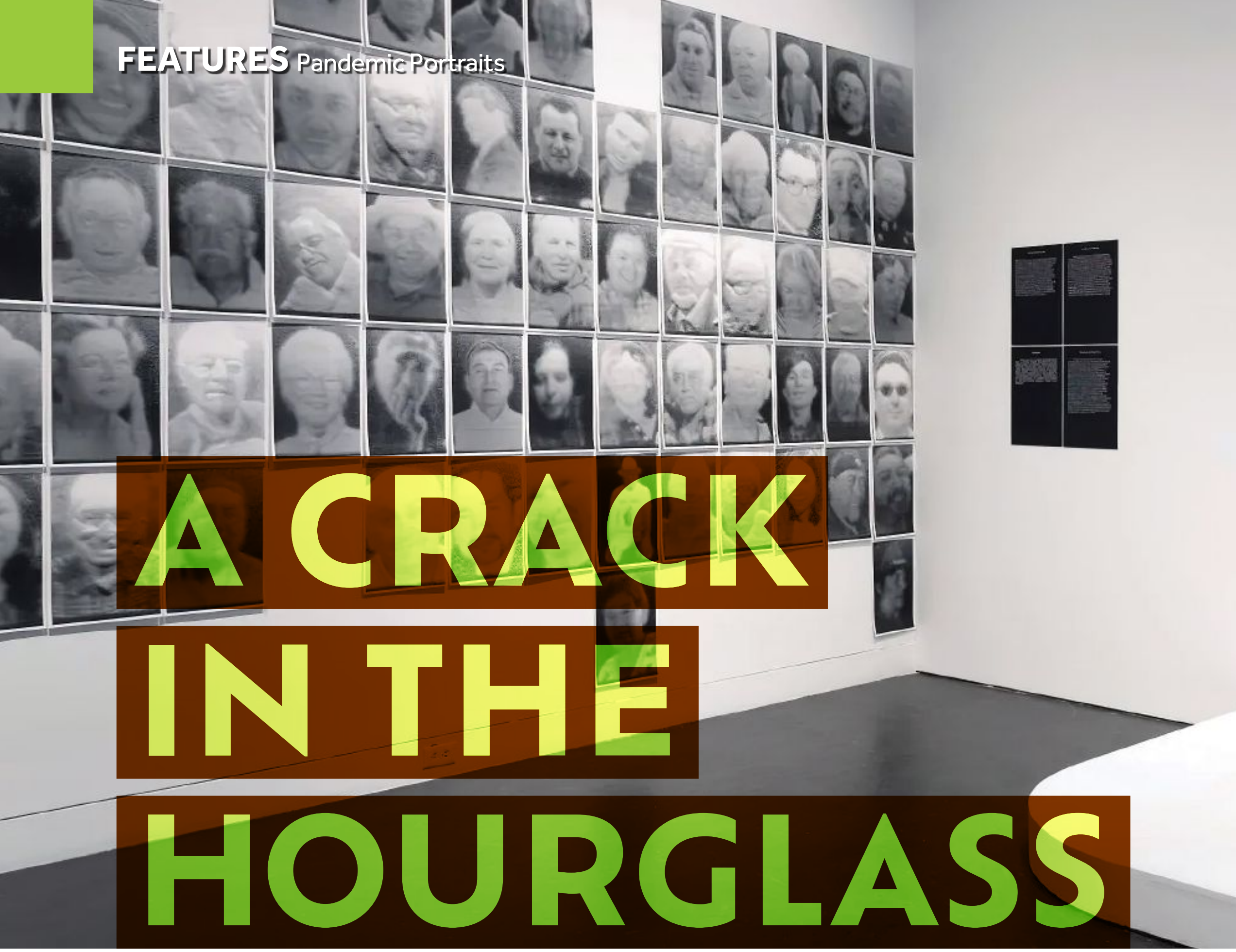
Rick Stanley makes very special clocks. He makes clocks out of beer bottles, clocks that walk, clocks with bicycle bells, clocks featuring coins, falling dominoes, and fluids. Rick makes novelty clocks of great complexity alongside his son **Vince Stanley** in Millville, Pennsylvania, at Stanley Clockworks which they founded in 2006.

Rick started dismantling clocks when he was 4, and they became a lifelong hobby. With a degree in mechanical engineering from the University of California, he has worked 20 years as a technician in the power generating industry, all the while inventing various machines on the side: medication dispensers, farm equipment, even a DIY electric motorcycle. But his clocks are his masterworks. His preposterous timepieces have won awards from clock collectors and been exhibited everywhere from horological museums to art galleries to the Philadelphia International Airport.

The Beer Bottle Clock stretches an impressive 20 feet, with separate dials for hours, minutes, and seconds, and gears made from more than 300 intermeshing beer bottles — all from a brewery that's stood the test of time: D.G. Yuengling & Son, America's oldest operating brewery, in nearby Pottsville, Pennsylvania.

Like most of Rick's contraptions, the Beer Bottle Clock's movement is wide open so viewers can see it all in action. "Most of the technology now we cover up," he told the local PBS station. "I don't think that's right. I think people should be able to look at how things work. That's kind of the excitement."

—Jennifer Blakeslee and Keith Hammond



A CRACK IN THE HOURGLASS

A MAKER FAMILY IN LOCKDOWN HELPS TO ENGINEER A MEMORIAL COVID ARTWORK

Written by Jennifer Dorner and Stephan Schulz

In A Crack in the Hourglass*, a media artwork by Mexican-Canadian artist Rafael Lozano-Hemmer, people are invited to submit a photograph and story of a loved one lost during Covid. Over a period of about 40 minutes a modified robotic plotter draws the image of the loved one using hourglass sand. Once the drawing is complete and after a short pause, a mechanism gently tilts the platform and the sand falls away. Then the machine begins to draw another portrait. The process is broadcast live, showing the robotic arm drawing each portrait. The numbers of Covid deaths are no longer abstract; they are tangibly represented in the portraits of mothers, fathers, brothers, and sisters.*

Our family had a unique window into the creative process behind *A Crack in the Hourglass*. Back in March 2020, when the pandemic abruptly shut everything down, our family became shut-ins and our home-work-school-hobby worlds collided.

My husband, Stephan Schulz, is head of R&D

MATERIALS

- » **Hourglass sand**
- » **Glass vessel**
- » **AxiDraw SE/A3 plotter** shop.evilmadscientist.com
- » **Teensy 3.2** microcontroller pjrc.com
- » **Anti-static polyurethane tubing, ID ¼", OD 3/8"** McMaster-Carr 5790K24, mcmaster.com
- » **Custom 3D-printed nozzle**
- » **Black cardboard, 32"×40"x1.25mm thick** Peterboro Black Core mat board
- » **Linear actuator, 2"/50mm stroke, DC 12V** AliExpress 1915825523
- » **Motor driver board, VNH5019** Pololu 1451, pololu.com
- » **USB cameras: Kurokesu C1 Micro M12 (1) and C920 (1)** kurokesu.com

JENNIFER DORNER is executive producer of POP Montreal International Music Festival and a board member of the Canada Council for the Arts. She enjoys working on creative projects with her two children that engage with the local community.

STEPHAN SCHULZ immigrated in 2007 from Berlin to Montreal, where he has since worked as the head of research and development at the media art studio of artist Rafael Lozano-Hemmer. stephanschulz.ca

Antimodular Research; Jennifer Dorner

at Rafael Lozano-Hemmer's studio, Antimodular Research. I am the executive producer of POP Montreal International Music Festival with a background in visual and media arts. In short, we are a family of creative innovators, and were well equipped to face the pandemic.

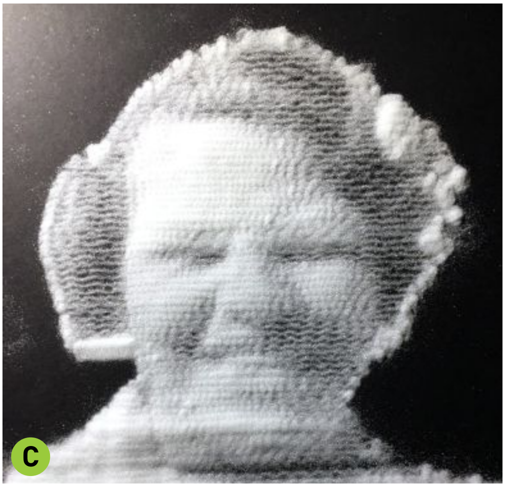
EMBROIDERY ENGINE

Our third-floor urban Montreal apartment became a laboratory, a studio, a space for dreaming, experimenting, and weathering the storm together. We found that coming up with DIY creative projects that responded to the global crisis gave us a sense of control over the situation and we wanted to contribute to efforts being made within our community. When there was a mask shortage, our daughters Thea and Odessa (11 and 10 at the time) began sewing masks for friends in the community and trying to come up with ways to personalize them (Figure A).

At the same time Stephan was following an initiative led by Golan Levin from The Frank-Ratchye STUDIO for Creative Inquiry at Carnegie Mellon University (CMU), to create PEmbroider, an open source Processing library for computerized embroidery machines (github.com/CreativeInquiry/PEmbroider). There was a call for beta testers, and Stephan jumped at the occasion, convincing the rest of us that the best way to personalize our masks was to make custom-made embroidery designs.

A

We purchased a low-end Janome MC230E



Jennifer Dorner; Antimodular Research

embroidery machine and began experimenting with it, tailoring the code, trying different approaches to make it work. The kids invited their friends to send us drawings, which were then run through the software, embroidered, sewn, and delivered to very happy customers. We also began embroidering portraits, downloading images of Ruth Bader Ginsburg (Figure B) and Aretha Franklin and running them through the program. The stark contrast within black and white images translated well to the contrasting colours of the thread and fabric.

THE PLOT THICKENS

As we continued to learn, play, and work together, we discovered the AxiDraw plotter. Developed by Lenore Edman and Windell Oskay, the AxiDraw was able to draw embroidery patterns using the PEmbroider library, making 2D drawings from images. When Stephan shared this finding with Rafael Lozano-Hemmer, it resonated immediately — a decade earlier, Rafael and his team had created an artwork called *Seismoscopes*, using vibration sensors and an automated X-Y plotter to illustrate portraits of philosophers.

Rafael had been thinking about how he, as an artist, could respond to the pandemic and contribute to the collective healing that was so desperately needed, especially at a time when coming together to mourn wasn't possible. Rafael wanted to explore ways in which technology could be used to create a communal space for mourning, and memorialize the many people who lost their lives due to Covid-19.

The AxiDraw plotter's open source command-line interface (CLI) tool and Python library made it possible to develop a platform for drawing images with sand. But there was a lot of research that took place in this working-from-home situation that eventually became *A Crack in the Hourglass*.

TRIALS AND TROUBLESHOOTING

The initial experimentation took place in a room adjacent to our kitchen, which meant that there were often odd mechanized sounds adding to the already cacophonous sounds of home; Thea's piano practicing, Odessa's class Zoom meetings, and my own work-related alert pings and bells. When a new sound came from the kitchen area, Thea, Odessa, and I would abandon our activities out of curiosity to come check it out. We enjoyed talking about the work as it evolved and provided feedback, which was generally well received!

Various methods, mechanisms, and materials were explored. One way involved covering a surface with sand which was then swept meticulously by a mechanized brush. At another phase, a small table vacuum was repurposed to remove small areas of sand, all combined with various techniques offered by the CMU Processing library. These materials and methods did not quite achieve the desired results. It was important that the processes reflect the care, love, and empathy that the individuals represented by the portraits warranted.

Rafael Lozano-Hemmer at the *A Crack in the Hourglass* installation at the Brooklyn Museum, New York, 2021.

There were also physical and technological hurdles to overcome, including humidity; dry conditions caused static electricity to accumulate in the very fine sand, which clogged the tubing. Many plastic and glass vessels were tested until a method of depositing the free-flowing fine sand onto the surface was found, but they still needed to figure out how to do this in a fluid manner.

Eventually the AxiDraw in combination with Gregg Wygonik's SquiggleDraw algorithm (github.com/gwygonik/SquiggleDraw) achieved finer control of the gradient values to display a greater grayscale range. This was made possible by controlling the amplitude of plotted sine waves based on the image brightness, which created thicker or thinner deposits of sand. The portraits were strikingly recognizable (Figure C).

Other open source tools used in the project were openFrameworks, *ofxArenaFueraDelReloj* library, JavaScript, FFmpeg, and OBS.

DUST TO DUST

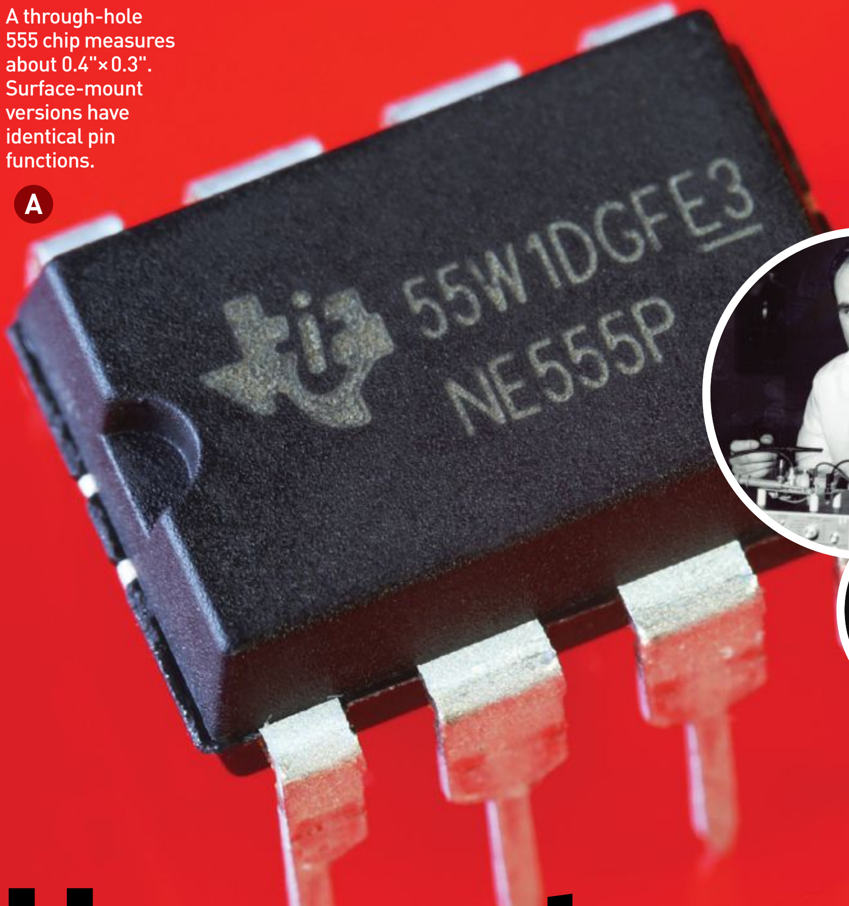
Rafael had the idea to use hourglass sand for its fine consistency and its ability to achieve greater definition. An hourglass uses a fixed quantity of sand to measure the ephemerality of time. Similarly, in this artwork the sand is recycled for each rendition. Rafael explains, "All of the portraits so far, hundreds of them, are made with the same small amount of sand. And for me, that was really important because it was a sense of universal solidarity around this, and a sense of connection."

The first iteration was produced as an online exhibition for the Museo Universitario Arte Contemporáneo (MUAC) in Mexico City, launched in November 2020. The machine itself was installed at the Antimodular studio with two cameras broadcasting the action live. The apparatus behind the cameras (not visible to the public) was made with repurposed materials including a 5-gallon water jug, garden hose tubing, La-Z-Boy linear actuators, and wooden crates were used to create the tilting platform.

In the months that followed, the studio team created a custom-made version for gallery presentation and worked with a local glassblower who made the hourglass. This machine was shown at the Brooklyn Museum in 2021 and 2022, and the studio is in negotiations to show it in Montreal in the near future.

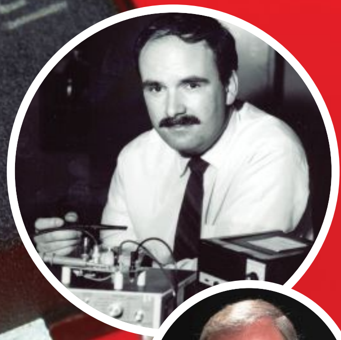
When the photographs started coming in from people around the world, the experience was intensely moving for us. As a queue of photographs waited to be rendered in sand, we waited for them too — a reminder of the importance of human connection, of leveraging strengths and capacity from multiple sources to find unity in the most challenging times.

- **Submit a photo of a loved one,** watch the drawings live, or view the portrait archive at acrackinthehourglass.net
- **Art21 documentary:** art21.org/watch/extended-play/rafael-lozano-hemmer-a-crack-in-the-hourglass



A through-hole 555 chip measures about 0.4"×0.3". Surface-mount versions have identical pin functions.

A



Hans Camenzind, in 1971 when he was developing the 555, and in 2002.

Homage to a Handmade Chip

THE WORLD'S MOST POPULAR INTEGRATED CIRCUIT TURNS 50

Written by Charles Platt

CHARLES PLATT is the author of the bestselling *Make: Electronics*, its sequel *Make: More Electronics*, the *Encyclopedia of Electronic Components Volumes 1–3*, *Make: Tools*, and *Make: Easy Electronics*. makershed.com/platt

The most enduringly successful chip in electronics history was created by one man working in a back-alley storefront. His name was Hans Camenzind, the chip was the 555 timer, and this year marks its 50th anniversary. It has outlasted all competitors, is still being manufactured in basically the same design, and has sold billions worldwide.

The 555 has endured because it is amazingly versatile and reliable. It can time an interval ranging from a millisecond to an hour — or can generate a pulse stream at a frequency exceeding 1MHz. It can create audio tones, and can even function as a logic gate. I consider it so important, despite its age, I devoted two chapters to it and several experiments in my book *Make: Electronics*.

Inside the Apple II, the blink rate of the cursor was controlled by a 555. It has set the delay of intermittent car windshield wipers, and has been used in spacecraft. In fact the SE555-SP variant, still available from Texas Instruments, is space-rated. The everyday version in Figure A currently retails for 50 cents apiece, while on AliExpress, generic 555s are 10 for $1.

Origins

In the late 1960s, Camenzind was wondering how to put an AM radio receiver on a chip. Normally a receiver uses inductors to discriminate between broadcast frequencies, but inductance is difficult to build into an integrated circuit.

He thought that someone, somewhere must have made a tuned circuit that didn't require an inductor, so he spent several days searching the MIT library in Boston, where he finally found the answer: A 1935 article describing an almost-forgotten concept called a *phase-locked loop*. This could generate such a precise frequency, he realized it could be used for something more interesting than a radio. It would be ideal for an oscillator, or a timer.

He took his idea with him when he relocated with his wife and children to the Bay Area to join Signetics, an upstart company that was trying to compete with Fairchild Semiconductor, the industry leader. But after two years, Hans became impatient with their "stodgy" attitude. He accepted a salary cut, became an independent consultant, rented his storefront, and set out to pursue his dream.

He built benches and shelves with boards from a lumber store, and since his wife, Pia, was an accountant, she did the bookkeeping. "He had a stipend of $1,200 per month from Signetics," Pia recalls. "We cut our expenses to the minimum. We never went out to dinner. But I thought — he needs to do this."

Hans was 36, had four children, and $400 in the bank. Later, he described his decision as "reckless." Still, he came up with a circuit, and breadboarded it using everyday transistors and resistors. He then tested it using equipment loaned by Signetics, and tried endless iterations, varying the component values because he wanted it to work even when the manufacturing process introduced errors.

Having perfected the circuit, he started on the most arduous part. Chip production requires multiple photographic masks when layers of silicon are partially etched away. In 1971, the only way to make the masks was by cutting them into plastic film known as rubylith, using an X-Acto knife at a scale of maybe 400:1.

Even at Intel, the vastly more complex 4004 (the first true microprocessor) was fabricated from hand-cut masks, because computer-aided design didn't yet exist. Hans spent many days hunched over a light table, cutting plastic and removing areas with tweezers.

The Launch

When Hans delivered his masks to Signetics, he faced a new problem: Engineers at the company were skeptical that anyone needed a timer chip. Fortunately, the marketing manager, Art Fury, overruled the engineers. It was Fury who assigned the easily-memorized 555 part number.

A micrograph of the very first Signetics 555 wafer is shown in Figure B on the following page. The chip was an immediate success, because it worked so well. You got consistent results if you ran it from a 5V supply or 18V. It worked the same way when driving a 20mA LED or sourcing 200mA for a small motor.

"Integrated components have the disadvantage of being inaccurate," Hans wrote later. But, "Whatever their variation may be, they all vary

Charles Platt, courtesy Pia Camenzind

together, since they are made at the same time and under the same conditions. In other words, they match very well. I used that feature to build a novel oscillator, which turned out to be extremely stable."

Within a year, other manufacturers were copying the design. "Everybody was stealing from everybody else," Hans recalled, "and in those days, nobody paid any attention to patents." In fact Signetics didn't even apply for a patent, fearing that if they tried to enforce it, they would start a war with other, larger companies. Today, anyone can build a copy of a 555 timer.

The Legacy

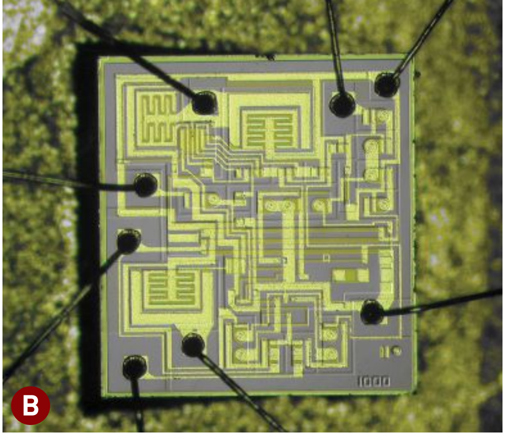
The 555 established Hans Camenzind as an authority on analog integrated circuits. By 2006, he had designed 140 standard and custom chips. He also wrote two amazing books: The definitive *Designing Analog Chips*, and a brilliant general introduction to electricity titled *Much Ado About Almost Nothing*, which included thumbnail biographies of all the pioneers. Both books are still available online through print-on-demand.

The 555, of course, has acquired legendary status. You can even buy a kit to build your own macro-scale replica from discrete components (see sidebar).

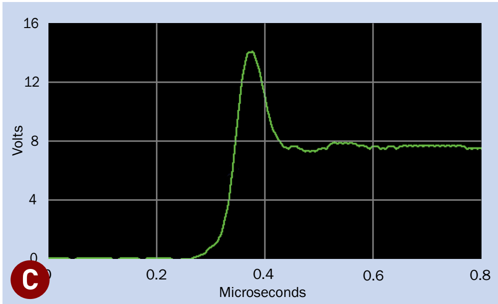
The chip has some well-documented defects. Its use of bipolar transistors results in a nasty voltage spike when its output transitions (see Figure C), and it is power-hungry. But a CMOS version has fixed those issues.

Hans Camenzind died in 2012 at the age of 78. Today, the storefront where he designed the timer is occupied by a real-estate broker (see Figure D). The alley is arrowed in the picture of Murphy Avenue in Figure E. Maybe one day Sunnyvale will honor Hans with a plaque beside his old workplace, but in the meantime his genius lives on in tens of billions of chips containing copies of his hand-made circuit.

The writer thanks the Camenzind family for their generous help, and Jack Ward of the Transistor Museum, where audio files of Hans Camenzind are archived at semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Index.htm.



The very first 555. (From the Camenzind photo collection.)



A voltage spike that occurs when bipolar 555 output goes high can disturb other components. (Reproduced from the book *Make: Electronics* by Charles Platt.)

The storefront where Hans Camenzind developed the 555, photographed in 2022. (Courtesy of Pia Camenzind.)

Location of the alley leading to the storefront. (Adapted from Google Street View.)

Camenzind collection, Charles Platt, courtesy Pia Camenzind, Google/Charles Platt, Signetics, Eric Schlaepfer, EMSL, Windell Oskay

Chip Worship

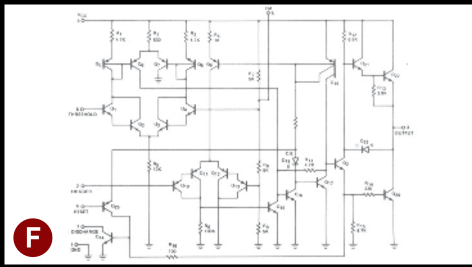
Eric Schlaepfer has a lifelong passion for vintage electronics — especially cathode-ray tubes, which he has repurposed as functional art objects such as clocks. He speaks lyrically about "the joy of a vectored display, with glowing phosphors."

But his most widely known project is a macro-scale 555 chip. "I found an old datasheet which showed the components, even including the resistor values," he says. "I built a copy from transistors and resistors, and it worked." (The circuit is shown in Figure F.)

Eric's big 555 is a handsome piece, shown in Figure G. Naturally, he showed it to people — including Lenore Edman and Windell Oskay, cofounders of Evil Mad Scientist Laboratories, which sells maker products. Windell has his own fetish for old electronics, such as Nixie tubes, so he and Lenore came to the obvious conclusion: They could sell Eric's big 555 as a kit.

The assembled version is shown in Figure H, and it's for sale at shop.evilmadscientist.com/productsmenu/tinykitlist/652-555kit. If you have steady hands and good eyesight, there's also a surface-mount version.

Eventually, Windell hopes to market a macro-scale 6502 microprocessor containing 3,510 transistors, if he can resolve some frustrating component supply issues. In the meantime, he has built a CNC-cut, laser-engraved, wooden (nonelectronic) 555 footstool, shown in Figure I with optional cat.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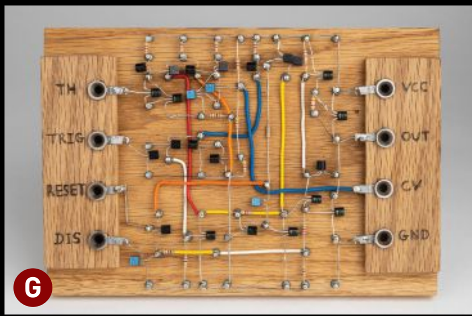
Schematic of the circuit inside a 555 timer chip, published in the original Signetics datasheet.



G

The original version of the big 555 timer, built by Eric Schlaepfer.

H

The Three Fives kit compiled by Evil Mad Scientist Laboratories.


I

CNC'ed wooden 555 footstool (no electronic function).

Emergency Prep!

HOW MAKERS CAN PREPARE FOR DISRUPTIONS AND DISASTERS OF ALL KINDS

Written by Tim Deagan

TIM DEEGAN loves to play with fire, metal, and computers (preferably all at the same time) at his shop in Austin, Texas.

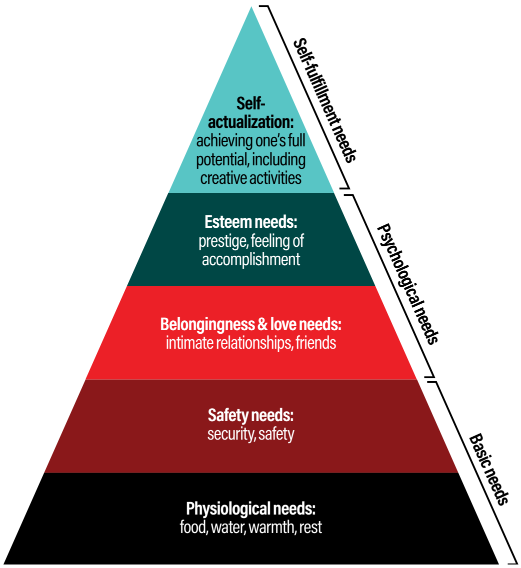
Responding effectively to emergencies and disasters is almost always a result of preparation. With a little forethought, know-how, and advance planning, makers with a DIY and community mindset are fantastically positioned to help themselves and others in extreme situations.

But which threats should we invest in preparing for? Risk is calculated by multiplying likelihood times consequences. Many small emergencies have minimal consequences, but happen frequently: power failures, network outages, even supply chain problems that limit our access to anything from food to fuel. On the other end of the spectrum are events that are less likely, but have dramatic impacts: disruptions that extend over a large area or last a long time, or rare catastrophic events like a tsunami, earthquake, or superstorm. The likelihood varies depending on your locality and situation.

It's near-impossible to prepare for absolutely any event, so determining the most significant risks for you requires some research and thought. But whatever the risks, your best investment is usually to prepare to address your most *basic needs* — food, water, shelter, and security — under a range of scenarios.

Survival experts talk about the Rule of Threes: Humans can survive about 3 hours in extreme cold or heat, 3 days without water, and 3 weeks without food. These numbers provide a fundamental framework for preparedness. If you travel icy roads during northern winters, then having an emergency kit in your trunk with blankets and a candle heater are a must to avoid hypothermia. If you live in an earthquake zone, storing enough water for your family can be a necessity. If you're someplace where food deliveries could be disrupted for a month, rotating food stocks is good sense.

The topic of "survivalism" is burdened with social and political issues that often distract from practical emergency preparedness. History shows that the best outcomes in disasters emerge from *strong communities working together*. So we see preparedness as something that's most effective when done in conjunction with our neighbors. We will leave the topic of self-defense for other forums to discuss.



Abraham Maslow's classic hierarchy of human needs.

Planning Your Prep

To structure your planning, it's helpful to consider some variables that will change how you prepare for events. At the highest level, these are: *time*, *severity*, *motion*, and *inclusion.*

TIME

How long is a disruption likely to last? It makes a big difference in how to prepare. Having food staples on hand is a great prep, but storing enough for a couple weeks is very different than for a year. Some skills, like rotating stocks so that you use the oldest first, are great for all plans, but worst-case scenarios can potentially change your target from "lots of cans" to "whole grain wheat stored in tubs with CO_2 to keep out bugs." It's comforting to think we can be prepared for any length of event, but doing so has a cost. Determining what works for your family, space, and budget is essential.

SEVERITY

How bad will it be? There's a big difference between a municipality issuing a boil water notice and actually having the water pipes go dry. (Or, as happened in Texas recently, a boil water notice at the same time as natural gas being cut off to residences!) Simple prep might be having a couple gallons of water on hand plus containers to store boiled water. Extreme situations might force you to rely on local non-potable water sources, or on alternate fuels to boil water. Knowing how much water your group needs is important for planning for different severities.

MOTION

Where will you go? One of my favorite survival books is dedicated to "the people of Pompeii and Herculaneum who, to the jeers and insults of their neighbors, got packed in the night and left." In many emergencies, sheltering in place isn't an option. Planning for flight brings a very different set of considerations into play — even more so if some members of your group will flee while others remain in-place. Communication plans, predetermined rendezvous, and go-bags all become essential tools for situations where bugging out is the right answer.

INCLUSION

Who are you prepping for? Taking care of yourself is less complex than taking care of children, the elderly, disabled family members, or pets. Those of us lucky enough to be engaged in communities often feel compelled to include neighbors and friends in our planning. Accessibility, medications, even entertaining distractions for kids all become critical factors when planning for a larger group. Of course, in a group, considerably greater resources may be available. Planning with, not just for, a group is essential for the best outcomes.

Few experiences are as well remembered as "We all pulled together." Building strong communities will always be the best preparation. You can learn about organizing a neighborhood response network on page 34 and see how makerspace networks pulled together to deal with Covid, natural disasters, and war on page 38.

At the highest level, resources like ready.gov are a great place to start exploring how to put together your personal preparedness plan. In addition, we've pulled together an array of resources, ideas, and know-how to help with your preparation.

When Communications Go Down

We take easy communication for granted, immersed in a rich spectrum of wireless transmissions, chatting internationally through laser beams under the ocean and satellites in orbit. But this incredible infrastructure can fail in any number of ways. Here are some infrastructure-free options to stay in touch.

FRS/GMRS RADIOS

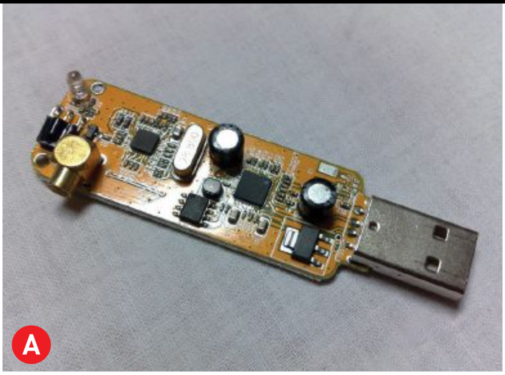
Your first priority? Connecting with family and friends. FRS/GMRS radios have become the entry-level, local-area tool for this. **FRS (Family Radio Service)** is the evolution of walkie-talkies. **GMRS (General Mobile Radio Service)** adds additional channels, can run at higher powers, and requires a single license for the whole family. midlandusa.com/blogs/blog/why-do-i-need-a-gmrs-license-how-do-i-get-it

POLICE TRUNKING RADIO DECODER

Old-school police scanners don't work in most localities anymore due to conversions to frequency-hopping "trunking" radio systems. But for a fraction of the cost of a scanner with trunk-decoding, you can use two cheap **SDR (software defined radio) modules** (Figure A) to listen to most modern trunked emergency service radio traffic. rtl-sdr.com/tag/unitrunker

AMATEUR (HAM) RADIO

Amateur radio is the original emergency comms and still the most robust. But different setups are needed for local vs. long distance communications. Handheld **VHF/UHF transceivers** usable by entry-level Technician class hams are excellent for local line of sight comms, but they rely on repeaters for any significant distance — and those repeaters rely on the internet to talk to each other over regional



Gustavo Belemmi, CC BY-SA 4.0; Dsimic, CC BY-SA 4.0; Andromeda321 at en.wikipedia (Yvette Cendes), CC BY-SA 3.0; Musskopf, CC BY-SA 4.0; goTenna

or national levels. **APRS packet radio** for data forwarding and **Digital Voice** modes like DMR, System Fusion, and D-Start have the same limitation.

When it comes to long distance communications, **HF radio (aka shortwave,)** is the gold standard and can potentially circle the globe without repeaters. Using these bands in all but serious emergencies requires a General or Extra class license. Local comms are still possible on HF bands, but generally require special antenna configurations (Figure B). www.arrl.org/what-is-ham-radio

LoRa NETWORKS

While most devices that operate above 30MHz are limited to line-of-sight comms, new technologies like LoRaWAN are starting to interoperate with satellites (Figure C). Experimenting with new protocols like LoRa can offer makers some exciting opportunities. Check these out!

- **Peter Mišenko's "Armachat" LoRa Communicator** makezine.com/projects/armachat-lora-communicator
- **Bruce MacKinnon's LoRa mesh networking birdhouses** github.com/brucemack/WARS-Birdhouse
- **Meshtastic, an open source off-grid, encrypted communication platform** meshtastic.org

CELLPHONE MESH NETWORKS

Cellphone-based mesh networking relays calls through neighboring phones rather than the tower-based cell network. This was hot after the Arab Spring, but a lot of the apps on the market disappeared not long after. **GoTenna** (an external device for the phone) is currently the biggest player (Figure D), but systems like the **San Francisco Wireless Emergency Mesh** are starting to pop up as well, using ham radio to connect nodes. gotenna.com and sfwem.net

LEARN MORSE CODE!

Morse code (aka ***continuous wave*** or ***CW*** in the ham community) punches farther, with less power, under worse conditions, than any kind of voice technology. But actually using it is a bear if you don't put in significant hours (months) learning it. **Get expert help from the CW**

Download Essentials in Advance

No internet? No problem. Download these resources now, and be ready.

- Google Maps may be offline, but you can still access maps locally if you've downloaded **open source maps and navigation from OsmAnd**. osmand.net
- Need to reboot civilization? Download **all of Wikipedia** in Kiwix's compressed *.zim* format, and read it offline. Set up a Raspberry Pi as a Kiwix server to share it with friends — plus Project Gutenberg library, Stack Exchange, TED videos, and more. kiwix.org/en/cardshop-access, and piwithvic.com/raspberry-pi/projects/offline-wikipedia-with-kiwix
- **What about Wordle!** Download the entire game and play in-browser without internet — cnet.com/culture/how-to-download-wordle-and-play-offline-for-the-next-5-years — or build this tiny ESP32-S2 web server and let your friends play too! learn.adafruit.com/wordle-personal-esp32-s2-web-server
- Build your own **smartwatch that works without internet** on page 52.

Academy. cwops.org/cw-academy

Given the extremely robust nature of Morse/CW, it has become increasingly appealing to folks prepping for emergency comms. **Morse coder/decoder devices** like the PreppComm DMX-40 do the work for you. the-tech-examiner.com/2021/08/13/preppcomm-dmx-40-hf-morse-code-transceiver-translator

CYBER DEFENSE

Cyberwar has left the pages of fiction and is now a real threat to our internet-enabled lives. Learn how to protect your home networks from botnets or bad actors, on page 58.

MAINTAIN MORALE

Experts agree: maintaining your attitude is essential in emergencies. Investing in entertainment options is an important way to keep your cool when things get tough. Build **a retro gaming console** on a Raspberry Pi and relive the classic pre-internet video games (Figure E). makezine.com/projects/build-retro-gaming-console-raspberry-pi

When Power or Gas Goes Out

When vital utilities are interrupted, here are hands-on solutions.

GENERATOR KNOW-HOW

Having a generator is great (Figure F), but only if it works when you need it. Learn how to:

- **Store it properly** so it's ready for action. rurallivingtoday.com/generators/how-to-store-a-generator
- **Do basic maintenance** to keep your genny running. familyhandyman.com/list/generator-maintenance-tips
- **Clean the carb** if you forgot to put fuel stabilizer in it. youtu.be/vmMgEZc65ew
- **Plan for how big a generator you will need** to replace utility power: homedepot.com/c/ab/choosing-the-right-size-generator/9ba683603be9fa5395fab901458f23e5
- **And how much fuel.** rurallivingtoday.com/generators/how-much-gas-does-a-generator-use
- **Dual-fueled generators** that use gasoline and/or propane (Figure G) are becoming

increasingly common and offer lots of flexibility. When run on propane, there's no fuel in the carb that will gum up. bobvila.com/articles/best-dual-fuel-generator

PORTABLE POWER STATIONS

These **big battery packs** are great for short-term use (Figure H) — but then they'll need to be recharged by generator, solar, or wind power. techradar.com/best/portable-power-stations

POWER WALLS

DIY "power walls" — whole-house backup batteries like Tesla's — are becoming very interesting (Figure I). Keep in mind that these installations involve working with life-threatening (and house-burning) amounts of power; if you don't know how to work with high power safely, then get an electrician involved. Don't create a disaster prepping for a larger one! Check out:

- Peter Matthews' work at secondlifestorage.com and youtube.com/user/nocrf50here
- Paul Kennett's at youtube.com/paulkennett and makeprojects.com/project/diy-powerwall
- Micah Toll's book *DIY Lithium Batteries: How to Build Your Own Battery Packs*

SOLAR POWER

Solar power is a great option, but it's often challenging for folks to figure out how to use effectively. A solar power station requires more than just panels!

- **To learn the basics**, build *Make:*'s DIY 20-watt solar panel, then connect it to an AC inverter and battery management system. makezine.com/projects/20-watt-solar-panel and makezine.com/projects/primer-solar-power-system-design
- Enlighten yourself with **Becky Stern's free solar class**: instructables.com/Solar-Class
- Check out Kurt Schulz's **mobile solar power station** (Figure J on the following page): makezine.com/2014/08/08/mobile-solar-power-plant
- Make an **off-the-shelf solar USB battery rig** to keep gadgets charged: afludiary.blogspot.com/2022/05/hurricane-preparedness-some-simple-off.html
- **Power your Raspberry Pi with the sun** using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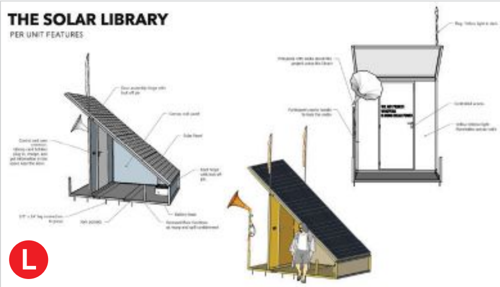

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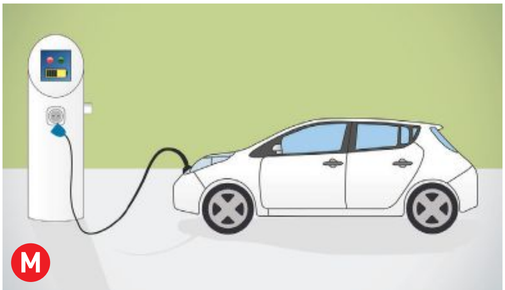
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PiJuice hats and solar panels (Figure K): uk.pi-supply.com/collections/pijuice

- Build an easy **solar phone charger** on page 74, a **solar bottle lamp** on page 44, and a **solar perpetual weather station** on page 82.
- **Lend solar to your neighbors.** Follow the modular Solar Library project at Burning Man (Figure L), by Jared Ficklin from Maker Faire Austin. instagram.com/thesolarlibrary

OPEN SOURCE CAR CHARGING STATION

With electric vehicles, no juice means no wheels. **Check out this open source car charger** based on an Arduino Nano 33 (Figure M). Could you run it off solar or wind power? hackaday.com/2021/04/06/open-source-electric-vehicle-charging

WIND POWER

Old motors are easily converted into **wind turbines to generate electricity**. Build a small one from a bike generator hub wheel (Figure N) or a big one from a treadmill motor: makezine.com/projects/backyard-wind-power makezine.com/projects/wind-generator

Or try Daniel Connell's vertical-axis **$30 kilowatt turbine** at Open Source Low Tech: opensourcelowtech.org/wind_turbine.html

ROCKET STOVES

Wood has served humankind for many millennia as a heating source. Modern rocket stoves offer super efficient ways to heat or cook with even scrap wood.

- Start with Connell's **$5 rocket stove** (Figure O). makezine.com/projects/tin-can-rocket-stove
- Prep for hard times and **practice your welding skills with a rocket stove kit** or a **big "mass heater" for heating well-ventilated spaces.** makezine.com/2019/08/23/make-workshop-rocket-stove-welding-practice-kit and build-a-gasifier.com/PDF/Zero%27s_Rocket.pdf

TINY STOVE

Don't underestimate high temps in small packages, like this **mint tin stove** (Figure P). makezine.com/projects/mint-tin-multi-fuel-backpacking-stove

SOLAR STOVE

Cook your food with nuclear fusion! **Make a solar cooker** and then **put it on a solar-powered platform to track the sun** (Figure Q). makezine.com/projects/cook-up-some-sol-food and makezine.com/projects/solar-tracking-platform

SEEBECK GENERATOR

Heat is often a waste product. Turn it into power — a 5V trickle charge — using the **thermoelectric Peltier cell** (Figure R). makezine.com/projects/the-amazing-seebeck-generator

When Weather Goes Wild

Climate chaos will create a tremendous range of needs for short- and long-term emergency response. Your local threats may be drought, hurricanes, fires, flooding, heat, cold, or any combination of those. Research what your area may be in for. grist.org/cities/we-broke-down-what-climate-change-will-do-region-by-region

BUILD AN EMERGENCY KIT

Scrambling to meet basic needs in the aftermath of an emergency is stressful and difficult. Advance preparation can make a tremendous difference. Putting together an emergency kit for your likely threats is a great investment (Figure S). Kits can range from pocket sized to pantry sized, but generally include food and water, flashlight, radio, batteries, can opener, medications, local maps, and important documents. Sleeping bags and camping gear are handy too. Get your kit started at ready.gov/kit.

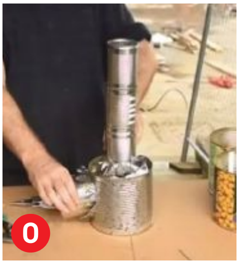
Rebuild an Industrial Base

Many of the essential tools that underlie our society are shielded behind patent restrictions. But amazing work has been done to create open source designs that anyone can build.

- Open Source Ecology wants to help with **open source blueprints for civilization.** opensourceecology.org
- The Open Hardware Observatory is creating a clearing house for **sustainable/off-grid projects.** en.oho.wiki/wiki/Home

GO BAGS

Like it sounds: a prepacked bag, usually day-pack sized, that you can grab on the go. "Go bags" or "bug-out bags" can be tailored for different emergencies, but generally contain snacks and water, clothes, flashlight, radio, matches, meds, cash, map, documents, maybe a tent or tarp — enough to travel a day or two and get somewhere safe. sierraclub.org/sierra/2019-1-january-february/material-world/how-pack-go-bag, state.gov/global-community-liaison-office/crisis-



PiJuice; Jared Ficklin; Pixabay, CC BY-SA 3.0; Clyde Robinson, CC BY 2.0

management/packing-a-go-bag-and-a-stay-bag, geico.com/living/saving/life-hacks/go-bag, and fema.gov/press-release/20210318/proper-emergency-kit-essential-hurricane-preparedness

TRAUMA KIT

Most first aid kits offer minimal supplies for serious trauma. When the EMTs aren't able to respond, knowing how to do **emergency trauma response** and having the supplies for it can mean the difference between life and death (Figure T). redcross.org/take-a-class/first-aid and outdoorlife.com/blogs/survivalist/survival-skills-build-your-own-trauma-kit

PARACORD ZIPPER PULL

Handy and hardy, what's more prepper than paracord (Figure U)? Bracelet tutorials are everywhere but if that's not your style, you can stash a foot or two of nylon cordage on any zipper, following Becky Stern's **paracord zipper pull project**: beckystern.com/2017/05/01/paracord-zipper-pull

FLOODS AND RISING SEAS

The majority of the US population lives within 50 miles of a coast. They'll be impacted by rising seas, storm surges, and displaced people if they don't have to move themselves. Assess whether your area will be impacted by looking at **flooding maps** and tools that **project sea level rise**. coastal.climatecentral.org and coast.noaa.gov/slr

SUPER STORMS

Bags for **sandbags** are fantastic to keep on hand, as is **boarding** for windows and doors (which disappears from hardware stores fast in an emergency). Tape and tarps can keep broken window glass from spreading, but plywood or polycarb panels are needed to keep them from breaking at all.

DIY EMERGENCY SHELTERS

Sandbags and barbed wire aren't just tools of war. **Earthbag homes (aka SuperAdobe)** turn these items into DIY homes and shelters (Figure V). calearth.org/intro-superadobe

Makers with access to CNC tooling should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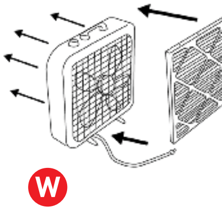
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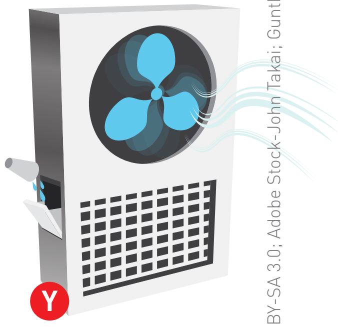
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check out **Shelter 2.0**, digital fabrication for small temporary housing. shelter20.com

WILDFIRES

Of course you've got **N95 masks** in your kit. But learning to **manage vegetation** around properties is critical for wildfires. smokeybear.com/en/prevention-how-tos/equipment-use-and-maintenance/how-to-prepare-your-home-for-wildfire

Air filtration, personal and household, is helpful in fire season. In a pinch you can build your own DIY room air filter from a box fan and a furnace filter (Figure W). makezine.com/projects/diy-air-filter

If the fire is upon you, in most cases you're at greater risk from the smoke than the flame. **Emergency escape smoke hoods** are extremely effective and easy to store (Figure X). youtu.be/6WE048Bv3H0

HEAT WAVES

Before the predominance of air conditioning, **swamp (evaporative) coolers** were a common solution (Figure Y). DIY swamp coolers are an easy build and can be battery or solar powered. backyardboss.net/diy-swamp-cooler, makezine.com/projects/rem-hist-air-conditioning and youtu.be/aHbQYajfGqM

DEEP FREEZES

Emergency heating often carries the risk of carbon monoxide poisoning. Build a **DIY CO detector**. hackster.io/greenpak/diy-carbon-monoxide-detector-03a5cf

There's no substitute for learning how to **dress warmly** in the first place (no cotton!) commonsensehome.com/best-cold-weather-clothing

And pack your **winter car kit** now! familyhandyman.com/list/things-you-need-in-your-winter-car-survival-kit

When Supply Chains Fail

Many of the things we buy, we could probably do without (at least for a while). But food, drinking water, and fuel are essentials we need to plan alternatives for.

LONG HAUL FOOD STORAGE

- How much food to store per person? **This calculator can help you figure out your needs.** whatifcolorado.com/scorm/courseFiles/calculator
- **How to stock an apocalypse pantry** lifehacker.com/how-to-stock-an-apocalypse-pantry-with-nutritious-food-1848873174
- Storing bulk staples requires preparation to keep out vermin. **Learn to fill 5 gallon plastic tubs them with staple foods, and top them off with dry ice (CO_2)** to flush out oxygen and keep out bugs. fcs.uga.edu/extension/preparing-an-emergency-food-supply-long-term-food-storage
- Many products are good well past their stated expiration date; **learn how long is too long**. businessinsider.com/how-long-can-i-eat-food-expired-food-2017-4 and blogs.cdc.gov/publichealthmatters/2022/02/food-labels

PRESERVING FOOD

- **Canning isn't just something your grandmother did**. It remains and effective and fun way to preserve food. livelytable.com/beginners-guide-to-canning
- **Fermentation for food preservation** isn't just a great idea, it can actually increase the bioavailability of the nutrients in the food itself (Figure Z). Try making yogurt, kraut, kimchi, kombucha, beer, wine, cider, sake, mead, even fermented hot sauce, all from *Make:* makezine.com/?s=fermentation&post_type[]=projects, makezine.com/2009/01/12/fermentation-nation, and makezine.com/2012/11/20/food-makers-food-preservation-and-fermentation
- An excellent guide to all this is ***Preservation* by Christina Ward** (Figure Aa) processmediainc.com/preservation

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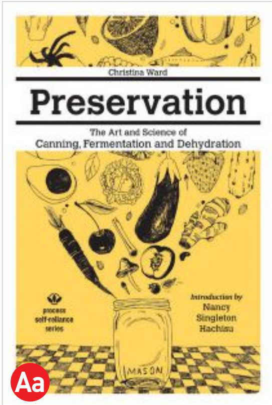

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GROWING FOOD

Growing enough food to be completely self-sufficient is much more difficult than we might imagine. But that doesn't mean a garden can't make a huge difference in sustaining you. Some high yield/high nutrition crops can be surprisingly easy to grow. permacultureapprentice.com/crisis-gardening-planning

- **Potatoes aren't just for castaways on Mars** (hat tip to Andy Weir!) gardendesign.com/vegetables/potatoes.html
- **Square Foot Gardening** is an amazingly simple and effective way to get the maximum output from the minimum space. squarefootgardening.org
- **Three Sisters "tangles" of corn, beans, and squash** have a long history and can produce a

complete nutritional protein. almanac.com/content/three-sisters-corn-bean-and-squash

WATER STORAGE

One gallon per person per day — it adds up fast. See page 94 to learn about water storage and build your own 55gal drinking water drum.

WATER PURIFICATION

While folks have different opinions, **bleach and chemical purifiers** are easy to use, very effective, and have long shelf lives. epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water

A **rock/sand/charcoal filter** (Figure Bb) is very easy to make and can handle all but the worst biological offenders, turning your locally found water into something that requires minimal purification. offthegridnews.com/how-to-2/how-to-build-a-bio-water-filter and opensourcelowtech.org/bucketfilter.html

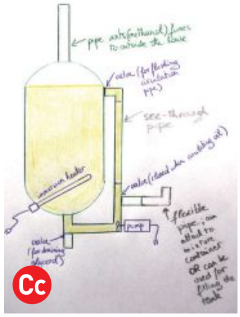
Use charcoal filtration as a first stage before a **LifeStraw** or other purification device, to make expensive devices last much longer. inhabitat.com/6-water-purifying-devices-for-clean-drinking-water-in-the-developing-world

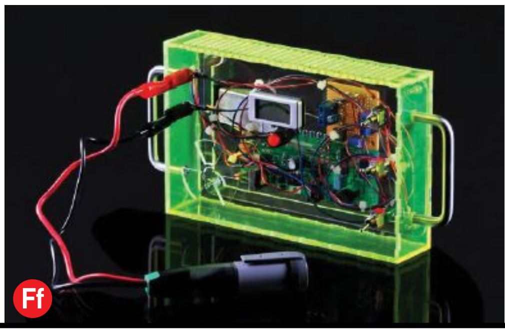
Pasteurization is an overlooked but super useful method — use heat from the sun to purify water with radically less fuel than boiling. solarcooking.org/pasteurization/solarwat.htm

Desalinization, i.e. removing the salt from seawater, is typically an energy intensive and industrial scale activity. Recent research and some new products are starting to make this tech viable for personal and family use. newatlas.com/materials/desalination-family-drinking-water and rainmandesal.com/portable-watermaker

MEDICAL SUPPLIES

Remember all those makerspaces 3D printing face shields and other PPE in 2020 when supply chains failed? **Open Source Medical Supplies** helped organize critical design information so that DIY PPE was safe and effective. They continue to help people prepare for the next crisis with 100+ open designs for masks, oximeters, and other devices, and links to local response groups. opensourcemedicalsupplies.org





MAKING FUEL

Refining your own **biodiesel** takes planning and preparation (Figure Cc). motherearthnews.com/sustainable-living/green-transportation/home-biodiesel-production-zm0z15aszmar

Household scale **methane** production is possible and done in some developing-world villages, but also requires preparation in advance. earthshipbiotecture.com/diy-methane-generator

If you're ready for more challenges, there are also **DIY refineries** for making **fuel oil** from plastic, **diesel** from waste mineral oil, and **ethanol** from sugar. instructables.com/Waste-Plastic-to-Fuel, youtu.be/8f81yn7yKLc, youtu.be/ILGEKPlmdoA, and wired.com/2008/05/make-your-own-e

PEDAL POWER!

You never forget how to ride a bike. **Knowing how to maintain and repair bikes is a great skill for sustainability and emergencies**. makezine.com/2016/04/10/lets-little-bicycle-repair-maintanence, rei.com/learn/expert-advice/bike-maintenance.html, and reviewgeek.com/37523/the-4-excellent-youtube-channels-to-learn-bicycle-repair-from

BICYCLE CARGO TRAILER

When pedal power is the best option, **increase your carrying capacity with a bicycle cargo trailer** (Figure Dd). itsoverflowing.com/diy-bike-trailer-plans

PEDAL POWER PROJECTS

- **Pump water:** makezine.com/2016/01/06/can-figure-bike-powered-water-pump-works
- Build a **electrical generator bike stand:** re-innovation.co.uk/docs/no-welding-pedal-generator-stand
- **E-bikes, trailers, panniers, lights, bike repair stand** — *Make:* has lots of DIY projects at: makezine.com/?s=bike&post_type[]=projects

KEEP BIKES WEIRD

- **Ride on the water:** makezine.com/2016/07/28/laura-kampf-builds-a-bike-you-can-ride-on-water
- **Unholy bicycle/shopping cart hybrid** (Figure Ee): makezine.com/2016/04/18/ditch-the-basket-this-goofy-bike-mod-gives-you-the-whole-shopping-cart
- **Wine barrel trailer:** makezine.com/2015/06/10/stylishly-port-passenger-wine-barrel-bike-trailer

When Radiation Gets Loose

"Duck and cover" isn't really a plan. Whether from malicious or accidental events, having a plan to deal with radiation can be a life saver.

RADIATION DETECTION

Learn to detect fallout with a **DIY Geiger counter** (Figure Ff). *Make:* has several builds you can try: makezine.com/?s=geiger&post_type[]=projects

Or use household materials to build this **DIY electroscope radiation detector**, aka **Kearny Fallout Meter (KFM)**, designed by physicists at Oak Ridge National Laboratories during the Cold War. abomb1.org/pdf/kfm_inst.pdf

EMP PROTECTION

Nuclear weapons and major solar storms create an electromagnetic pulse (EMP) that can fry unprotected electronics. Shield your small electronics in a **Faraday pouch** to block EMPs. makezine.com/projects/amateur-scientist-solar-flares-emp-and-faraday-shields

And check out page 50 to protect your ride with an ultrafast **vehicle EMP surge protector**.

NUCLEAR PREPAREDNESS

Governments and individuals have been **planning and preparing for nuclear situations** since the 1940s. Take advantage of their work. forum.effectivealtruism.org/posts/DL7gYYA2BKjmXABse ready.gov/nuclear-explosion and www.nrc.gov/about-nrc/emerg-preparedness/in-radiological-emerg.html

We Are All MacGyvers Now

WHEN THE GOING GETS TOUGH, **MAKERS GET IT TOGETHER**

Written by Lee David Zlotoff

LEE ZLOTOFF is an award-winning writer, producer, and director of film and television with over 100 primetime credits including the iconic *MacGyver* TV series that debuted in 1985. He wrote the "MakeShift" column in *Make:* from 2005 to 2011 (makezine.com/tag/makeshift) and he is currently producing *MacGyver: The Musical,* in which Mac is played by a different audience member at each performance. macgyver.com

Just in case you missed it, almost nothing is the same as it was just two years ago — *especially the future.* So, if you're feeling an underlying but constant sense of anxiety, welcome to the rest of the world. Because the inescapable truth is that whatever we all thought the future was going to be, has gone right out the proverbial window. And that's unnerving whether you're a country, a company, or one of us fragile 7.9 billion humans trying to figure out what to do next when pretty much *no one has a clue what might really happen.*

And it's not just the pandemic. That was a global wake-up call to be sure. Someone somewhere caught a new virus and within just a few months, the whole world came to a screeching halt.

Just like that.

But whatever the long-term impacts of Covid may prove to be, we all know it's only one of a host of challenges — or threats — looming on the horizon. Like managing to feed, hydrate, shelter, and provide even a modicum of health care for those billions. All of which depends on a climate that is, to say the least, changing — fast. Droughts, fires, storms, floods, and a seemingly

Adobe Stock - spaxiax and Lumos sp

endless array of weather-related upheavals of historic proportions. Not to mention all the political, economic, social, and war-caused tumult that fuel our 24/7 news cycle.

Fear Itself

So, that anxiety you're feeling? It's totally understandable and wholly justified. We all have good reason to be scared. And anyone who claims otherwise is either not paying attention or in some serious form of denial. But here's the thing. *There's nothing wrong with being scared.* As long as we don't allow ourselves to be paralyzed by it. Because courage is not the absence of fear. Courage is knowing you're afraid — and doing what you must anyway.

Because life doesn't stop, does it? We have jobs, school, families, responsibilities — in short, all the things that were there *before* this added uncertainty came swooping into our heads like a bird that gets caught in the house and is too panicked to find its way out. We all need to get on with living in spite of the fear. Indeed, we all need to find some way to adapt to that fear, come to terms with it, and *manage it* lest it make our already complex lives so stressful that the joy and purpose of life are lost entirely. At which point we are no longer really living. We are merely existing.

So, how exactly does one do that? It's easy to say, "Just manage your fear," but I'd be the first to admit that it's much easier said than done. Nobody can simply will or wish the fear away with the wave of a hand. It's fear after all. And it's there. All. The. Time.

Perhaps then managing that fear isn't like flipping a switch; one instant it's on, and the next it's off. Maybe it's more like a process. A simple but gradual series of steps — or shifts in our thinking — that eventually lead us to a place where we accept that the fear is still there, but it doesn't always occupy our thoughts, or our choices, or our *being*. So that it no longer gets in our way. *We own it instead of it owning us.*

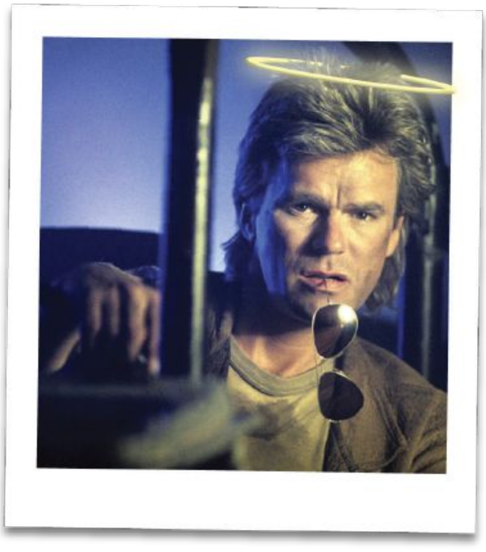
And I promise to get to some specifics about that process shortly, but I want you to really consider that last sentence for another moment, because that may be the most important and crucial shift in all of this: namely, between you and that fear, who owns who? I mean, it's *your* fear after all. It lives inside of you. So, at least in theory, you should be able to control it, right? Instead of letting it control you.

Own It Like MacGyver

Or to put it another way, that's the real MacGyver moment here, isn't it? Angus "Mac" MacGyver was constantly facing perilous and life-threatening situations. But he never panicked. On the contrary, he thought, "What have I got at hand to overcome this? How can I use all that to escape, or defeat the bad guys, or save whoever?" In other words, "What can I do to *change the story?*" so that he owned the situation instead of letting the situation own him.

Granted, Mac is a fictional character and the issues we're facing are all too real. But that doesn't make the approach or the principle any less valid. You have a choice in how you confront that fear and the problems behind it. We all do.

Okay then, let's assume for the moment you've opted to *MacGyver* your fear and uncertainty about what the future holds and own it, now what? What specifically could you do to prepare for unexpected weather, power or other disruptive events that might occur? For many, the first thing that comes to mind is to hunker down, batten the hatches, isolate yourself, and hope and pray whatever storm you're trying to shelter from passes by quickly and leaves you in one piece. And, if the disruption is short and not too intense, that just might work.



Courtesy macgyver.com

Stronger Together

Then again, maybe, like Mac, we should try thinking outside the box, and go at it *in exactly the opposite way.* So, instead of isolating yourself, perhaps your first move is to *reach out and connect* with those around you who are all facing the very same situation. Let's face it, no one individual or household can be prepared for every contingency. There are simply too many variables and curveballs to cover them all yourself.

But expand that to a group of say, 10 to 15 people or households, that are connected in even a low-key network, and now the potential resources for responding to a crisis grow dramatically — if not exponentially. Because the fact is more than 50% of the world's population now lives in cities, which are the most interdependent and susceptible to disruptions in the supply chain of practically everything.

But ask yourself, if you live in an apartment building, how many people in your building do you actually know — or have even met? How many even on your *floor*? And, if you live in the suburbs, how many people do you know in your neighborhood? Or even on your street?

Because of the continued arc of our civilization's mobility and the technology which enables and sustains that, the need to know and depend on our neighbors has become almost irrelevant. Most of us have our own space, with power and water and local stores and the internet and Amazon: what more do we need?

Believe me, I think our technology is awesome. Never in the history of humanity has anything like what we have existed. And it's stunning in both its reach and capabilities. Right up until the moment *that it stops working.* And then my friends, we are well and truly screwed. And, for the vast majority of us, woefully unprepared.

For example, say you're driving a rental car in an unfamiliar city, comfortably following the confident voice of the GPS directions guiding you from your phone to wherever your destination might be. And then, the GPS stops working — along with your phone. And you are suddenly and utterly lost. No clue exactly where you are. No way to call for help. And you can bet there's no folding map in the glove compartment.

Now what do you do? Pull over and wait for those systems to fix themselves? Drive around in circles hoping you might magically regain some sense of direction? Probably, not. Your best course would be to seek out a local human who could tell you where you are and then perhaps have some idea as to how to direct you towards your destination. So, what's the moral of this little nightmare scenario? When technology fails, *we are going to need each other* to manage the crisis *and the fear that goes with it*.

> **When technology fails, we are going to need each other to manage the crisis — and the fear.**

Humans are a social species. We needed and relied on each other to construct this impressive civilization. And as it continues to come under more frequent assaults, be they natural or man-made, we will once again need each other to cope. And you can bet all those breakdowns, power outages, and extreme weather events are only going to become more frequent in the days ahead, not less.

During the frightening onslaught of the Covid pandemic, I would often be asked, "What do you think we should do?!" And my reply was as simple as it was constant: If you need help, ask for it! From family, friends, neighbors, or strangers if need be. And, if you don't need help, then offer it! To whoever is in need.

Join a Local Emergency Response Network

So then, perhaps the best way to prepare for the future disruptions that await us is to form a *Local Emergency Response Network* or — in our culture of acronyms — a *LERN*. That is, a geographically close group of individuals or households who can be there for one another in the face of a crisis. I'm thinking that should be a minimum of five to seven households and, say, a maximum of 20. If there are too few of you, it may not be enough to pool or share resources in a meaningful way. And, conversely, if there are too many of you, then communication and coordination could be cumbersome.

Maybe it's the apartments on your floor, or in your building. Maybe it's a string of households on your block. At the very least then, if a crisis arises, you immediately know there is a group of people who you can reach out to and who can reach out to you. And believe me, that will go a long way to managing that fear — and may prove life saving for all of you.

So, how to start one of these LERNs? Well, you could print up a bunch of flyers explaining the concept (with a copy of this article if you think that'll help) and stick them in people's mailboxes or tape them to their doors. If someone is more concerned with their privacy than their safety, that's of course their prerogative. But I'm guessing you shouldn't have much trouble finding enough takers. And from there, all you need do is throw a party with all those interested to discuss the idea and how you all want to structure things. Perhaps each member of the group could focus on a different resource: medical supplies, generators, extra food, or water. Or the group could pool its resources to purchase some of those things to be stored at a central point.

Or maybe all you want to do is exchange phone numbers and emails. You can sort out the details however you want. But establishing a *known community of people near you* is in all likelihood the very best way to prepare for — and survive — when a crisis hits. You may also discover it's a nice thing to have, should just you or someone else in the group have an individual crisis that might require an assist. Who knows, you could even make some new friends. Really, when you think about it, there's not much of a downside to this and there could be a whole lot of upside.

Because, whether you care to admit it or not, *we are now all in this together.* If nothing else, the pandemic made that abundantly clear. And all those systems we've come to depend on are clearly not as robust and reliable as we once thought. So, it's time to look to ourselves for how to deal with the unexpected — and the fear of it.

Or, as I like to put it, the world has changed ... and we are *all* MacGyvers now.

The Ripple Effect

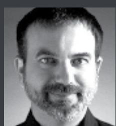
By Joseph Pred

So you've MacGyvered your fear and you want to build resilience through a supportive network. Are you overwhelmed with all the different ways you could potentially do that? Let me introduce you to the **ripple effect** model for emergency preparedness, which, along with an incremental approach, will significantly improve your disaster resilience.

You don't have to do all the training and preparedness at once. Instead, over time, you incrementally add capacity by adding layers, or ripples, to the resources you have available. Picture a rock being thrown into a pond and the ripples that emanate from it. The center is **you,** and the first ripple is **your household**. These are the two most important preparedness domains you can have a meaningful impact on. Focus on the training and supplies that will sustain you and your family first.

But no matter how well prepared or trained you are, there will be other skills or resources you won't have. Leverage the skills you do have with those of your next ripple, **your immediate neighbors,** to see who can do what. That's the idea of a local emergency response network.

One of the best ways to get more training and experience with the next ripple out, being of service to **your community,** is by joining a Community Emergency Response Team (CERT). Not only will you be able to help others, but the skills you gain — such as fire safety, search and rescue, and disaster medical operations — will also help you with the ripples that matter most, those which are closest to home. Learn more at ready.gov/cert.

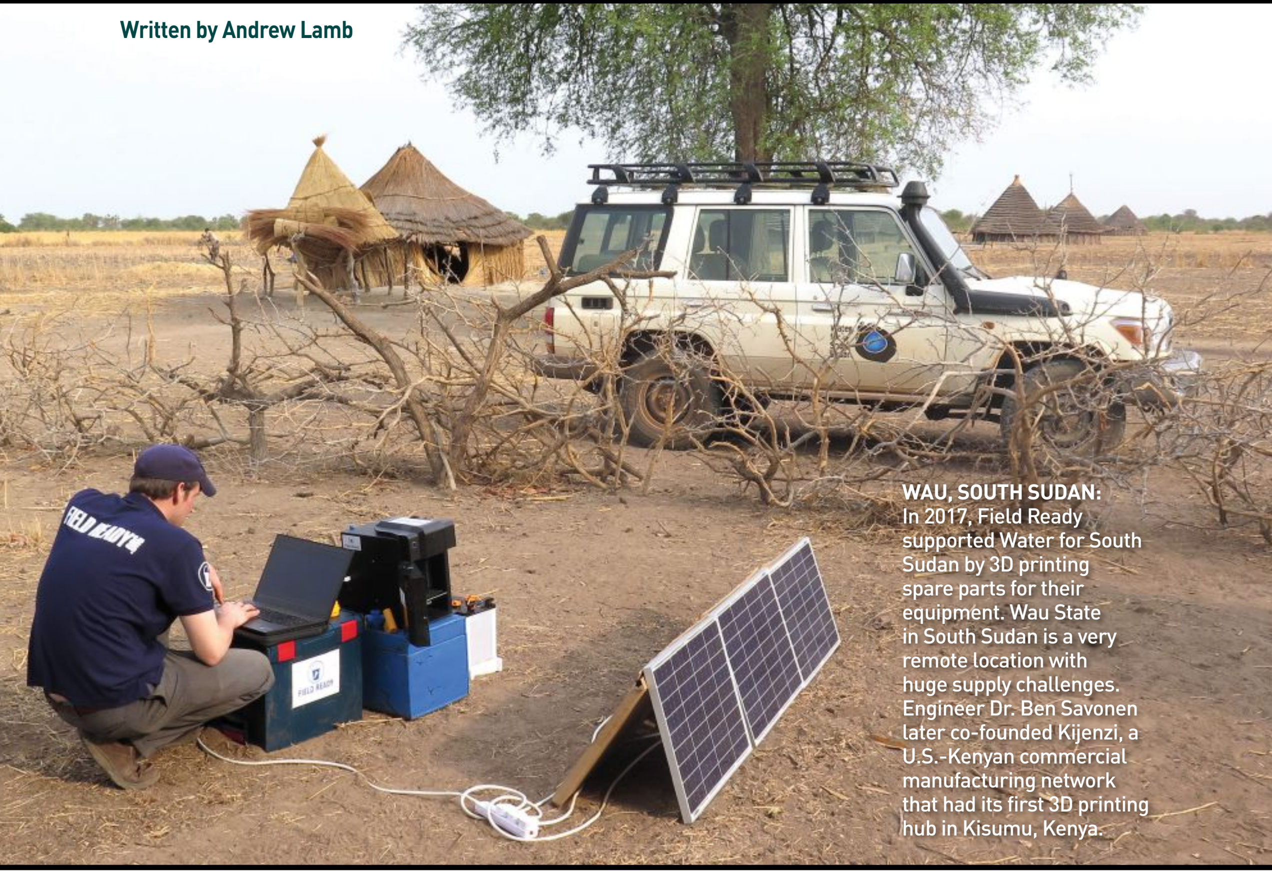


JOSEPH PRED is an emergency and risk manager who specializes in public safety for events and temporary mass gatherings, including Burning Man and Maker Faire. His most recent book is *The Essential Pandemic Survival Guide*. mars911.info

From Emergency to Emergence

SCALING AN INTERNET OF PRODUCTION THAT'S READY FOR DISASTER RELIEF

Written by Andrew Lamb



WAU, SOUTH SUDAN: In 2017, Field Ready supported Water for South Sudan by 3D printing spare parts for their equipment. Wau State in South Sudan is a very remote location with huge supply challenges. Engineer Dr. Ben Savonen later co-founded Kijenzi, a U.S.-Kenyan commercial manufacturing network that had its first 3D printing hub in Kisumu, Kenya.

A radical change has taken place in the last decade: the Maker Movement, makerspaces, and digital fabrication have now reached every country on Earth. This change has transformed the way I work. I no longer respond to emergencies directly; instead, I try to help create the conditions for *emergence* — the emergence of local manufacturing and local responses.

When I joined Field Ready as a volunteer in 2012, it was still just an idea — a brilliant one — that maker machinery could be deployed into disaster zones to make supplies on demand. More broadly, it was about getting cutting-edge innovations ready for the field of humanitarian relief. Starting operations in 2014, we built a great team right across the globe — our team meetings soon covered Fiji, Vanuatu, Australia, Philippines, Bangladesh, Nepal, Sri Lanka, Iraq, Syria, Jordan, Lebanon, Turkey, Kenya, Uganda, South Sudan, Germany, the U.K., and all across the U.S. too.

We were printing medical implements in Nepal after earthquakes. We fabricated search-and-rescue equipment in Syria during conflict. We co-designed and roto-molded deployable toilets in Fiji for cyclone responses. We made soap with toys inside to encourage refugee children in Iraq to wash their hands more often, reducing the spread of waterborne diseases.

We started supporting local communities to establish makerspaces, FabLabs, and manufacturing businesses in places that didn't have them, most notably in several cities across Iraq. We learned firsthand — and we tried to make the case to the humanitarian sector — that basic aid items could be supplied cheaper, faster, and better if they were made locally; a result that helps more people, more quickly and more effectively. (Indeed, a recent independent evaluation of our innovation in Syria confirms this.)

Think Global, Make Local

Today, importing makers, makerspaces, or other manufacturing capabilities in response to disaster is a last resort.

It is far better — and indeed more in line with humanitarian principles and objectives — to build responses upon existing *local* capabilities. And I find that, now, these capabilities exist nearly everywhere and they are growing stronger and stronger.

ANDREW LAMB is the global innovation lead for Field Ready, chair of the Internet of Production Alliance, and CEO of Massive Small Manufacturing. He lives in London and loves Lego. andrewlamb.info

Field Ready

PAGIRINYA, UGANDA: Together with the Youth Empowerment Foundation, a refugee-led youth organization, local manufacturer Masaf Engineering Ltd. in northern Uganda made siphon hand-washing stations for distribution in the nearby Pagirinya settlements, with Field Ready's engineer John Asiimwe supporting quality assurance. Matching local supply to local demand using open maps and designs — and without the usual globalized supply chains — is what the Internet of Production will bring to scale.

So today, my colleagues and I at Field Ready work with 3D printing companies in northern Uganda to help them sell to the aid sector by providing financing and quality assurance. We support factories in the South Pacific to extend their product portfolios to include key humanitarian items. And we build the capacity of startups across Nepal and in Bangladesh to locally upcycle waste plastic into shelter products. We now work in *advance* of a crisis, not just in response. We now support local manufacturing, not just humanitarian relief. And happily, several

Field Ready

SUVA, FIJI: In the South Pacific, Field Ready works with local factories to introduce water and sanitation aid products to their portfolios, replacing items imported from warehouses as far away as Western Europe. But in the Covid-19 pandemic, Laisa Meo and her colleagues at Field Ready Fiji were able to quickly pivot to making PPE.

humanitarian agencies — like the Red Cross in Kenya, the U.N.'s International Organization for Migration in Djibouti, or Terre des Hommes in Gaza — became part of the Maker Movement as well by building makerspaces or FabLabs to support their educational activities. I particularly admire Habibi Works which supports Syrian refugees in Greece.

The global Covid-19 pandemic brutally but clearly made the case for the local manufacture and supply of aid. The aid community really struggled to operate during the pandemic. It highlighted just how expensive, slow, and fragile our globalized supply chains really are. Major aid agencies started approaching us to ask for advice on how they could 1) find and buy locally made supplies, 2) enable local manufacturing of aid supplies, or 3) even start to make supplies themselves. Indeed, much of my work is now about co-creating initiatives to help the humanitarian sector do these three things.

Internet of Production

But the key challenge I think about now is one of scale. A batch size of one is all that is needed to replace a part and repair a medical device. Batch sizes of hundreds or even thousands might be needed by local communities or markets, even in remote locations. But many of the aid agencies I engage with are looking to secure stable supplies of hundreds of thousands or even tens of millions of often identical products. So naturally, they buy from mass producers who are very often not local to where these products are needed — and hence those vulnerable, globalized supply chains are necessary.

The Internet of Production will connect people to find, make, and share their designs, machines, know-how, and hardware.

What if we could network together massive numbers of makers and small manufacturers in every place where these products are needed to reliably deliver this supply locally, and on demand? Ideally this would be done within a single header contract, because most procurement systems favor placing small numbers of large orders, and definitely not large numbers of small orders! What we need is a way for, say, the Ministry of Health in a country to place an order for 200,000 items that can be made in 200 locations near where these items are needed, with each maker/manufacturer producing around 1,000 of the total — and all under a single header contract. Such an approach wouldn't need mass manufacturing. It needs what I call *massive small manufacturing*.

Since 2015, I have been part of a community that is building what we now call the *Internet of Production*.

The World Wide Web has connected people to find, make, and share their ideas, data, knowledge, and software. The Internet of Production will connect people to find, make, and share their designs, machines, know-how, and hardware.

While most "Industry 4.0" initiatives are focused on efforts *within* factories, *within* vertical supply chains, or on customization *within* mass production, the Internet of Production would *connect between*. And it will reach further than globalized supply chains have been able to reach (perhaps because small, remote, or poorer areas just aren't viable markets for mass production).

Remember that to really compete, it's the price the consumer pays that matters — known as the *total landed cost*. So even if the production cost of a locally made item is higher, local makers and manufacturers can still compete because of the often enormous cost of the supply chain for mass-produced items. The Internet of Production aims to bring down the cost of distributed local manufacturing at scale to something with zero marginal transaction cost when compared to traditional supply chains.

The concept draws upon recent examples, ranging from systems used by makers across France to make millions of items of PPE during the pandemic, to the work of a humanitarian innovator working with small and medium enterprises (SMEs) in Bangladesh to a U.S.-Kenyan company focused on commercial 3D printing networks in secondary cities. It also draws upon pilots that I was involved in with Field Ready in Kenya and Iraq.

GULU, UGANDA: Takataka Plastics in central Uganda was one of thousands of local manufacturers mapped to the Open Know-Where standard by Field Ready's teams as part of its response to the Covid-19 pandemic. This innovative recycling company had the capability to injection-mold thousands of protective visors using molds and machines based on open hardware designs.

Open Standards

The Internet of Production is being built by an alliance of people and organizations who share these ideas, and who are already helping to make parts of it a reality. Rather than duplicating the work of our members, the Internet of Production Alliance is creating the common language that's needed to build the network. To make anything, you need: People & Skills, Designs & Documentation, Machines & Tools, Materials & Components, and Contracts & Business Models. So we are developing open standards in each of these areas to help our community connect.

The first open standard improves the discoverability of hardware designs online. Dubbed "Open Know-How," anyone can use it to create meta-data about their designs so that others can find them more easily online, regardless of how they publish designs on the web. A search engine for hardware designs is being developed. The standard is now moving on to issues of portability and interoperability between organizations and platforms.

The second helps people to find manufacturing capabilities near them. Not suppliers, not products, but machines. An understanding of local manufacturing capabilities enables economies of scope — because you can work out what could be made, not just find out what products are currently available. This was called "Open Know-Where" because it's an open standard that helps you know where to make things. Some 30,000 machines have been mapped so far — from primary data collection or by interfacing with some existing databases.

By the end of this year, you should be able to choose a design online and automatically find out where it can be made near the location of your choice.

Makerspaces and Local Capability

Makerspaces foster emergence. They help people to learn, prototype, and make. And as we've seen around the planet, they can help people to mobilize and respond to emergencies. Many are already essential to enabling economies of scope and so mass producers often rely on them to help develop new products.

I believe that makerspaces will become fundamental to the Internet of Production; they are to distributed manufacturing what cloud services are to the web. You don't have to own one, but you can access their services to develop your activity. Makerspaces will not only be places of experimentation and learning. They will play a role in organizing commercial production, provide accreditation and quality assurance processes, and be hubs for flows of materials, components, and circular economies. Makerspaces must become civic infrastructures that are funded by government — like libraries, sports centers, or parks. The governments of the Philippines and Bangladesh provide good early examples of public investment in makerspaces for the purpose of promoting entrepreneurship, business growth, and industrial development.

Open hardware also has an enormous role to play. The internet and the World Wide Web would not exist as we know it without open source software, and vice versa. Open hardware will be an early adopter of, and thrive in, the Internet

DOHUK, IRAQ: Children living in the refugee camps near Dohuk in northern Iraq designed "surprise soaps" through interactive workshops that made use of rapid prototyping. The product significantly increased the rates of handwashing among children.

The toys inside the soap were then made by distributing the manufacturing across existing local 3D printing companies, like this one run by Mr. Shirwan in Dohuk. The distribution of the contracts and the quality assurance was all done manually by Field Ready's field team.

Field Ready

MOSUL, IRAQ: MosulSpace is a groundbreaking facility created by young entrepreneurs trying to rebuild their futures and the future of their city (after its capture and destruction by conflict with Islamic State). It is one of several makerspaces across Iraq that Field Ready supported, all of which are now run locally and independently. Here, Mohammed Azzam is inducting new members.

of Production. So I am a big fan and a strong advocate of open hardware. Just like the web, however, the Internet of Production must work for a full range of purposes and revenue models if it is to incentivize people to connect to it. Further into the future, I am excited to see how the Internet of Production might interact with, affect, or disrupt the global patent system.

Open hardware and good documentation allow for anything to be made (almost) anywhere. But most of the engineers I've worked with will automatically start designing a solution before they check to see if a solution already exists. Field Ready encourages design and rapid prototyping in the field with and by the communities we support. But I often remind our engineers that if we are designing things then we're not making things, and if we're not making things then we're not helping people; we are a humanitarian organization after all. So I introduce them to platforms and organizations that share existing open hardware designs that they might be able to make and deliver readily in the field.

Across the Maker Movement, I genuinely think we need now to encourage design reuse with some form of prize for plagiarism — something to celebrate the copying and reuse of existing open hardware — rather than continually celebrating the new.

People who create are happier than people who consume. If the Internet of Production becomes a reality, I genuinely think it will give everyone the power to create (hardware) and to determine their own development. It will help communities to become more resilient, and less dependent on imports or aid. It will restore economic activity in places left behind by globalization and favor a deepening of richness and complexity in local economies rather than having to continue the pursuit of unsustainable economic growth.

Challenges remain in the humanitarian sector. For very good reasons, the aid sector looks at people affected by disaster and poverty through a lens of vulnerability — to see and support those most at risk. But I think we should all view people through a lens of capability, not vulnerability.

Through Field Ready, over the last decade, I have been fortunate to see capabilities emerge firsthand. An entrepreneur in Nepal now running 3D printing companies. A welder in a refugee settlement in Uganda making washing machines. An architecture graduate in Fiji demonstrating plastic recycling to the U.N. Secretary General during an international summit. Young business owners in Bangladesh taking to the factory floor to retool injection molding machines on the fly because they weren't satisfied with the already impressive quality of their product. FabLab managers in the Philippines helping local firms take new products to market. African innovators making machines to sell to university labs and car manufacturers. And many more.

The radical change of the next decade will be to shift the paradigm of production – from mass production to production by the masses.

So I know these capabilities exist the world over. And not only should we build upon these capabilities, particularly in an emergency, but we should continue to support their emergence. And I sincerely hope that the Internet of Production — when it exists — will help them all to compete on a level, local playing field with General Electric, Toyota, or Foxconn.

I think the radical change of the next decade will be to shift the paradigm of production from mass production to production by the masses. And I think we will all be better off, happier, and more resilient if an Internet of Production can help us all make that radical change.

Learn more:
internetofproduction.org
fieldready.org
andrewlamb.info

DIY Solar Bottle Lamp

REUSE WASTE PLASTIC BOTTLES TO MAKE THIS 3D-PRINTED SOLAR LAMP

Written and photographed by Debasish Dutta

DEBASISH DUTTA is an electrical engineer, YouTuber, blogger, and maker from India. Find more of his projects at opengreenenergy.com and youtube.com/opengreenenergy.

TIME REQUIRED: 1–2 Hours

DIFFICULTY: Easy–Intermediate

COST: $15–$20

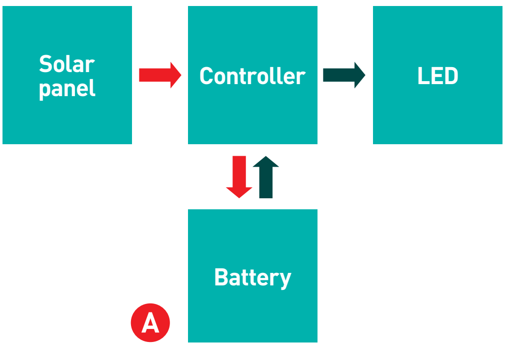
MATERIALS

For more part numbers and sources, see instructables.com/DIY-Solar-Bottle-Lamp-V20.

- **Soft drink bottle, PET plastic**
- **Solar Bottle Lamp circuit board** Download the Gerber files or buy PCBs direct from pcbway.com/project/shareproject/TP4056_Based_Solar_Bottle_Lamp_30d3cb2b.html
- **Solar panel, 5.5V 80mA, 60×60mm** such as PCBWay LP441
- **TP4056 lithium battery charging module, 5V 1A, micro USB** such as Amazon B00LTQU2RK
- **Transistors, 2N2222A (2)**
- **Resistors: 5.1Ω (1), 22Ω (1), 1kΩ (1), and 10kΩ (1)**
- **Schottky diode, 1N5819**
- **High power LED, 8mm "straw hat," white/transparent** 3V–3.5V forward voltage, 120–250mA
- **Li-ion battery, 14500 size**
- **Battery spring plate terminals** AliExpress 2251832697974737
- **Pushbutton flashlight switch, 3 pin** TLZWLA model 213BS, AliExpress 2255800494498765
- **Straight header pins, male (6)**
- **JST connectors, M-F pairs (3)**
- **Hookup wire, 24AWG**
- **Heat-shrink tubing**
- **Self-tapping screws, M3 size: 8mm (2) and 20mm (2)** for plastic
- **3D-printed enclosure** Download the free files for printing at thingiverse.com/thing:5330215.
- **Epoxy glue**
- **Chlorine bleach** a few drops

TOOLS

- **Soldering iron and solder**
- **Wire cutters/nippers**
- **3D printer**
- **Hot glue gun**
- **Screwdriver**



The Solar Bottle Lamp is a solar-powered light that reuses a waste plastic bottle by attaching a 3D-printed solar lamp in place of the old plastic cap. It also makes clever use of the light-refracting properties of water!

I designed this lamp as a low-cost solution for lighting rural homes, replacing their harmful kerosene lamps and at the same time upcycling some of the millions of waste plastic bottles that are daily thrown into the garbage. These lamps are also great for decorating a garden, for camping or traveling, or for emergencies when the power is out.

A Liter of Light

My design was inspired by the Moser bottle daylight lamp invented by Brazilian mechanic Alfredo Moser (believe.earth/en/turn-a-plastic-bottle-into-a-lamp). The concept is that clear plastic beverage bottles filled with water can be fixed into the roof of an unlit building to refract sunlight around a room, equivalent to a 40W–60W bulb. In 2011, Illac Diaz used Moser's technology to start Liter of Light (literoflight.org), a grassroots movement to provide solar lighting to communities around the world.

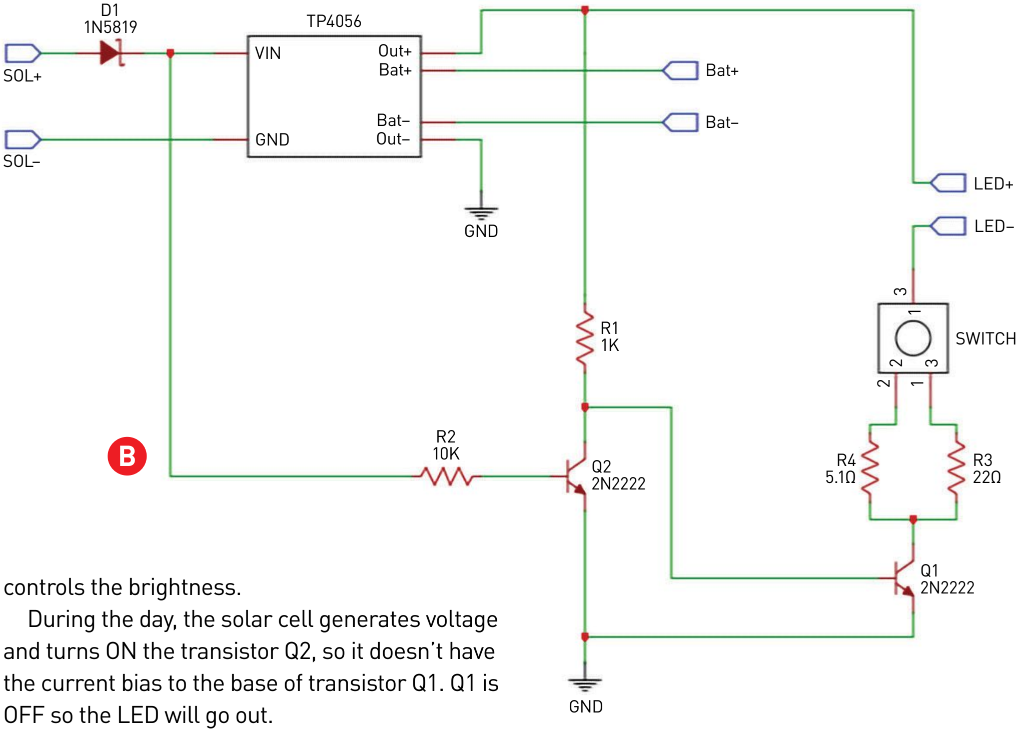
The Moser bottle is simple and inexpensive, but it only works during the daytime. So I designed a solar bottle cap that can provide light during the night.

How the Circuit Works

The solar lamp can be considered as a standalone solar photovoltaic (SPV) system and contains four basic components (Figure A):

- **Solar panel** — converts solar energy to electrical energy
- **Controller** — charges the battery (charger) and drives the load (driver)
- **Battery** — stores the electrical energy
- **Load (LED)** — provides the desired light output

The circuit, shown in Figure B on the following page, can be broadly divided into two parts. The charger circuit extracts power generated by the solar panel during the day and charges the battery. It's based on a TP4056 single-cell Li-ion charger module. The LED driver circuit powers the LED, automatically switches it on at night, and

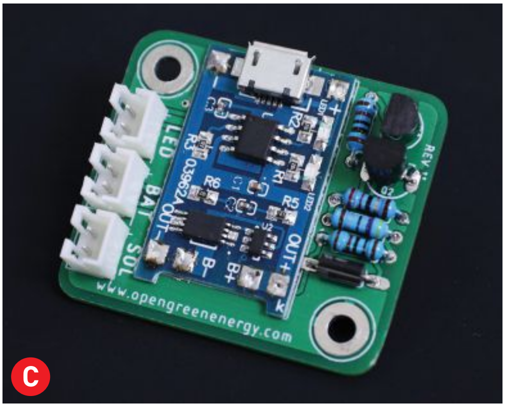


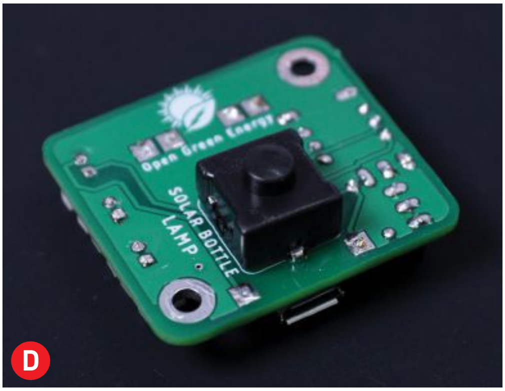
controls the brightness.

During the day, the solar cell generates voltage and turns ON the transistor Q2, so it doesn't have the current bias to the base of transistor Q1. Q1 is OFF so the LED will go out.

When there is no sunlight, there's no solar current to base Q2 so it will not conduct, but at the same time, transistor Q1 will conduct. Now the battery's current will flow to the LED through the resistors (R3 or R4).

The 3-pin button switch is used to connect either R3 or R4 in the LED circuit. When the pole is connected to R3, the brightness is Low (high resistance, low LED current) and when connected to R4, the brightness is High (low resistance, high LED current). You can learn more about the circuit in my video at youtu.be/Ll-qlYK30J0.



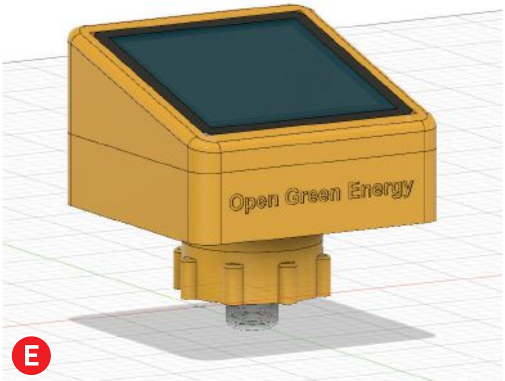


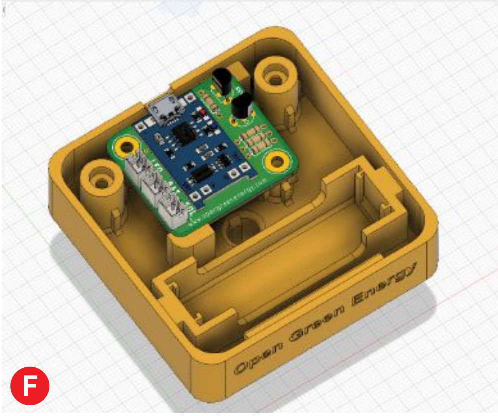
Build Your Solar Bottle Lamp

1. ASSEMBLE THE PCB

For assembling the PCB, you'll need a decent soldering iron, solder, and nippers. It is good practice to solder the components according to their height, beginning with the shortest components: first solder the resistors, diode, and transistors, then the female JST connectors, the button switch, and finally the TP4056 module (Figure C). Trim the excess legs off the components using a nipper.

Note that the button switch is mounted on the bottom side of the PCB (Figure D).





2. 3D PRINT THE ENCLOSURE

The enclosure (Figures E and F) has 5 parts. The main body is designed to fit all the components including the battery. The top cover is designed to cover up the main body and accept the solar panel on top. The LED holder is used to hold the LED, and the diffuser is used to diffuse the LED light in all directions. The button cap is used to operate the pushbutton switch on the PCB from outside.

Download the STL files from thingiverse.com/thing:5330215 and print the parts in PLA, ABS, or PETG filament. You need support structure for printing the main body and top cover (Figure G).

Removing the support from the cap's threaded area may require a screwdriver or other sharp object. After removing the support, smooth out the threads by twisting and untwisting the cap a few times on a soft drink bottle.

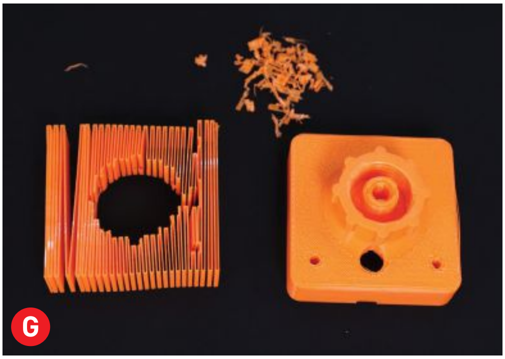
3. MOUNT THE SOLAR PANEL

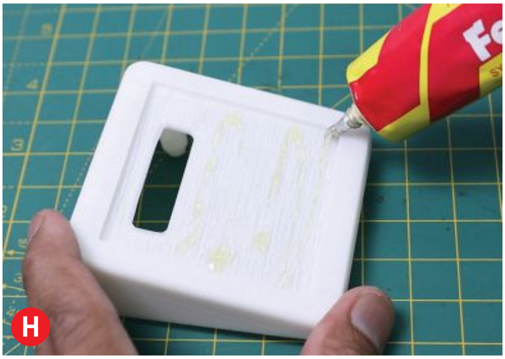
The enclosure is designed to fit a typical 55mm or 60mm square solar panel. The panel I've used here is rated for 6V and 50mA. Insert the terminal wires from the solar panel into the slot in the top cover and solder them to a male JST connector's wire leads. Or you can solder them directly to the PCB pads later (SOL+ and SOL–).

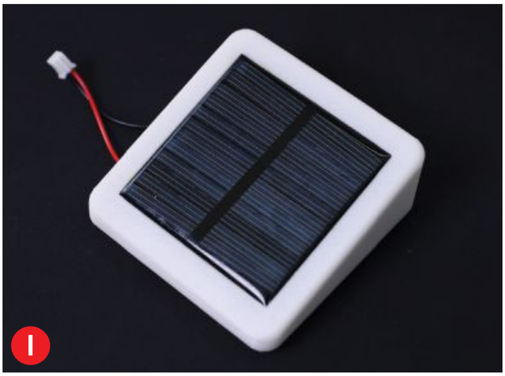
Mount the solar panel on the top cover by using epoxy glue (Figures H and I). Also seal the panel from inside using epoxy, so that water will not enter the enclosure.

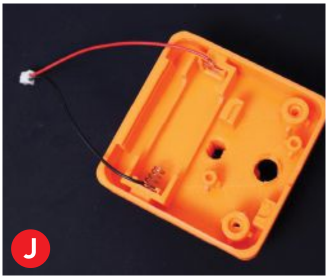
4. INSTALL THE BATTERY TERMINALS

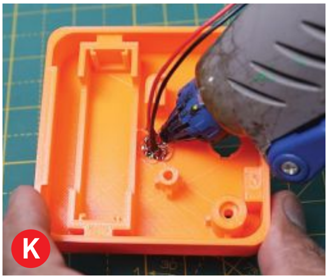
Solder a male JST connector to the battery terminals. I always prefer to use red wire for

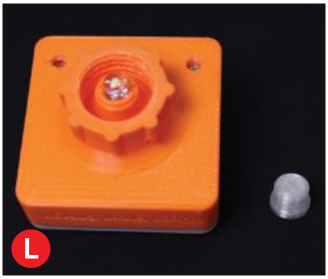


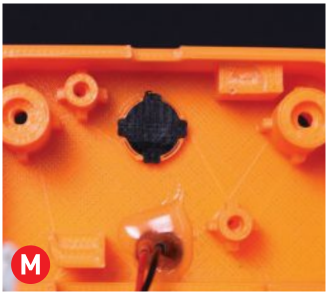


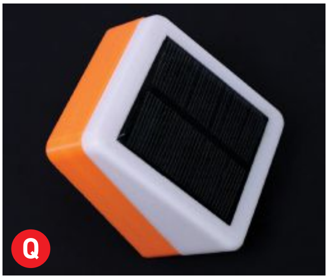












the positive terminal and black for the negative. The one with the spring contact is the negative terminal. Again, if you're not using JSTs, you can solder these terminal wires directly to the PCB later (BAT+ and BAT– pads).

Then install the terminal plates into the battery slots as shown in Figure J.

5. MOUNT THE LED

For illumination I've used a big 8mm 0.5W "straw hat" LED. Solder another male JST connector (or hookup wires) to the LED's terminals: red to positive and black to negative.

Mount the LED into the holder and then install it in the main enclosure, using the notch to align it. Now seal the LED from all sides. You can use hot glue (Figure K), but I recommend using epoxy glue instead.

Then install the diffuser (Figure L). You can apply epoxy glue to this joint as well.

6. INSTALL THE BUTTON CAP

Insert the switch button cap into its hole in the main body. You have to align the notches perfectly (Figure M).

7. INSTALL THE PCB

Align the PCB mounting holes with the mounting studs in the enclosure. Then secure it with two 8mm screws (Figure N).

8. CONNECT EXTERNAL COMPONENTS TO PCB

Now connect the LED, battery, and solar panel to their terminals on the PCB. You can connect these via JST connectors (Figure O) or directly solder to the soldering pads. If you prefer to solder directly, be sure the polarity is correct. To prevent mistakes, the polarity is marked on the PCB.

9. ASSEMBLE THE ENCLOSURE

Close the top cover by aligning the mounting

studs. For a better joint, I've designed this as a snap-fit arrangement (Figure P). Now use 20mm screws to tighten both the parts together (Figure Q). You may apply epoxy glue at the joints to make it weatherproof.

10. PREPARE THE BOTTLE

The solar lamp is compatible with any soft drink bottle cap. Take an empty soft drink bottle and clean it thoroughly. Fill the bottle with water and add a few drops of chlorine bleach to prevent algae formation and keep the water clear.

Close the bottle with the Solar Bottle Lamp (Figure R) and your lamp is ready to use!

Bottled Sunshine

Enjoy your new Solar Bottle Lamp! You can make a few similar bottle lamps and place them around your garden or lawn.

CHARGE IT

Your Solar Bottle Lamp can be charged in two different ways:

- **USB charging** — Before the first use, it is recommended to charge the battery. You can easily charge the lamp through a micro USB cable by connecting it to any USB power source like a phone charger. The red LED indicates that the battery is charging and the blue LED indicates charging is complete.
- **Solar charging** — You can also charge the battery by placing the bottle lamp in bright sunlight for at least a day (Figure S).

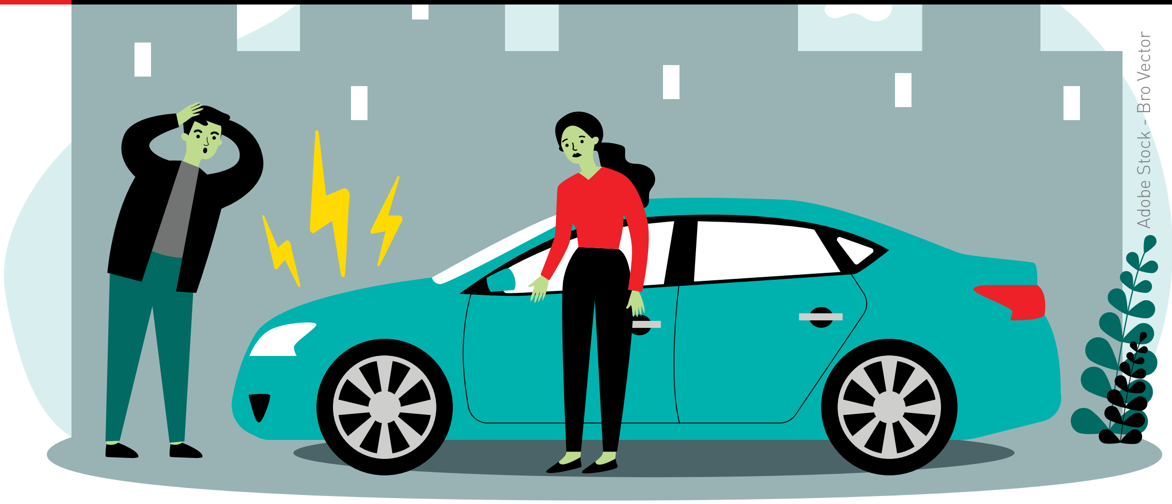
TEST IT

Press the button switch to set the desired brightness (Low/High) and test the lamp by covering the solar cell with your hand. The light should be turned on (Figure T)!

Place the bottle lamp in the bright sunlight, and the solar cell will charge the battery. When the sun goes down, the lamp will be automatically switched on (Figure U).

MODIFY IT

- **Weatherproofing** — You can apply epoxy spray paint at the joint of the 3D-printed enclosure to make it more water resistant. Apply conformal coating to the PCB to protect the board and its components from the environment and corrosion.
- **Easier build** — Use a PVC-wrapped battery with its own JST connector to avoid use of terminal plates.
- **Light mods** — Add some soap solution to the water to diffuse the light more, or add food coloring to make the light colored.
- **Roof mount** — To light a room or shed, you can follow Liter of Light's instructions for mounting the lamp on the roof: instructables.com/How-to-build-a-SOLAR-BOTTLE-BULB.



Nuke-Proof Your Ride

HARDEN VEHICLES AGAINST EMP BLASTS WITH SUPERFAST SURGE SUPPRESSION

Written and photographed by Forrest M. Mims III

TIME REQUIRED: 1 Hour

DIFFICULTY: Easy

COST: $55–$200

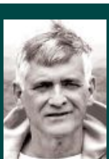
MATERIALS

» **TRAP high-speed surge protector** $54 from disasterpreparer.com. Or get a kit for $199 with one TRAP, one TRAP-B, and two ferrites (see text).

TOOLS

» **None** for TRAP

» **Wrench** for TRAP-B, to remove and reconnect car battery terminals



FORREST M. MIMS III, an amateur scientist and Rolex Award winner, was named by *Discover* magazine as one of the "50 Best Brains in Science." He has measured sunlight and the atmosphere since 1988. forrestmims.org

The first two of the three electromagnetic pulses (EMPs) emitted during a nuclear explosion are by far the briefest. The first pulse has a duration of nanoseconds; the second lasts only microseconds. Both, especially the first, can permanently damage solid-state electronics.

Electronic devices can be protected from an EMP by storing them in a *Faraday shield*, an enclosure made entirely of an electrically conducting metal, plastic, or fabric. I showed how to make your own Faraday pouch in *Make:* Volume 72, makezine.com/go/faraday-pouch.

Protecting vehicles is another matter, for they are much larger. Fortunately, the metal from which most cars are made provides some EMP protection. The U.S. Congressional EMP Commission subjected 37 running and nonrunning cars to EMP up to 50,000 volts/meter. The vehicles that were not running were unaffected. Of those that were running, eight showed no response to EMP, and 25 experienced minor nuisance failures, such as blinking dashboard lights. Three vehicles stalled when pulses exceeded 30,000 volts/meter.

The Commission noted that an EMP-induced failure of 10% or more of vehicles on a busy expressway could cause significant vehicle crashes, injuries, and deaths. Ten percent should be considered a conservative estimate, for today's vehicles have far more electronic controls than the pre-2008 cars studied by the Commission.

EMP Protection for Vehicles

Carmakers include some EMP protection against surges caused by the starter motor and various electronic systems. Ideally, all vehicles should have full EMP protection to prevent massive accidents should an EMP attack occur. The complex electronics in modern electric vehicles might be more vulnerable than conventional cars.

Arthur Bradley, a NASA engineer who holds a doctorate in electrical engineering, is known for his online videos demonstrating Faraday shields. Bradley has developed the Transient Reducing Auxiliary Plug (or TRAP) surge protection device for vehicles. The TRAP plugs into a car's cigarette lighter (Figure A), which is connected directly across the vehicle's battery. An ultra-high-speed transient voltage suppressor inside the TRAP switches on within a few picoseconds of detecting an EMP and shunts the EMP pulse away from the vehicle's battery cables.

A similar device called the TRAP-B is connected directly across the battery (Figure B). An EMP pulse that reaches the battery cables is almost immediately shunted by the TRAP-B. Bradley also sells ferrite surge protectors that clamp around the cables (Figure C) to reduce the amplitude of a high-frequency EMP pulse.

You can learn more and watch a demonstration at disasterpreparer.com/product/double-car-bundle. While Dr. Bradley cannot guarantee total EMP protection, his tests are encouraging.

A Higher Priority

If you're away from home during an EMP attack, reliable transportation to your residence or prearranged security site will be your highest priority. If you're at home or close by, making sure you have adequate water, food, and security may take precedence. In any case, a working car could be important if you can find fuel to run it. At minimum, the car's battery can become a useful power source.

In "Life without Electricity," a supplement to the 2008 EMP Commission report, Peter Vincent Pry described the rapid collapses in society that follow major natural disasters (makezine.com/go/life-without-electricity). He wrote: "Therefore, we can reasonably infer from the data on storm-induced blackouts and the known greater severity of high-altitude nuclear EMP that the consequences of an EMP attack on the United States' infrastructures and society would be an unprecedented and first order catastrophe."

If you're intrigued, I've written more on surviving nuclear war and EMP for *Mind Matters*: makezine.com/go/mind-matters-emp.

A Modern Watchmaker

CREATING A PRIVATE, OPEN SOURCE SMARTWATCH THAT ANYONE CAN BUILD, REPAIR, AND PROGRAM

Written and photographed by Paul Smith

I got my first watch when I was 8. It was a Turkish Railroad pocket watch and I can remember popping open the back cover to peek at the wheels ticking away inside. I spent the next two years saving my pocket money for a Casio outdoor watch. The possibility of reading weather conditions and tracking elevation during hikes with my parents was simply mind-boggling to me: How could such a tiny device do all this?

Fascinated by technology, I went on to study computer science and work as a software developer. I stumbled across microcontrollers and Arduinos during university, but always saw them as big and clunky boards, perfect for hobby projects, but not wearable devices. But this perspective would change as I progressed from the Arduino Blinky example to using ESP8266 boards and designing my own sensor network with custom PCBs.

Learning Hardware as a Hobby

Open source had always played a great part in helping me understand how code works. Now, open hardware projects gave me the possibility to see which components made things work. Looking at the code or design of a project is a bit like popping the back of a pocket watch to see what turns, ticks, and reacts to a push of a button.

The more maker projects I studied and built, the more familiar I got with microcontrollers, displays, and sensors. I documented my progress on social media, listening to suggestions from others which ICs to try out next, building up my know-how on hardware. The more I tried, the better I got at designing and 3D printing things, and reducing the size of my designs, eventually circling back to watches. What seemed to be an unthinkable piece of technology suddenly looked buildable at home using open source tools. Building a smartwatch seemed realistic at last.

Design Goals

Creating a smartwatch itself wasn't something new since the success of the Pebble. And from my experience as a software developer it was clear that whatever I created would not be on par with what is available on the market. But I knew there are areas where a DIY watch could still be better.

First of all, I'm not a huge fan of wearing a device that measures my environment and tracks my physical health and activities while it's also connected to the internet at all times. Where does my data go and what happens with it? Also, where is my charger again? These devices have a shorter runtime than a pocket watch from the 1950s and require a lot of trust in the vendor. My watches work with no internet connection, and no third-party snooping. All calculations are done offline.

Another reason that caught my eye was the possibility to 3D print custom watch cases. The almost infinite supply of different filament types and colors gives a level of personalization that a

TIME REQUIRED: 2–20 Hours

DIFFICULTY: Intermediate

COST: $45–$100+

MATERIALS

- **Open-SmartWatch PCB and display** Preassembled, or make your own from the open designs. Includes:
  - **TTGO Micro-32 EPS32-PICO-D4 module: 2×240MHz, 320kB RAM**
  - **Bluetooth 4.2 BR/EDR/BLE**
  - **Wi-Fi 2.4GHz 802.11 b/g/n**
  - **GC9A01 round TFT display, 240×240 16-bit**
  - **BMA400 accelerometer + pedometer**
  - **MCP73831 LiPo charger**
- **3D printed watch case**
- **LiPo battery, 4.2V, 350mAh**
- **Watchband, standard or 3D printed**

TOOLS

- **3D printer** The watch is designed for FDM printing, 0.1 or 0.2mm layers, 0.2 or 0.4mm nozzle; SLA is also possible.
- **Screwdriver, hex H1.5**
- **Computer** with Visual Studio Code and PlatformIO plugin using Arduino Framework
- **USB-Micro cable**

PAUL SMITH is a software developer in Belgium with a passion for 3D printing, electronics, and sci-fi. p3dt.net

A

B

C

commercial watch does not provide. You can use the exact colors you'd like to wear.

And during assembly, you can also choose the size of the battery, adapting the design to your taste and giving it a battery lifetime far greater than a couple of days (Figure A).

Open Tools

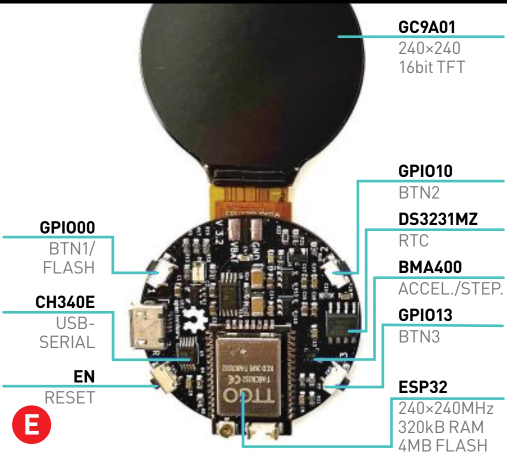
To build my watches I've used Blender to design the 3D-printed cases and KiCAD to design the PCBs. Both are free and open source software, which means that whoever wants to take a look at my designs and modify them can do so without any monetary hurdles.

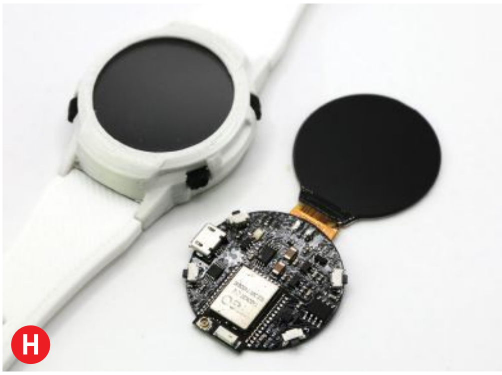
Making Progress (Iterations)

My first prototype, the EspWatch, was based on a 1.54" e-paper display combined with ESP8285 microcontroller and BME280 sensor modules (Figure B). I tested this setup on a breadboard and then designed a PCB with KiCAD that merged everything together, adding two buttons, a switch, and a MCP73831 LiPo charging circuit along the way (Figure C). This was already a great watch, but it didn't feel watch-like yet.

With the next iteration, the Open-SmartWatch Light Edition, I wanted to build something that looked closer to a wristwatch using a round display (Figure D). I chose a GC9A01 TFT LCD screen with 16-bit color depth and a resolution of 240×240 pixels. I added a BMA400 accelerometer for a step counter and for tilt/tap detection to turn on the screen, and I switched to an ESP32-based module, namely the TTGO Micro-32, which provides Bluetooth in addition to Wi-Fi. I increased the number of buttons from two to four for better usability and added a USB-to-serial controller to program it directly with a serial cable (Figure E). I published the project with all its sources on open-smartwatch.github.io and it quickly got the attention of many makers, building an amazing community over the following year. So far there are over a hundred forks of the OS on GitHub and dozens of contributors behind the project.

With the release of the Light Edition I worked in parallel on the GPS Edition, adding a Quectel L96 GPS module and microSD card for map data. This increased the complexity of the PCB





again but I got it to work (Figures F and G). The only drawback — the signal isn't stable when tracking satellites while the device is strapped to your wrist. It's been an interesting learning experience that will be continued in the future.

A Watch's Nemesis: Water

While wearing the Open-SmartWatch on a daily basis I noticed that the biggest issue was that any droplets from rain or washing hands had a chance of making their way inside the case. As the enclosure was 3D printed with four buttons, a USB port, and a display, there were gaps around each of these, due to the usual tolerances of consumer FDM 3D printers.

With the use of a round lithium battery I managed to design a case that's made up of an outer shell of PLA and a thin inner shell printed with TPU. This way the electronics and display are confined to a flexible, sock-like casing through which the pushbuttons on the PCB can be pressed. The screen is protected by a 2mm watch glass, so any brief splashes should not reach the electronics (Figures H and I).

Current Work in Progress

Currently I'm working on another iteration, Open-SmartWatch Mono Edition (Figure J). This design is done from scratch again, based on the lessons I've learned from the previous designs. The pushbuttons take up space on the PCB and add complexity in creating a water-resistant case, so they've been replaced by touch buttons integrated into the bezel. This bezel is a PCB itself with four pads hidden under the silkscreen. The USB port is removed, also freeing up space on the PCB, and charging is done with two contacts on the back of the case. Updates will be installed via Wi-Fi.

Along with the accelerometer I've added two more sensors: a magnetometer to implement a compass, and a pressure sensor for an altimeter. The color screen has been replaced with a round 240×240 pixels Sharp Memory Display, which consumes a lot less power and thus allows for the screen to be kept on all the time. With this setup the battery runtime is already at 4 weeks, with room for improvements on the hardware side as well as software optimizations such as longer deep sleep durations at night.

With this watch I'm on par with the functionality of my first digital watch that amazed me as a kid, but with the addition of Bluetooth, Wi-Fi, 8MB flash, and 2MB RAM, which leaves heaps of space for more creative applications in the future, e.g. tide estimations.

Try It Out

If you'd like to try it out and join the community, you can order an assembled Open-SmartWatch Light Edition from Makerfabs at makerfabs.com/open-smartwatch.html for about $45. This watch comes with a nylon SLA printed case and a standard 20mm watch strap. There are

Comparisons

	EspWatch	Open-SmartWatch Light V3	Open-SmartWatch GPS	Open-SmartWatch Mono	Open-SmartWatch Light V4
DISPLAY	152×152 e-paper	240×240 TFT	240×240 TFT	240×240 SMD	240×240 TFT
MICROCONTROLLER	ESP8285	ESP32 Pico D4	ESP32 Pico D4	ESP32 Pico V3-02	ESP32 Pico D4
FLASH	1MB	4MB	4MB	8MB	4MB
RAM	80kB	320kB	320kB	320kB + 2MB	320kB + 2MB
SD	N/A	N/A	MicroSD	N/A	opt. MicroSD
RADIO	Wi-Fi	Wi-Fi + BT	Wi-Fi + BT	Wi-Fi + BT	Wi-Fi + BT
ACCELEROMETER	N/A	BMA400	BMA400	BMA400	BMA400
PRESSURE	BME280	N/A	N/A	MS5847	BME280
TEMPERATURE	BME280	N/A	N/A	MS5847	BME280
MAGNETOMETER	N/A	N/A	N/A	QMC5883L	QMC5883L
THICKNESS	15mm	16mm/14mm	17mm	10mm	?
INPUT	Reset + 1 button	Reset + 3 buttons	Reset + 3 buttons	4 touch buttons	Reset + 3 buttons
BATTERY MONITOR	N/A	Analog (V)	Analog (V)	MAX17034 (%)	MAX17034 (%)
BATTERY LIFE (OFFLINE)	<1 Week	1 Week	1 Week	1 Month	?
WATERPROOF	No	No / partial	No	Yes?	?
STATUS	Prototype	Available	Discontinued	In development	In development

community case designs that are slimmer than the ones that I have made so far. If you'd like to know more about the project or would like to build your own from scratch (for $100 or more) you can head over to open-smartwatch.github.io. For questions, join my Discord server at discord.gg/SBtSmbZNqY.

The Open-SmartWatch OS currently has analog/digital/binary watch faces, a stopwatch, a web-based configuration tool to modify color themes and general settings, manual time setting app, step counter including a statistics widget showing the last 7 days, and a bubble level. There are games made by the community (Snake, Blockout). You can program the watch with your own apps using Visual Studio Code + PlatformIO using the Arduino framework. And when the internet goes down, your Open-SmartWatch will still work just fine.

Another idea I'm working on is to enable watches to exchange firmware updates directly with each other, without internet. If you meet someone with a newer Open-SmartWatch OS, you'll be able to share it with the push of a button.

Next Steps

Currently I'm working on the Mono as well as the next Light Edition, fine tuning the hardware components and rewriting the OS from scratch. Due to the global chip shortage I haven't been able to acquire all the components I'd like to use, so I'm using the time to select optimal ones. I expect to see further improvements in battery life, functionality, and display colors.

Until then I've also picked up a new hobby: writing sci-fi novels! My first book, *Mars Will Divide Us*, is available at amazon.com//dp/B098BN9KBF. Maybe this can shorten your waiting time until I finish the next watch models, and give you a chance to support my projects.

Written by David J. Groom

Cyber Prep

HARDEN YOUR DIGITAL DOMAIN AGAINST DISASTERS AND BAD ACTORS

The good news: The actual for-real Apocalypsageddon is not actually upon us yet. The bad news: You may already be under attack from malicious actors without even realizing it! If you use the internet at home or on a mobile device, or have devices on a home network — and who doesn't? — then chances are you have been or will be a target of hackers or scammers. Here are a few basic cyber security tips to help you stay protected.

Broadband Blunders

Most home users are connected to the internet via a **broadband modem/router**, either with its own Wi-Fi capabilities, or with an external Wi-Fi router connected. This is the first threat vector in your home network, so never use the default password! Reduce your vulnerability by choosing a **strong but memorable passphrase**, 15 or more characters in length, for the router administration functionality. You should also **update your router's firmware** — manufacturers regularly release updates to address newly discovered vulnerabilities, but if you're not up-to-date, then you are by definition potentially vulnerable.

Network Nastiness

If your broadband modem includes Wi-Fi capabilities, or you have a separate Wi-Fi router, you'll also want to take steps to protect your wireless data. While WEP, WPA, WPA2, and even the latest WPA3 protocol have been shown to be possible to crack in specific circumstances, **WPA2 Wi-Fi encryption** is more commonly supported by devices, and is probably sufficient for most situations. Most sensitive internet traffic is sent via HTTPS, so it will be encrypted even in the extreme scenario of someone being able to eavesdrop after exploiting your router.

Adding a VPN — a virtual private network that protects your data over public networks, or even your private home network — can offer another layer of security. Consider an **alternative DNS** to protect your family from malware as well.

Many Wi-Fi routers incorporate **guest network** functionality, which provides a connection

Adobe Stock - Jane Kelly

for visitors that is isolated from your private network, so you can share without over-sharing. With Amazon acquiring Eero and Ring, Google similarly acquiring Nest Wi-Fi and connected home devices, and most modern routers collecting user data and using it for marketing, or even selling it to third parties, you may want to spend a moment thinking about what devices are on your network, what they're doing with your data, and how much you trust those companies. (Build your own private video door camera on page 98).

Internet of Compromised Things

If you are running IoT devices like 3D printers, smart appliances, or your own Raspberry Pi or other connected projects, consider creating a separate **virtual LAN** so that they are firewalled from your main computers, and **limiting their port usage** to the minimum required for their given application.

If the notion of these simple devices being a threat seems far-fetched, not long ago, 3D printer owners around the world woke up one morning to discover that their printers had been compromised by a popular plugin, up to and including finding prints that they did not authorize on their machines. There were no reports of lasting damage, but the same exploit could have sent malicious commands, for example overheating beds and hot ends, and causing serious damage to devices and property.

Forget Your Passwords

Passwords are ubiquitous these days, and trying to remember them all can be an immense challenge. One way to solve this is by using the same password for everything, but this leaves you massively exposed, since a password cracked or obtained on one service (say, via recent Facebook or LinkedIn breaches) can then be used to access others. Instead, use a **password manager** such as Bitwarden or KeyPassXC, which are open-source, and free for most users. Use your password manager to generate your passwords, so that you never even have to know them, let alone memorize them. For cases where your password manager can't log in for you, choose a **long, memorable passphrase**, and avoid biometric logins, which can be used against you. Use **multi-factor authentication** everywhere it's offered, and favor **authenticator apps** such as Duo over SMS whenever possible, since phone numbers can be spoofed or cloned.

Back It Up

It is a truism in life that it's good to have a backup plan. But when it comes to the digital realm, you should absolutely have a plan for your backups. When possible, a **3-2-1 backup strategy** will help mitigate data loss: that's three copies of your data, two of which are local but on separate devices, and one copy off-site. You have the first copy of your data on your computer or other devices already, and can affordably add an external hard drive or thumb drive in order to keep a second, local copy. Your third copy should be offsite, to protect against local disaster, and could be as simple as syncing your files to Dropbox or another cloud provider.

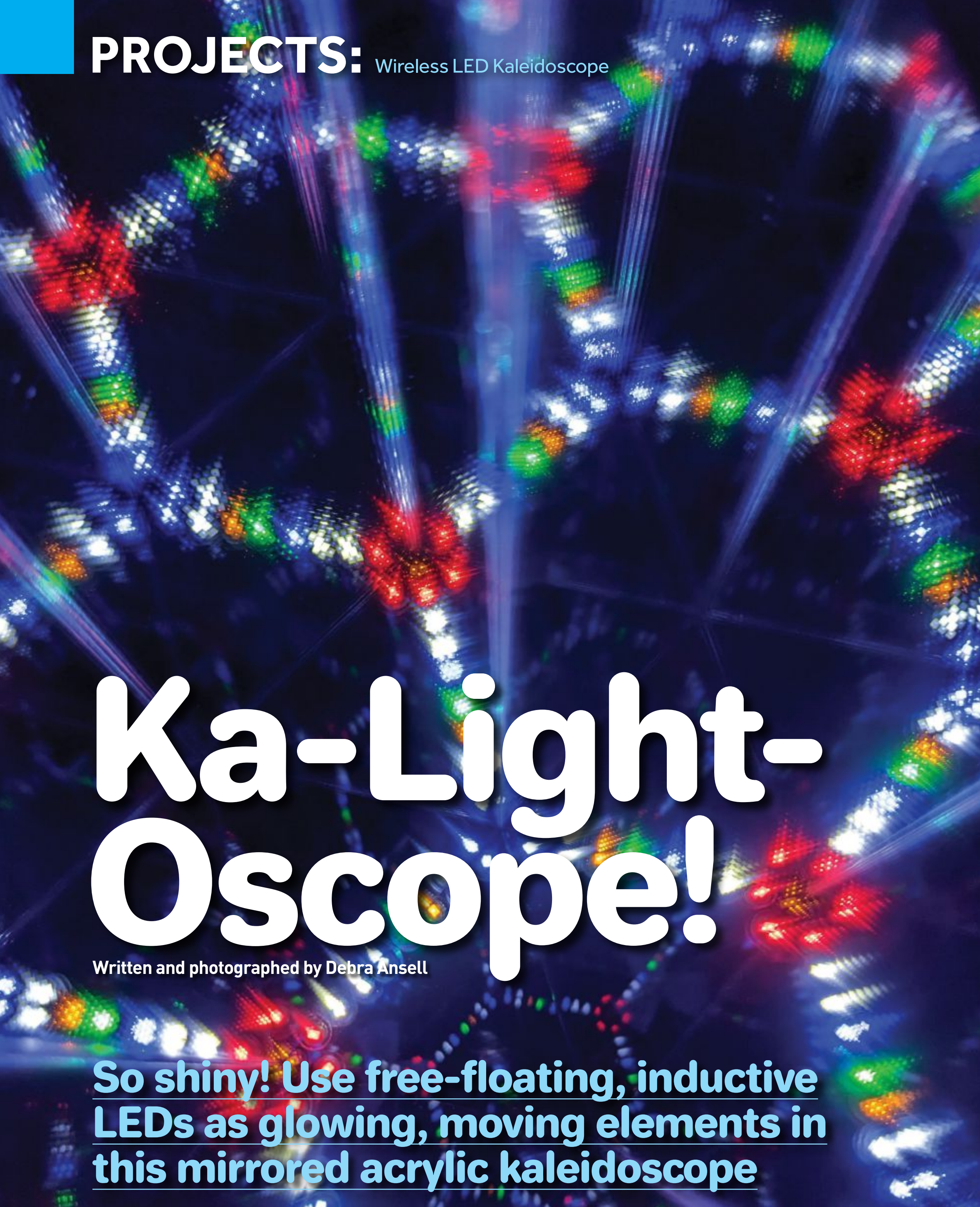
And critically, remember to **check your backups**! Many solutions can alert you when backups fail, but you should regularly simulate catastrophic failure to confirm that your backups would allow you to fully restore your data in the case of an actual event.

Stay Safe

If this all sounds a bit scary, that's because it is — there are many individuals and organizations with a vested interest in stealing your data, and unfortunately, defending against these attacks largely falls on the individual user. But by following a few simple best practices, you can dramatically reduce your threat attack surface, and help avoid Apocalypsageddon — of the digital kind at least!

DAVID J. GROOM loves writing code that you can touch. If he's not hacking on wearables, he's building a companion bot, growing his extensive collection of dev boards, or hacking on 90s DOS-based palmtops. Find him on Twitter at @IShJR.

Read the extended version of this article, with even more tips and links, at makezine.com/go/prep-cyber



Ka-Light-Oscope!

Written and photographed by Debra Ansell

So shiny! Use free-floating, inductive LEDs as glowing, moving elements in this mirrored acrylic kaleidoscope

DEBRA ANSELL is a maker and educator who believes LEDs improve everything, and puts that belief into practice as much as possible. See her work at geekmomprojects.com and brightwearables.com and follow her on Twitter @GeekMomProjects.

Working with "wireless" LEDs feels a bit like magic. These tiny LED assemblies can emit light without directly connecting to a power supply. The secret to their energy source is a nearby wire coil in which a high-frequency oscillating current generates a fluctuating magnetic field. Each induction-powered LED is attached to its own tiny wire coil, which responds to this changing magnetic field by producing a small (about 2mA) current.

A LITTLE LIGHT SELF-REFLECTION

I often obsess over finding novel ways to use LEDs in projects, such as my weather displaying edge-lit rainbow (build it at makezine.com/projects/edge-lit-rainbow-weather-display) and Twitter-connected LED matrix handbag (makezine.com/projects/led-matrix-handbag). I had impulsively purchased a set of 10 wireless LEDs in mixed colors and a 5V transmitting coil, hoping to generate new project possibilities from this unique LED form factor. Disappointingly, an online search produced numerous articles on how to build your own induction-powered LEDs, but very few examples of ways to use them!

Any project using induction-powered LEDs will be subject to some constraints. Power transfer between the 5V transmitter and the LEDs drops off dramatically over distances larger than a few centimeters, so the coil must remain close to the LEDs. Also, inductive power transmission works best if the receiving and transmitting coils are oriented parallel to each other; this limits the ways in which the LEDs can move while remaining illuminated (see Lee Wilkins' "Inductive Adornments" in *Make:* Volume 81, makezine.com/go/inductive-adornments, and "Skill Builder: Induction Instruction" and "Inductive Charging Bag," both in Volume 41).

With these restrictions in mind, I wondered how wireless LEDs would look inside a kaleidoscope. The idea was compelling because a small number of colorful lights could create a large visual impact through repeated reflections in the kaleidoscope's symmetrically placed mirrors. Induction-powered LEDs are particularly well suited for this use because they're free to slide around when the kaleidoscope is moved, generating dynamic patterns with their shifting configurations. Encouraged by the possibilities, I designed and built this laser-cut kaleidoscope that uses wireless LEDs to generate colorful illuminated patterns. You can create your own version of the build from the instructions that follow.

TIME REQUIRED: 3–4 Hours

DIFFICULTY: Intermediate

COST: $40–$80

MATERIALS

- **Wireless LEDs, multicolor, with 5V transmitting coil** such as Adafruit 5140
- **USB power supply, regulated 5V**
- **DC power adapter, screw terminal to female barrel jack** Adafruit 368
- **Adapter cable, male barrel jack to USB plug** Adafruit 2697
- **Painter's tape** or other easily removable tape
- **Clear acrylic sheet, ⅛" (3.2mm) thick, 5"×5" or larger**
- **Mirrored acrylic sheet, ⅛" (3.2mm) thick, 10"×8" or larger**
- **Wood or acrylic sheet, ⅛" (3.2mm) thick, 20"×12" or larger** for the kaleidoscope frame
- **Machine screws, M3×12mm (10)** with nuts
- **Machine screws, M3×16mm or longer (3)** with nuts
- **Decorative adhesive vinyl, 12"×10" or larger**
- **Vector design files** available at makezine.com/go/wireless-led-kaleidoscope

TOOLS

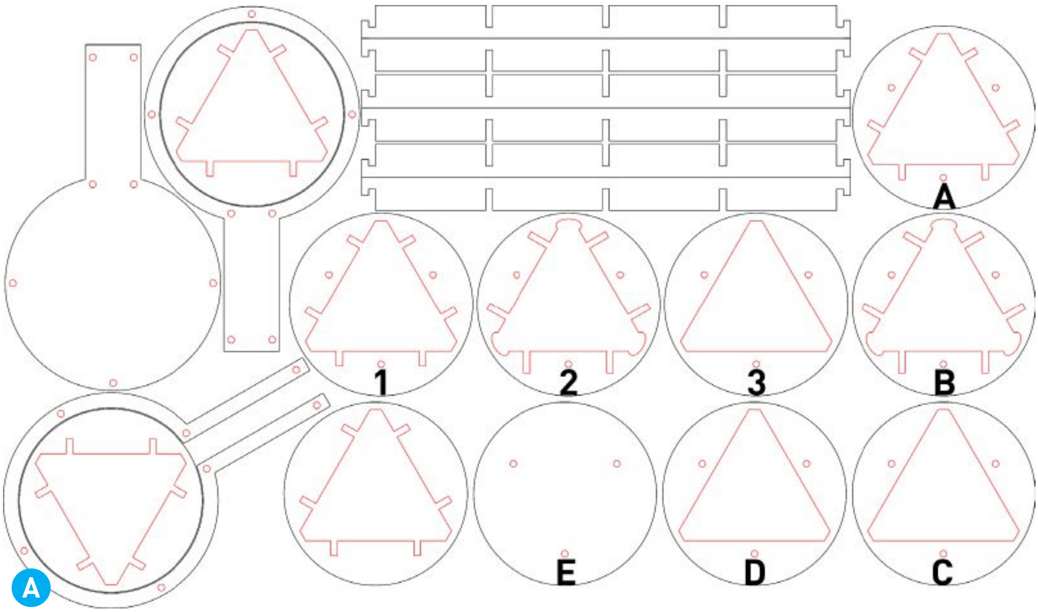
- **Laser cutter** or a laser-cutting service like Ponoko
- **Craft knife and cutting mat**
- **Screwdriver**
- **Scissors**
- **Wire stripper**

BUILD YOUR FLOATING LED KALEIDOSCOPE

1. LASER-CUT THE PARTS

The kaleidoscope's parts are laser-cut from ⅛" (3.2mm) sheet materials. The three different vector design files, available at makezine.com/go/wireless-led-kaleidoscope, contain the outlines of the pieces to cut for the frame, the eyepiece covers and LED "collars," and the mirrors. Cut the three rectangular mirrors from ⅛" mirrored acrylic sheet, and cut the eyepieces and collars from ⅛" transparent acrylic sheet.

The kaleidoscope frame may be cut from any



A

⅛"-thick wood or acrylic that has a nice finish on both sides. Kaleidoscopes are often displayed as art pieces, and an appealing construction material will result in a build with visual interest on the outside as well as on the inside. I used ⅛" black acrylic for my frame, but many other materials can work as well.

When laser-cutting shapes from the design files, cut along all blue, black, and red lines. Any green letters or numbers are intended to differentiate similar looking pieces from each other and should be etched or scored on the surface of the piece (Figure A). After you've cut the parts, remove the protective paper from every piece except the three mirrors.

B

C

2. ASSEMBLE THE FRAME AND EYEPIECE

To start the assembly, gather the parts of the frame (Figure B). Select the six identical notched brace pieces and the three circular pieces without screw holes. Connect the three center notches in each brace piece to a notch in each of the three circles. After slotting each brace piece into all three rings, tape it in position with painters' tape to prevent it slipping out. (Figure C). Be sure the brace pieces are seated as close to the outside edge of the circles as possible.

After all six notched brace pieces are taped into place, select the circular pieces numbered 1, 2, and 3 as well as one of the clear acrylic triangles. These parts form the kaleidoscope's eyepiece. Slide circle 1 just over the ends of the brace pieces so that each notch in the circle slots into the end notch of one brace piece (Figure D). Next, set the frame on its end, with circle 1 on top, and place circle 2 over circle 1, so that the top surface of circle 2 is flush with the very end of the six brace pieces. Slip the clear acrylic triangle into the triangular hole inside circle 2 (Figure E). Finally, lay circle 3 on top of circle 2, and secure all three circular pieces together with three of the 12mm M3 screws and nuts (Figure F).

3. PREPARE AND INSERT THE MIRRORS

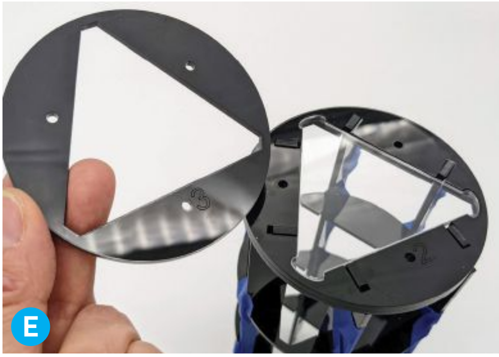
Before inserting the mirrors, flip the frame over so that the eyepiece is at the bottom, and slide circular piece A over the free ends of the brace pieces so that each notch in circle A settles into a notch at the end of a brace piece (Figure G). Then set the partially assembled frame aside and gather the three rectangular mirror pieces.

The matte side of the mirrored acrylic is a dull gray. Covering it with a prettily patterned adhesive vinyl gives the kaleidoscope a more polished appearance that you can customize to your taste. The vinyl I selected has a holographic silver sparkle pattern (Figure H). There are a wide variety of decorative adhesive vinyl options to choose at most craft stores. While applying the vinyl, leave the protective paper on the mirrors' reflective surfaces until you're done, to avoid accidentally smudging or scratching the mirrors.

For each mirror, use scissors to cut a piece of vinyl large enough to slightly overhang all four edges of one of the mirrors. Take the piece of vinyl, remove the paper backing, and adhere it to the matte side of the mirrored acrylic, pressing out any bubbles with your fingertips or the edge of a plastic ruler. Then flip the mirror over so that the vinyl is on the bottom and run a sharp craft knife along all four mirror edges to slice off any excess vinyl (Figure I). Repeat this process for the other two mirrors.

When you have trimmed all overhanging vinyl from the mirror, remove the paper from its reflective surface. Next, slide the mirror down into the triangular compartment inside the frame with its reflective surface facing inward.


D


E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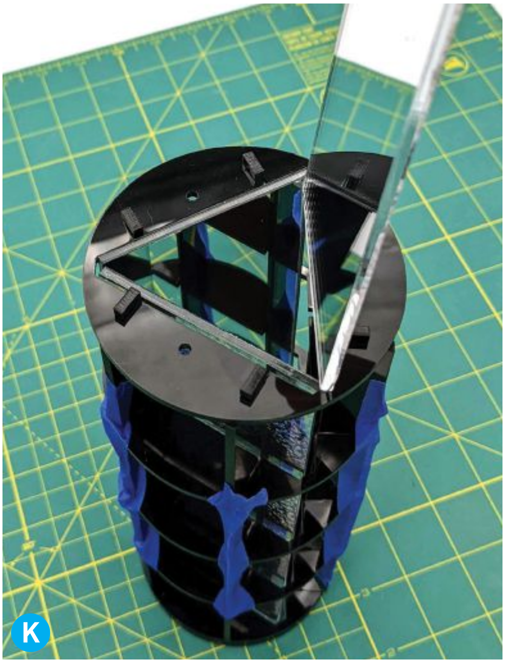

K


L

It's easiest to insert the first mirror while holding the frame horizontally (Figure J), and then turn the frame vertically before sliding the last two mirrors into place (Figure K). If a mirror "catches" on the frame during this step, tug each of the long brace pieces toward the outside of the frame to create a bit more room inside the frame.

With the mirrors inserted, place circle B on top of circle A, and place the second clear acrylic triangle into the hole in circle B. Finally, lay circle C on top of circle B (Figure L) and insert the three long (16mm) M3 screws and nuts into the holes. Fasten the nuts loosely for now, as we'll remove them later to add the LEDs and their container to the frame. Remove the painter's tape from the frame and discard it.

4. TAKE A BREAK TO ENJOY THE VIEW

Before incorporating the wireless LEDs, now is a good time to pause and reflect (pun intended) on what you've created. You have built a working kaleidoscope! Place your eye at the eyepiece and point the other end at any colorful object to see unexpected patterns emerge. Even simple images like Makey (Figure M) acquire new dimensions inside a kaleidoscope.

5. PREPARE THE INDUCTION COIL AND HOLDER

In this step, we'll set up the electronics to power the LEDs. The induction coil and current driving circuitry are fragile, so we'll create a protective case for them using the laser-cut parts shown in Figure N. We'll use the same holographic vinyl that covers the mirrors to secure the transmitting coil to its case.

First, trace the outline of the induction coil case onto the vinyl's paper backing and cut the resulting shape from the vinyl — cutting along a line that is about 5mm inside the outline you traced. The vinyl should cover most of the bottom layer of the case without blocking the holes.

Lay the vinyl on a flat surface with the protective paper facing upwards, and peel off the backing. Carefully stick the transmitting coil onto the vinyl, centered as well as possible (Figure O). Now turn the vinyl and coil over together and adhere them to the bottom layer of the transmitting coil case (Figure P). Trim away any


M


N


O

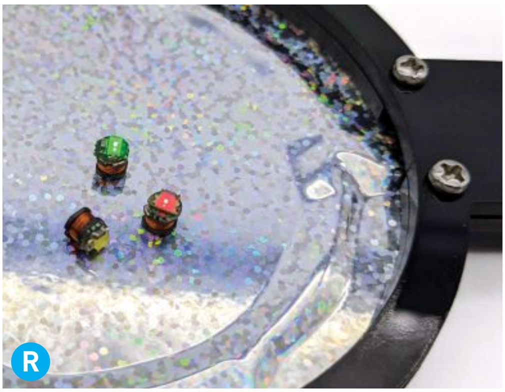

P

vinyl that covers the current driving PCB or the screw holes in the case. Place the next case layer, which has the open slot in its handle, on top of the vinyl, then place the final, solid-handled layer on top of that one. Secure the three case layers together with five M3×12mm screws and nuts. The transmitting coil's power wires will extend from the end of the case's handle (Figure Q).

When the case is completed, strip the ends of the red and black power wires if necessary and screw them into the corresponding +/– terminals in the screw-terminal-block-to-barrel-jack adapter. Check carefully to be sure the wiring polarity is correct. Then insert the barrel-jack-to-USB cable into the adapter.

Now attach the USB cable to any 5V regulated power source. Test the transmitter by placing a few wireless LEDs in the center of the coil to be sure they light up. Figure R shows that the LEDs facing upwards, with coils parallel to the transmitter, light up, but the LEDs whose coils are perpendicular to the transmitter may light up


Q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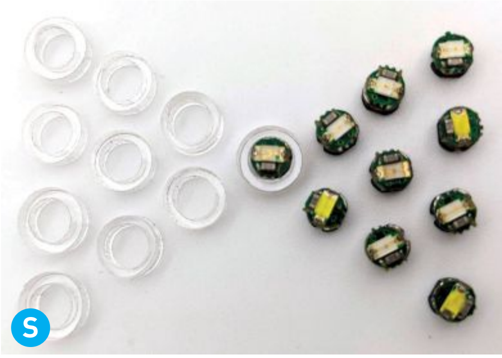
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T

only slightly or not at all.

Once you're certain the electronics work properly, unplug the USB cable from the power source and set the transmitting coil to one side while you attach the LED compartment to the kaleidoscope in the next step.

6. ASSEMBLE THE LED COMPARTMENT

The powered LEDs will shine brightest when facing directly upward into the kaleidoscope, so we'll place them inside tiny clear acrylic "collars" that maintain their orientation as they slide around (Figure S). Be sure that you've removed any protective paper from the acrylic rings before carefully slipping the LEDs into them. The LEDs should slide easily into the rings. Do not apply pressure to force them in. If the rings seem too small for your LEDs, laser cut another set of rings with a slightly larger inner hole. The LEDs and their collars are easily misplaced, so put them in a small container and set them aside for the moment.

To attach the LED compartment, set the kaleidoscope vertically onto its eyepiece with circle C visible on top. Remove the three M3 screws that hold layers A, B, and C together. Carefully put an acrylic collar around each LED, then place each assembly on top of the clear acrylic triangle with its LED facing downward into the kaleidoscope (Figure T). Once all the LEDs have been placed, stack circle D on top of circle C so that the LEDs sit inside the triangular holes in both layers C and D. Next, place circle E on top of D, lining up the screw holes in all five lettered layers. Reinsert the M3 screws into their holes so the screw heads rest on top of layer E. Secure the screws underneath layer A with the M3 nuts.

Now, when you move the kaleidoscope, the LEDs are free to slide around, but their collars keep the LEDs always pointed toward the viewer.

Your wireless LED kaleidoscope is now complete!

GO WITH THE GLOW

To use your shiny new kaleidoscope:

- Power the transmitter by plugging the USB cable into a 5V source.
- Set the end of the kaleidoscope with the LED compartment into the transmitter case to generate power for the LEDs.
- Look through the eyepiece to see the symmetric shapes created by the infinite reflections of colorful LEDs!

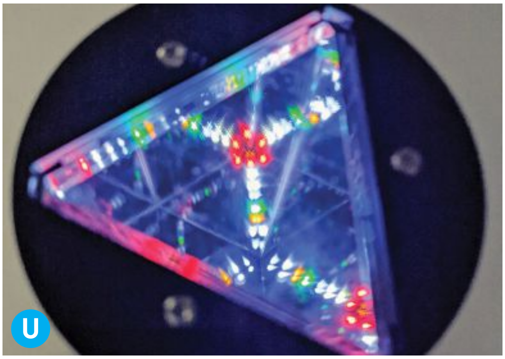
To create new visual patterns, tilt and rotate the kaleidoscope within the transmitter base to move the LEDs around (Figures U and V).

BRIGHT IDEAS FOR FURTHER EXPLORATION

To take this project a step further, you might try adding reflective beads or rhinestones into the container along with the LEDs. Choose objects that won't catch on the small acrylic rings. Or try laser-cutting new collars of different shapes and colors to place around the LEDs. Or make the project portable with a small 5V phone power bank.

ALTERNATIVE MATERIALS

You can easily change the appearance of this build by cutting the frame from an alternative sheet material and selecting a different color of adhesive vinyl. Figure W shows a kaleidoscope I created with a clear acrylic frame and a striped holographic vinyl backing on the mirrors.



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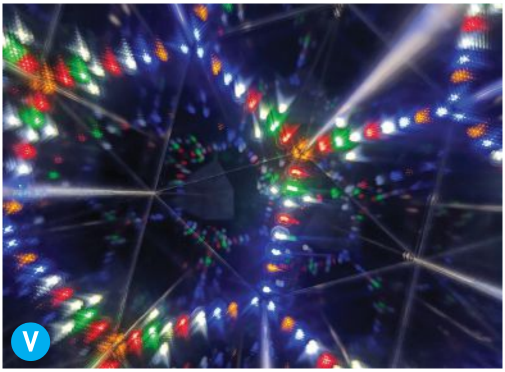

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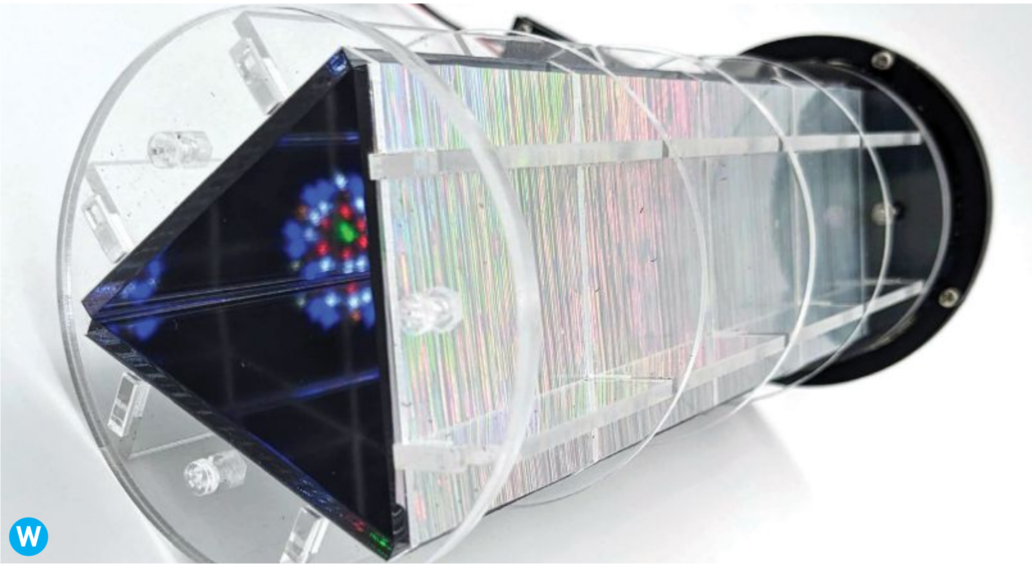


W

The build instructions in this article will work for any choice of ⅛"-thick opaque sheet material, however they require small modifications if you select a transparent acrylic for the frame. Modified instructions and adapted design files for a clear frame are found in a sub-folder called *TransparentFrameDirections*, so be sure to read them before you laser cut your materials.

Regardless of what materials you choose, the very best part of creating your own wireless LED kaleidoscope will be showing it off to others and watching their eyes light up when you do.

Build a Bamboo Garden Gate

Cut, join, and weave bamboo to make a beautiful shiorido tea garden gate

Written, illustrated, and photographed by Douglas Arensberg

A couple years ago, longtime *Make:* author Len Cullum came to my house to purchase a pile of granite cobbles that I had left over from a driveway project. We chatted a bit and found that we shared an affinity for Japanese aesthetics. I gave him a copy of a little instruction booklet I had made on how to construct a *shiorido* tea garden gate, which he later shared with the folks at *Make:* magazine.

Many years ago, at an instructional class at the Portland Japanese Garden, I had made a shiorido, but that gate is long gone. So I told *Make:* I'd build another one, so that you can see the actual finished product. The design of the gate is not mine. It is a traditional and ubiquitous design, long used throughout Japan.

> **A *shiorido* is a very simple light partition inside a garden made by wrapping thin strips of bamboo sheath around a rectangular frame of fine round bamboo poles, weaving the strips into a diamond-shaped pattern. The name *shiorido*, or "bent branch door," comes from the bending of the strips of bamboo sheath around the frame.**
> —*Isao Yoshikawa,* The Bamboo Fences of Japan

It's a simple and rewarding build that looks beautiful in your yard or garden. Once you've finished making the frame from bamboo poles, also known as *canes* or *culms*, you'll apply the lattice-work of split green bamboo sheathing. For that, you'll need to search out culms of thin-walled green bamboo, which can be difficult to source, but you'll find some eventually.

WORKING WITH BAMBOO

- Wear heavy leather gloves when splitting bamboo.
- Place all vertical bamboo to match the direction of natural growth. Observe a node to determine direction (Figure A).
- Check poles for "zigzag." Place zigzag in line of sight with the viewer to hide it.

MAKE YOUR SHIORIDO BAMBOO GATE

To see how the professional folks do this work in Japan, please watch this YouTube video from

TIME REQUIRED: 2–3 Days

DIFFICULTY: Intermediate

COST: $100–$200

MATERIALS

- **Bamboo poles, 8' long: about 1¼" diameter (1) and ¾" diameter (2)** green or recently dried, but not cracked
- **Bamboo poles, green, 12' long, 1½"–2" diameter (2)** Green poles are not always available. Call your bamboo supplier to make sure they have stock or can order some for you.
- **Twine or rope, black, 3mm-4mm diameter, about 50' length** The rope can be of hemp, sisal, jute, or palm, and should be dyed black, e.g. Amazon B07D1W15TL.

TOOLS

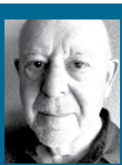
- **Heavy leather gloves**
- **Drill and twist bits: ¼", 3⁄16"**
- **Hole saw or Forstner bits, ½"–¾"** Don't use spade bits.
- **Pole sawing jig** such as a wood V-block for cutting and drilling dowels
- **Small, sharp paring knife**

Preferred, but may be costly or hard to locate:

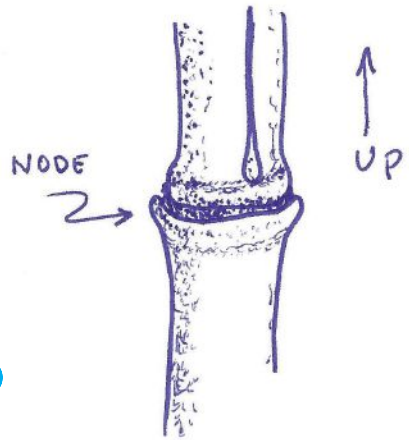
- **Japanese bamboo hatchet**
- **Thin blade fine-tooth saw**

OK to use, but may not provide the finest or quickest results:

- **Heavy old chef's knife**
- **Hacksaw**



DOUGLAS ARENSBERG is a lifelong resident of the Seattle area with an appreciation for Japanese aesthetics and a particular interest in Japanese architecture and garden design during the Edo period.



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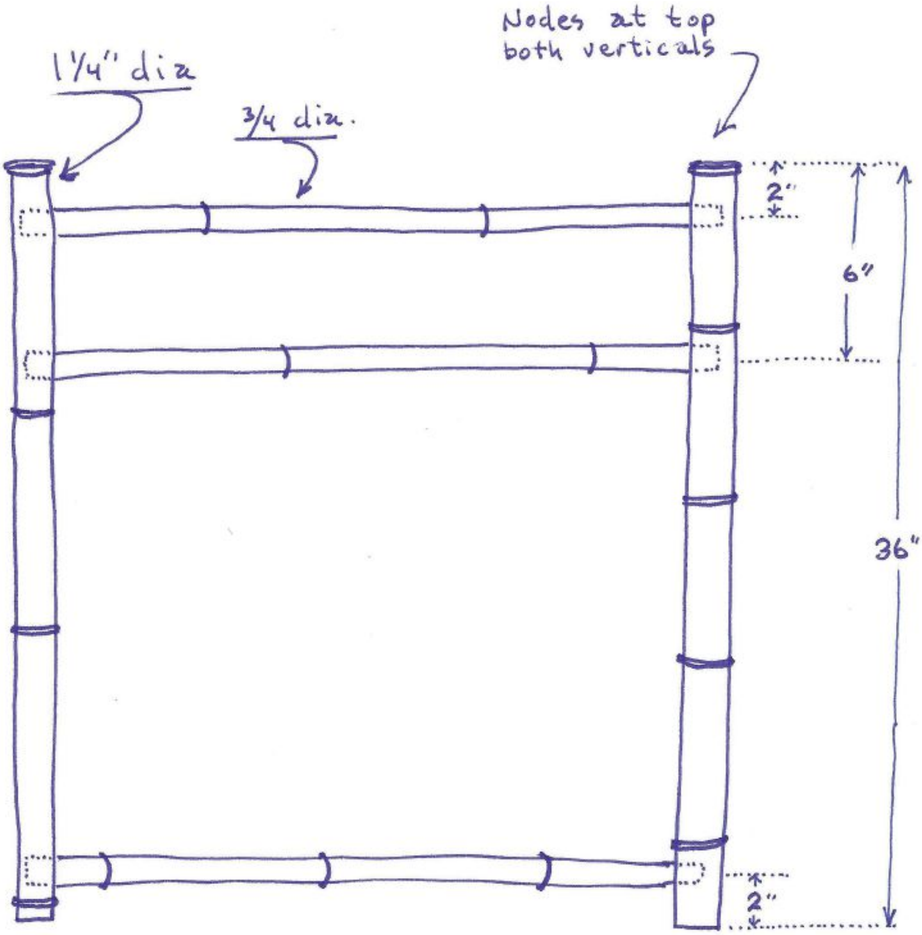

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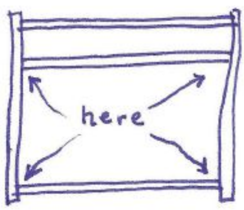

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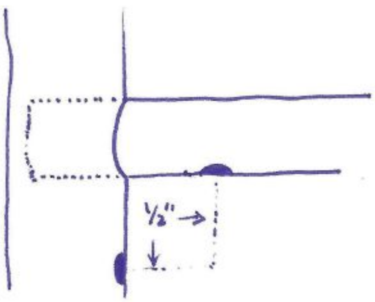


E

Japanese Garden TV, youtu.be/7O7HMcTG5J0. I wish I had access to their bamboo inventory!

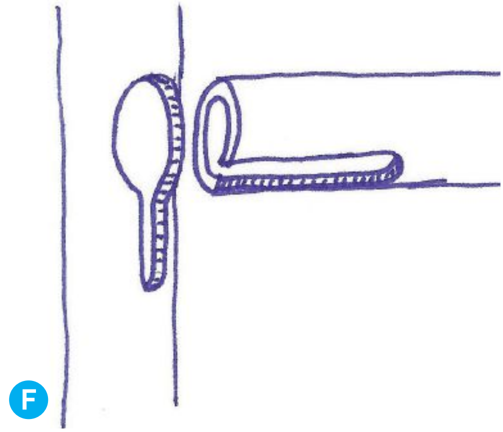
1. CUT THE POLES

Use a fine-tooth saw to cut the poles. For the cleanest edge, rotate the pole in the jig as you cut.

Vertical gate pieces should be about 36" long, with a node at the top (Figure B). Horizontal pieces should be about 32". Use 1¼" diameter for vertical, ¾" diameter for horizontal.

2. JOIN THE FRAMEWORK

After positioning the poles to minimize any obvious zigzag, mark the vertical poles for the location of the horizontal poles. Drill each hole in one side of the vertical pole, not all the way through, sized just under the smallest cross-section diameter of the horizontal pole. Do not use excessive pressure or bamboo may split.



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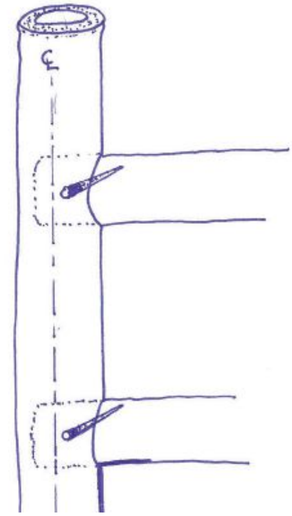

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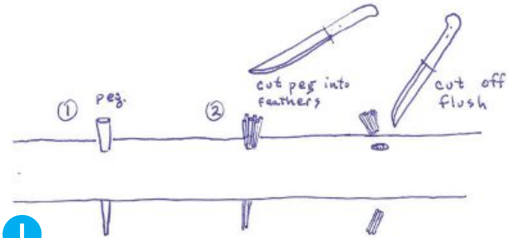

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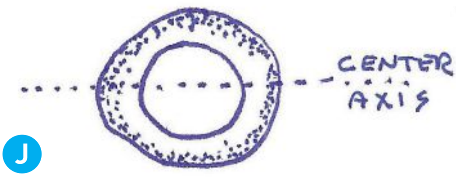


J

Once holes have been drilled, carefully enlarge them to match the size of the end of the ¾" pole by carving with a small knife. To avoid splitting, carve each quadrant in the direction shown (Figure C).

The ¾" pole should fit snugly into the 1¼" pole and rest against the back side. Do not force or the bamboo may split!

Repeat this step in six places to temporarily assemble the basic frame.

3. CUT THE BRACE KEYWAYS

The following steps are done only in the four places indicated in Figure D.

Drill ¼" holes ½" away from where two poles join (Figure E).

Then carve openings from each hole back to the joint, as shown in Figure F. These are the keyways for the structural X bracing.

4. PEG THE FRAME JOINTS

To pin the horizontal poles in place, drill 3⁄16" holes ⅛" inside the centerline of the vertical (Figure G). Use bamboo scraps to carve snug-fitting pegs. Taper the pegs slightly to ensure a tight fit.

Lightly tap pegs in with a hammer (Figure H), leaving ¼" of peg protruding from both front and back. Then cut off pegs as shown in Figure I.

5. SPLIT GREEN BAMBOO FOR LATTICE

The remainder of the gate structure is built using strips of fresh "green" bamboo from 1½"–2" diameter poles.

Split the bamboo through the center axis for the first cut (Figure J), using your bamboo hatchet or similar tool. Be sure each pole is at least 12 feet long. The idea is to make at least six strips of bamboo that are 12' long by ½" wide, because each loop in a three-loop gate takes two back-to-back strips. Add to that the four 4-foot strips for the X brace.

Splitting the green bamboo will be the most difficult part of building this gate. It takes some practice to get the hang of it. Split the bamboo from the top down; it's easier. Much difficulty and time may be saved if your bamboo supplier will agree to split your 2" diameter poles into 8 strips using a specialized bamboo splitter tool.

Bamboo strips are used back to back, in pairs, so a "finished" side always faces out. Soak the strips in water or wrap in wet newspaper until just before use.

Use a sturdy and very sharp knife to rid each strip of pithy material from inside, leaving the woody, outer ⅓ of the strip (Figure K). The thinner the strips, the easier they'll wrap around the gate frame without splitting or breaking. It is important to keep them wet to keep them pliable.

6. FABRICATE THE X BRACING

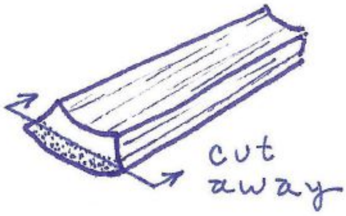
The X bracing fits from peg to peg on the diagonal, to make the gate rigid and square (Figure L). Cut the bracing ⅛" "too long" to ensure that it continually pushes against the pegs to hold the gate square. These X braces will tend to bow out now, but will be held down when the lattice work is finished and tied.

7. WEAVE THE LATTICE

For the first loop, lay out a lattice strip so it's parallel with an X brace and crosses the top rail at the ¼ point, then loop as shown in Figure M. Strips may crack if forced to bend too sharply, so handle them carefully and keep them wet. Avoid having nodes at the apex of sharp bends.

> **TIP:** While weaving the lattice strips around the frame, I found it easier to keep them in position by using zip ties to temporarily secure them where they cross the other strips. When the lattice weaving was finished, one-by-one, I removed the zip ties and replaced them with the more decorative black twine for a final product that was strong and rigid.

Complete three loops using back-to-back strips (Figures N, O, and P). Always weave over-under-over-under wherever strips cross — except do not alternate strips over the top rail.



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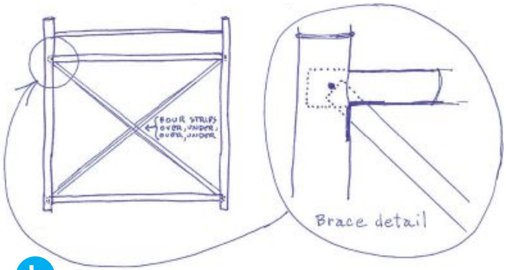

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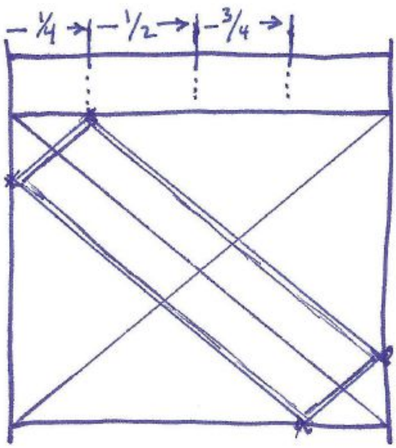

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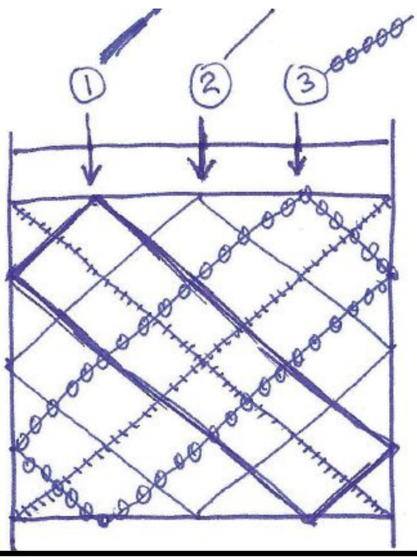

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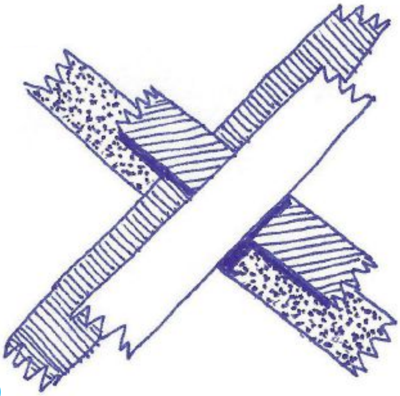

O

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Q

Begin and end strips in the bottom 1/3 of the lattice area. Tuck the beginning pair inside of the ending pair, overlapping the ends 12". The overlap should extend through two intersections with the perpendicular strips. Cut the ends horizontally.

8. TIE THE KNOTS

At all points where strips cross, tie them with the hemp/palm twine to strengthen and finish the gate (Figure Q). The traditional Japanese knot for this is the *ibo musibi*, the knot that's used in the traditional *yotsume-gaki* bamboo fence. You can learn to tie it from YouTube videos such as youtu.be/Fva7A07Ioak or youtu.be/46lCdSS3yRw.

I started my knots as an ibo by crossing the twine in the back, but finished with an ordinary square knot in the front. In my opinion the square knot looks fine as a substitute for the ibo.

Soak the twine in water before tying and it will shrink when dried, making a tight knot.

YOU CAN SWING IT

Your finished shiorido gate is very light, less than 4 pounds, so the hardware can be light, too. In Japan, specialized hardware is available for this type of bamboo gate, but it's not available in the United States. A very good substitute can be made using two eye bolts (such as Uxcell M5×40mm stainless eye bolts), with appropriate nuts, on the gate. For the gate post, use two #10 stainless wood screws, bent into an L shape, with the heads cut off. The L's point up, and the eye bolts simply slide over.

The traditional Japanese "latch" is a simple braided circle about 6" diameter (made using three ¼" bamboo strips) that rests over both the gate post and the gate, on the opposite side from the hinges.

This gate looks good anywhere you'd like to hang it. I recommend one round gate post on each side of the gate, each 3"–4" in diameter, stained black (or, traditionally, char-flamed with a torch until black).

If you'd like to learn to build a bamboo fence to go with it (a yotsume-gaki for example), YouTube would be a good place to start.

Solar Power on the Move

Experiment with mini photovoltaic panels and turn your phone case into a mobile solar charger

Written by Lee Wilkins

LEE WILKINS is an artist, cyborg, technologist, and author of our new "Squishy Tech" column in *Make:* looking at technology and the body and how they intertwine. Follow them on Twitter @leeborg_

It's fun to use mini solar cells to charge your gear or power small gadgets, and once you've learned the basics you can scale up to bigger panels. Let's explore ways you can harness solar energy for your own DIY projects — mobile, wearable, or otherwise — and say goodbye to (some) batteries and plugging things in!

EARLY SOLAR ENERGY

While the first solar electric panel is credited to Bell Labs in 1954, there have been a variety of other solar-powered devices for hundreds of years. The cell produced by Bell chemist Calvin Fuller and physicists Daryl Chapin and Gerald Pearson was the first ***silicon solar cell***, following their success with semiconductors in 1947.

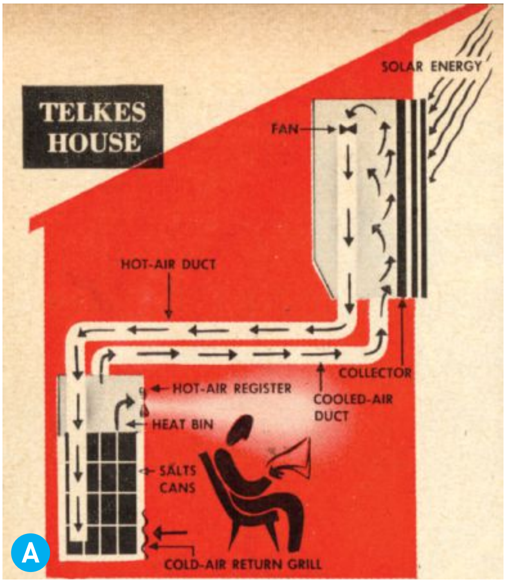
Solar heat energy has also been used in a variety of ways, including architect Eleanor Raymond and MIT engineer Maria Telkes's Dover Sun House in 1948 (Figure A). What looked like a wall of windows was actually a heat-collecting panel, with hot air transferred into "heat bins'" containing chemical salts which absorbed heat and stored it for later. The goal was to store enough energy to heat the building two to three days without sunlight. The processes Telkes developed are still used in molten-salt energy storage systems today.

Of course, solar energy goes way back to ancient civilizations using sunshine to dehydrate foods, using magnifying lenses to light fires, using reflection and positioning to tell the time or light a room, among other uses. When we think of it like that, contemporary solar cells are just a single point on a long continuum of solar possibilities!

PHOTOVOLTAIC PHENOMENA

Solar panels utilize what we call the ***photovoltaic effect*** — the ability of a material to emit electrons when exposed to light — to produce electricity. This effect was observed as early as 1839 by French physicist Alexandre-Edmond Becquerel, who discovered that metal electrodes in an electrolyte solution produced a current when exposed to solar radiation. Although at the time he couldn't explain it, it lay the foundation for what was to come.

Today many solar cells are made primarily of silicon (Figure B). Silicon is a semiconductor — a material that partially conducts electricity, but also has some of the properties of insulating materials that don't conduct.



Lee Wilkins; *Popular Science*, March 1949

A SINGLE CELL

A solar panel like you might see on someone's roof is made up of many individual solar cells that are wired together. Each solar cell works by converting the sunlight hitting the semiconductor into electricity. The energy from the light (photons) is absorbed into the panel, which knocks electrons loose in the cell.

Each cell is designed with positively (***p-type***) and negatively (***n-type***) charged semiconductors in a sandwich, which creates an electric field that forces the drifting electrons to flow toward conductive metal plates on the outer layers of the cell, and then through wires like any other source of electricity (Figure C). This is the current, the strength of which determines how much electricity each cell can produce. The voltage of the cell is determined by the material, and solar cells also have an internal resistance to consider. Not 100% of the energy from the sun is converted to usable power by the cell; some light is reflected from the surface of the cell, or blocked by the metal lines on top of the solar cell that wire the cells together. Other factors like shade and sunlight intensity also affect the actual output of the panel, even if it has a particular rating.

A SOLAR PANEL

Much like other electrical circuits, individual solar cells can be wired in series or in parallel to modify the amount of voltage and current produced by the panel. Often, cells may be arranged in a combination of both to create the desired parameters. In a parallel circuit, current (amperage) increases and voltage remains the same. In a series circuit, voltage increases and current remains the same. In Figure D, you can see some mini solar cells arranged on a breadboard, wired in both configurations: series (top) and parallel (bottom). Each solar cell and panel will have a positive and negative wire.

Many solar cells are often sealed into a single panel that has a wattage and voltage rating. Wattage is the power produced or used per second. For example, a 60-watt light bulb uses 60 joules of power per second. You can calculate the wattage of a circuit you want to power by multiplying volts by amps, for example in a 3 volt, 0.33 amp LED:

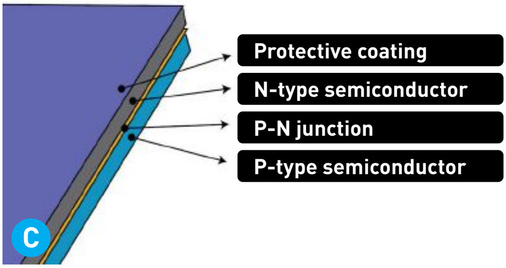
W* = *V* × *A

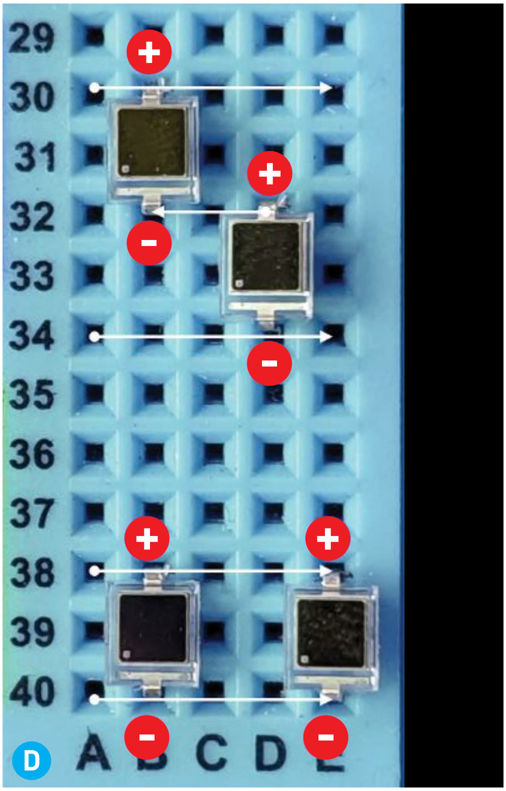
***W* = 3 × 0.33**

So this is a 1-watt LED.

Power over time is measured in watt-hours, which is watts × hours. To get an idea of how much power you might need to power your home for a whole day, you can check your power bill, which is often measured in kilowatt hours (kWh). The average household uses 20–30kWh a day; today I'm slightly embarrassed to admit I used 43 somehow.

Let's say we got a new 250-watt panel. To determine the capacity of our setup, we will





Reading the voltage on a 5V solar panel.

Lee Wilkins, Adafruit, SparkFun

multiply panel watts × average hours of sunlight × 75% (as it is unlikely to be at full efficiency):

250 watts × 5 hours × 0.75 efficiency
= 937.5 daily watt-hours.

And then convert it to kWh like our electricity bill:

937.5 / 1000
= ~0.94kWh per solar panel.

Your panel will usually tell you its voltage output, but that indicates the performance of the panel in ideal conditions. A great exercise is to take your panel outside, connect a multimeter to the panel's positive and negative leads, and turn the meter to the voltage reading setting. As you move the panel, you can clearly see how the voltage output is being affected (Figure E). You can do the same thing to see the amperage output of a panel.

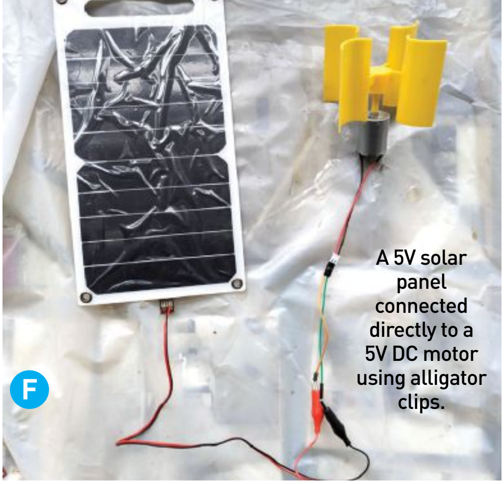
Most solar panels have no amperage rating. Your circuit will draw current measured in amps (or milliamps, depending on the scale of your circuit). The consumption of amperage over time is measured in amp-hours (or milliamp hours). You'll typically see this on batteries which have an Ah or mAh rating, so you may be familiar with the concept. Why is this important? Because most solar circuits, as we'll see below, use a controller to charge the battery while the circuit draws power from the battery, instead of the panel directly powering the circuit. So you'll want to calculate the draw of your circuit, and then find a battery that charges faster than your circuit discharges it.

Again, it's important to remember that your solar panel output is charging your battery, and it's your battery output that has to match your circuit requirements. For example, if my battery has 500 milliamp hours, and my LED draws 20 milliamps, my battery will last for 25 hours at full brightness:

Battery capacity (mAh) / Current draw (mA)
500 / 20 = 25 hours

Don't forget to make sure you're always working in the same units, and convert if needed by moving the decimal point.

You can connect a solar panel directly to the power and ground wire of any simple electronic component to power it with the right voltage (Figure F). But be careful: If the device has a processor or controller on it, the fluctuations in power might cause it to fail or to break. This is why we use tools to moderate the flow of electricity and ensure it doesn't under- or overpower our electronics as the output of the panel changes. For example, while my panel might output 5V, my battery may only output 3.7V in a circuit with a controller.



F

A 5V solar panel connected directly to a 5V DC motor using alligator clips.

G

H

SOLAR TOOLBOX

After you've decided what exactly you want to power, you'll need to find a solar panel. They come in all sizes, but I'm going to focus on simple electronics rather than powering your home, RV, or boat.

Adafruit sells a wide variety of panels, from a tiny 5V 40mA badge, #700 (Figure G) to larger 6V panels in a variety of wattages and

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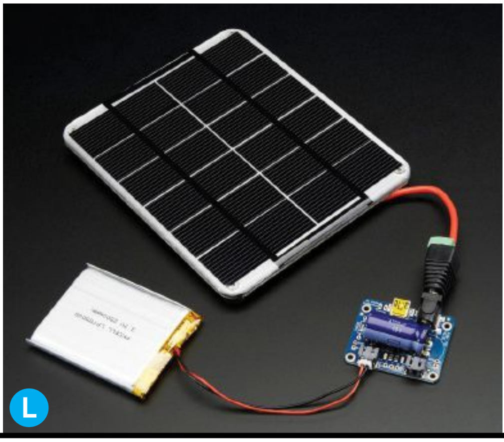


L

OSRAM, Anysolar, Lee Wilkins

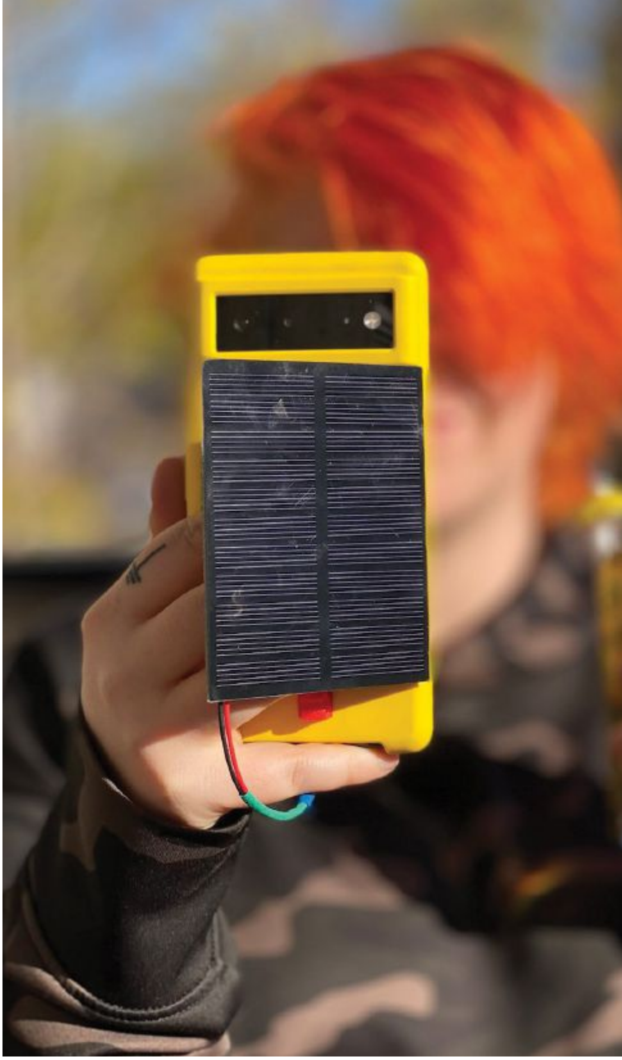
configurations. But my favorite is SparkFun #16835, a 10W 5V panel with a built-in USB port (Figure H on the previous page). There are also some great flexible panel options if you want to make a wearable that is solar powered.

In addition to the solar panel specs, it's a good idea to keep an eye on the connectors it comes with: either barrel jack, JST, or USB, depending on your use. There's nothing worse than getting all the parts for a project and winding up with the wrong connectors.

If you're looking for something smaller, I also love Osram's tiny, $1/8$" BPW-34 through-hole solar cells (Solarbotics #SCPD, Figure I), 0.5V at 1.9mA, which isn't enough to do much, but you can chain them together in any configuration. The Anysolar KXOB25-14X1F-TB offers 0.55V at 55mA, but in an even tinier surface mount package (Figure J); Digi-Key stocks it.

After you've chosen a panel, you'll want to pick a battery and a controller board. My favorite is the SparkFun Sunny Buddy solar charging board, #12885 (Figure K). You can connect a single LiPo cell or similar battery that meets your specs to the board, and the panel will charge the battery while the battery runs your circuit. Adafruit has a very similar DC solar charging circuit as well, #390.

If your battery outputs 3.7V but you want to build something like a solar-powered Raspberry Pi which requires 5V, you may want to use one of Adafruit's PowerBoost boards, #1903, to power your project (Figure L).



TIME REQUIRED: 1–2 Hours

DIFFICULTY: Easy

COST: $50–$60

MATERIALS

- **5V solar panel, smaller than your phone**
- **USB-C plug** or whichever port your phone takes
- **Heat-shrink tubing**
- **Metal hinges, small**
- **Gorilla Super Glue Gel**
- **Rare earth magnet, tiny and flat**
- **Phone case, with a magnetic base**
- **Cable holder** 3D-print the free file from makezine.com/go/solar-phone-charger, or buy a tiny cable clip.

TOOLS

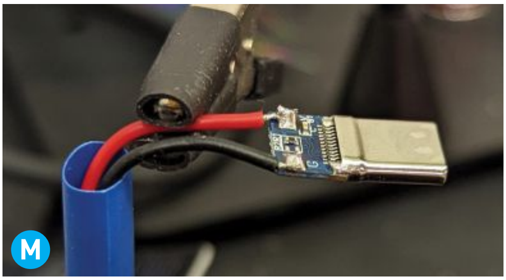
- **Soldering iron and solder**
- **Heat gun or butane lighter**
- **3D printer (optional)** to print a cable holder

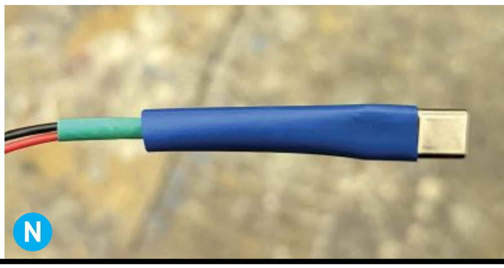
MAKE A SOLAR PHONE CHARGER

In this tutorial, I'll show you how to connect a solar panel to your phone so that you never run out of power. There are lots of variations of this circuit, so make sure to verify your phone's capabilities and ports, and your solar panel specs, before beginning.

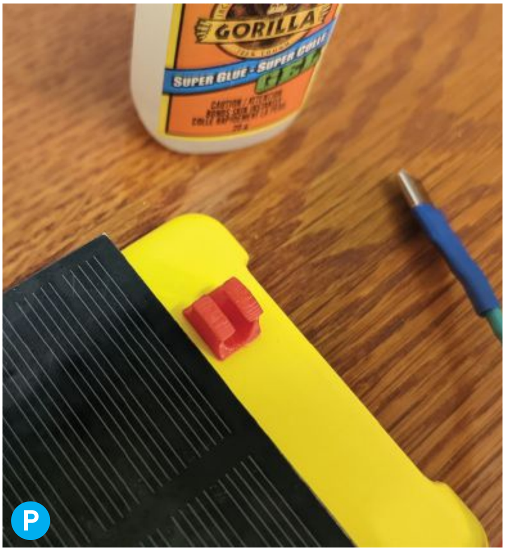
1. SET UP THE CHARGING CABLE

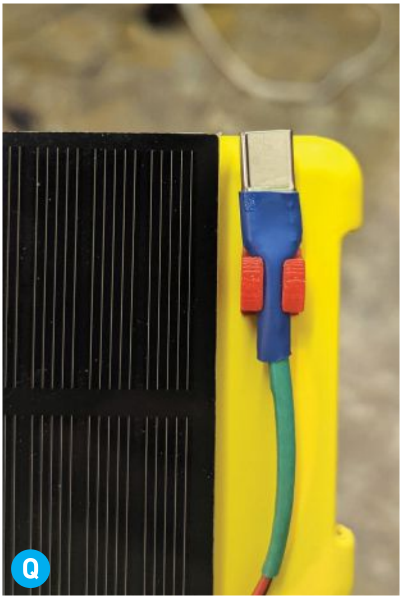
First, cut the existing connector off the solar panel and place it on the back of the phone case to get the right position. Measure and cut the wire so that it can be plugged in, but doesn't have much extra slack. Put the heat-shrink tube on, and solder the red and black wires to the USB connector (Figure M). Heat the tubing so that the USB circuitry is covered (Figure N).





Lee Wilkins





Lee Wilkins

2. MOUNT THE PANEL AND CABLE HOLDERS

Glue the hinge to the edge of the solar panel and to the back of the phone case (Figure O). Glue the rare earth magnet to the bottom of the solar panel so that it is held in place flat when it's not being used.

Print the cable holder from the project page, makezine.com/go/solar-phone-charger —or buy a suitable cable holder — and glue it next to the panel (Figures P and Q).

3. CHILL AND CHARGE!

Sit back, enjoy a drink, and charge your phone in the sun! Depending on the panel output, power consumption of your phone, and position in sunlight, you may get mixed results in the charge rate. Experiment!

Thanks to the Solar Media Research Group for being delightful collaborators in exploring Solarity. Check out their work at www.solar-media.net.

Song Spotter!

Teach a Raspberry Pi to identify 3,000 birds by sound alone

Written by Keith Hammond

Adobe Stock-Piotr Krzeslak, BirdNET-Pi

In 2016 the bird nerds at the Cornell Lab of Ornithology collab'ed with coders at TU Chemnitz in Germany to create **BirdNET** — an artificial neural network that recognizes 3,000 different birds by sound alone (birdnet.cornell.edu). Next they turned it into a free phone app — imagine stashing John James Audubon, Sir David Attenborough, and the real James Bond (legendary ornithologist) in your pocket to help identify avian species when you're out on the trail.

But what if you'd like to ID every bird at your location, all the time? Now there's **BirdNET-Pi**, a dedicated version for installing on a Raspberry Pi (birdnetpi.com). It does 24/7 recording and analysis, automatically extracts birdsongs and creates spectrograms (Figure A), and logs every species detected (Figure B). If you wish, it'll host its own web server for remote access, stream live audio, send notifications, and integrate with BirdWeather to share your data. It's an awesome citizen science project for just a few bucks!

The team has begun work on a TFLite version for the Arduino Nano 33 BLE, because it has a mic, says team leader Dr. Stefan Kahl, but "Right now, our focus is Raspberry Pi as an embedded platform because it can run Python and TFLite without having to sacrifice much performance." You can adapt BirdNET to the platform of your choice; it's an open source project at github.com/kahst/BirdNET-Analyzer.

KEITH HAMMOND is editor-in-chief of *Make:* and believes ravens are the best bird, because they *rawk*.

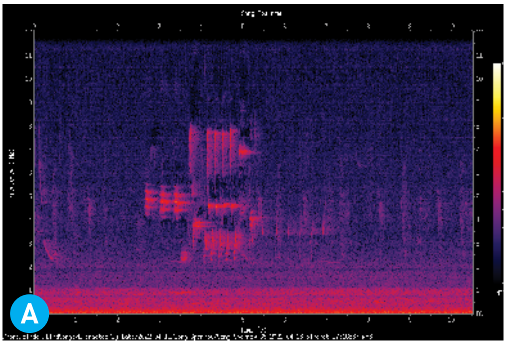
TIME REQUIRED: Minutes

DIFFICULTY: Easy

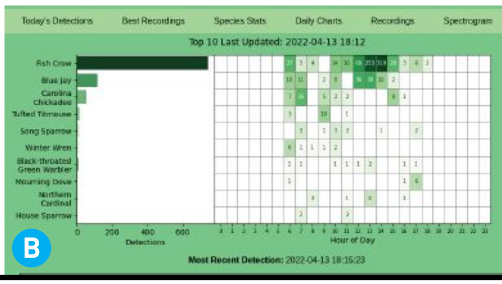
COST: $20–$30

MATERIALS

- **Raspberry Pi single-board computer** running Raspberry Pi OS Lite (64-bit); models 3x, 4, or Zero 2 W
- **USB microphone**



A

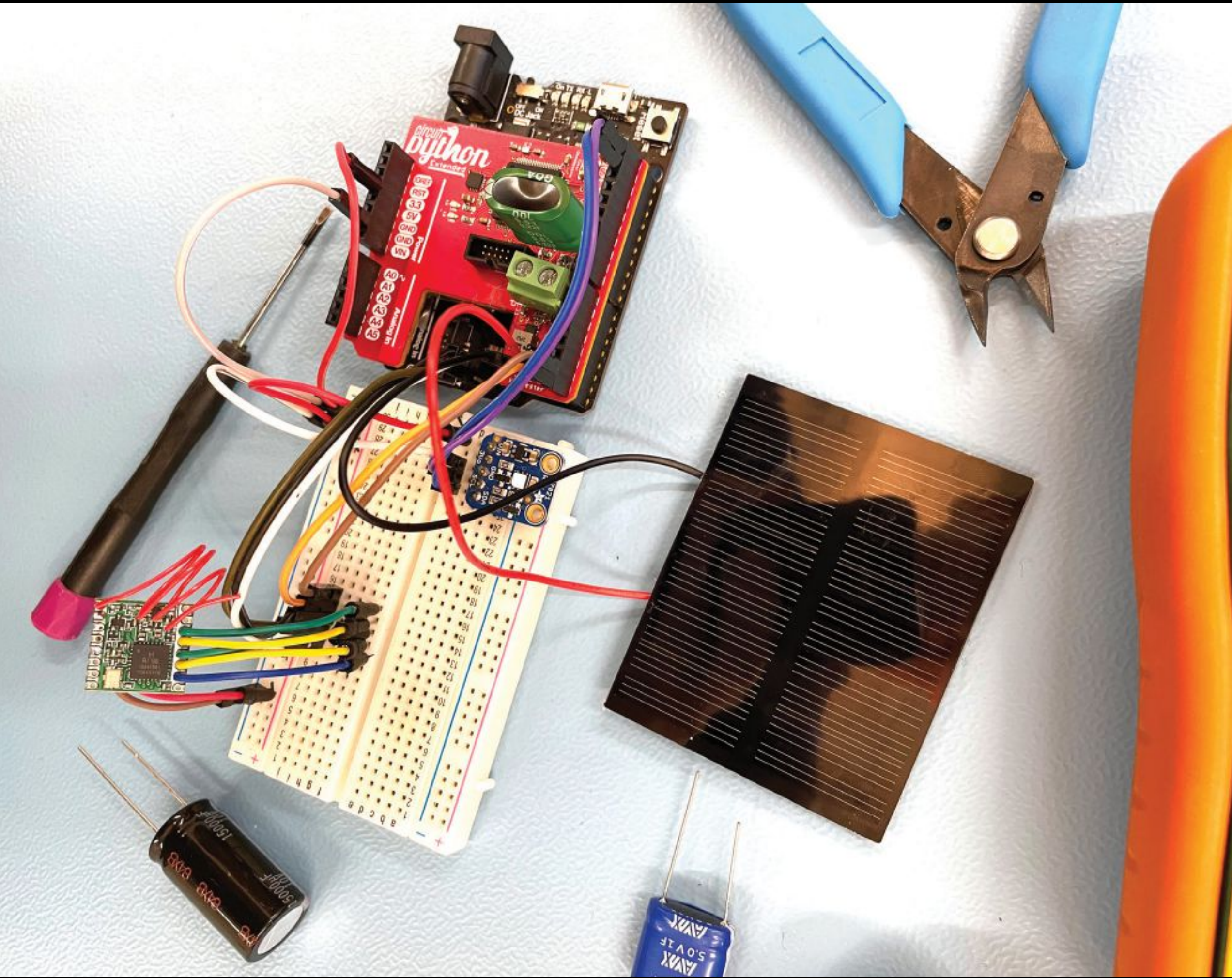


B

Perpetual Battery-Free Weather Station

Build a remote, energy-harvesting weather transmitter that can run CircuitPython forever — despite power failures

Written by Vito Kortbeek and Przemysław Pawełczak



VITO KORTBEEK is a Ph.D. student in the Sustainable Systems Lab (github.com/tudssl) at TU Delft in the Netherlands, where he works on ultra-low-power embedded systems. vitokortbeek.com

It's now possible to build remote, low-power microcontroller projects that can operate indefinitely without batteries and still not crash, even if power is interrupted. Let that sink in.

As an example, we'll show you how to build a LoRa-based weather station that's powered solely by solar panels. Its code is written in CircuitPython, running on a popular hobby-grade microcontroller board: the Adafruit Metro M0 Express. The novelty is that it can keep the state of the weather measurement program, even during periods of complete darkness when it runs out of power. This is called *intermittent computing* or *perpetual computing*, and it opens up a new world of sustainable electronics, where many applications will work well, and practically forever, without reliance on a battery.

The trick is a specially modified version of the CircuitPython interpreter that is resilient to power failures. (Not the language — the CircuitPython syntax stays intact). This means we don't have to supply our weather station with a continuous power source, such as a battery. Instead, we harvest energy from a solar cell and temporarily store it in a capacitor. The system will boot when the capacitor contains enough energy to execute some code, and the program will pick up where it left off before the power ran out. This way, we can opportunistically collect weather information without relying on a potentially polluting battery and frequent travel to replace that battery.

Finally we can build truly perpetual, battery-free, energy-autonomous embedded systems using off-the-shelf components! We proved the concept in 2020 with our Battery Free Game Boy project led by Jasper de Winkel (jasperdewinkel.com), where we powered the game by solar panels and kinetic energy from the player's button presses (github.com/TUDSSL/ENGAGE). Now we've brought it to CircuitPython.

We call our system BFree. You can program your microcontroller in regular CircuitPython, and a specially designed extension board stores

TIME REQUIRED: 2–4 Hours

DIFFICULTY: Intermediate

COST: $150–$175

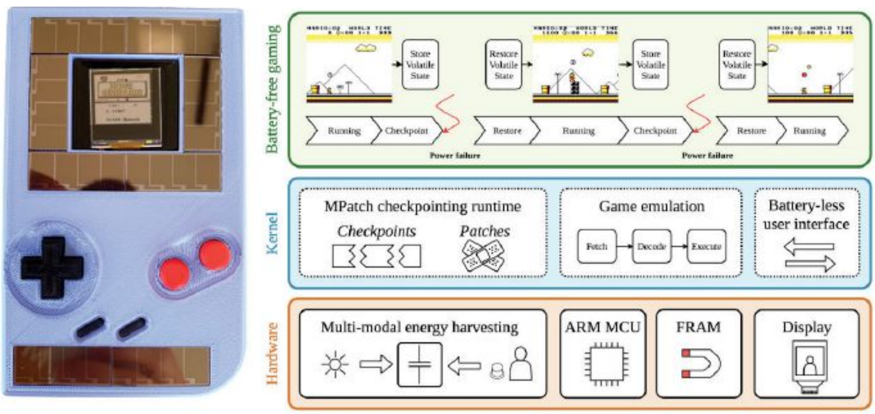
MATERIALS

- **BFree shield** about $30, to connect to Metro M0 Express. Download the component BOM and the PCB files for fabrication from github.com/TUDSSL/BFree/tree/main/hardware/BFree-shield.
- **Adafruit Metro M0 Express microcontrollers (2)** Adafruit 3505, with USB cables
- **Temperature/humidity sensor board, Si7021** Adafruit 3251
- **LoRa radio transceivers, RFM96W (2)** Adafruit 3073
- **Solar panel of your choice, at least 0.5mA at 2V** such as Seeed 313070004
- **Supercapacitor, ESR less than 5Ω, capacity greater than 0.15F** such as Samxon DDL224S05F1ERRDAPZ, 0.22F
- **Breadboards, half size (2)** Adafruit 64
- **Jumper wires, male/male** Adafruit 758

TOOLS

- **JTAG/SWD debugger** to flash Metro M0 board with new firmware if needed. We use the Segger J-Link EDU Mini, Adafruit 3571, $20.
- **Personal computer** with USB port. This tutorial is described for a Linux-compatible operating system.
- **Multimeter (optional)** to test that the system is working. We like SparkFun 12966, $15.

Vito Kortbeek and Przemysław Pawełczak; Jasper de Winkel et al., *Proc. ACM IMWUT (2020)*



Battery Free Game Boy, September 2020, from *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, doi.org/10.1145/3411839

the intermediate state of the computation during power failures. Then your microcontroller can pick up where it left off, and continue executing CircuitPython correctly when power resumes!

HOW DOES BFREE WORK?

BFree is two things: an **extension board** ("shield") attached on top of the Metro M0 Express and a piece of **software** running transparently on the Metro M0. This combination enables CircuitPython applications written for the Metro M0 to continue where they left off after a power failure. BFree is designed to operate in an environment with insufficient energy to continuously power the Adafruit Metro M0.

The BFree shield houses a Texas Instruments MSP430FR series microcontroller (ti.com/product/MSP430FR6005). What's special about this MCU is the presence of **non-volatile RAM** in the form of ferromagnetic RAM (FRAM). This type of non-volatile memory is low-power and byte-addressable. It functions just like standard SRAM, but with the bonus of not losing its data when power is removed. It is a better choice than flash memory, which is power-consuming to write and requires writing of a complete "page" at a time.

The BFree software is a modified version of CircuitPython (which we call BFree-core) that talks with the BFree shield over an SPI connection. BFree has several available **checkpoint** strategies for when and what to store in the shield's FRAM memory from the CircuitPython program. The default strategy is creating a checkpoint every 100ms, but this can all be configured within CircuitPython.

When BFree-core decides it's time for a checkpoint, it instructs the BFree shield to make one, and sends the CircuitPython **Virtual Machine**'s content to the shield, which stores it in non-volatile memory so that BFree-core can fetch it when power is restored. The shield's microcontroller also acts as a **memory controller**, so that a valid checkpoint of the CircuitPython program is always available, even if power fails while creating a new checkpoint!

Additionally, the shield houses the energy harvesting system needed to provide BFree with bursts of energy. A **capacitor** on the board is connected to an **energy harvesting source**, such as a solar panel. The harvesting source will slowly charge the capacitor. When the voltage of the capacitor reaches a (configurable) threshold, a **boost converter** is enabled to supply the rest of BFree with constant 3.3V supply. When an on-board BFree **comparator** notices that the boost converter cannot maintain the target voltage of 3.3V, the boost converter is disabled, power to the Metro M0 is cut, and the charge cycle starts again.

To protect BFree from a harvesting source that produces too much energy, i.e. greater than 3.3V, the shield is equipped with over-voltage protection circuitry. This circuit dumps any surplus energy in a **power resistor** located on the back of the shield. This way, no energy is lost during typical operating conditions

For more details, see our paper at dl.acm.org/doi/10.1145/3432191, and the schematic diagrams at github.com/TUDSSL/BFree/tree/main/hardware/BFree-shield.

MAKE YOUR PERPETUAL BATTERY-FREE WEATHER STATION

1. BUILD YOUR BFREE SHIELD

The BFree shield isn't for sale yet, as it originates from a recent academic project (see youtu.be/Msp5l23rcl8). But you can build your own, using the open-source Eagle design files and component list at github.com/TUDSSL/BFree/tree/main/hardware/BFree-shield. Fabrication houses like OSHPark and PCBWay will make the PCB for you for a few bucks.

2. FLASH THE METRO AND SHIELD FIRMWARE

Next you'll flash the BFree shield and the Metro M0 Express board with new firmware, so they can work together to restore a CircuitPython program after a power failure.

Follow the instructions at the Github repository github.com/TUDSSL/BFree/tree/main/examples/Weather%20Station to program your BFree shield with its pre-compiled *.elf* firmware file. (Optionally, the complete source code for the BFree shield, and how to build it from source, can be found at github.com/TUDSSL/BFree#building-the-bfree-shield-software.)

The BFree-compatible version of CircuitPython is called BFree-core (github.com/TUDSSL/

BFree-core). Download the pre-compiled *.elf* version of BFree-core, from the folder *Metro M0 Express BFree Firmware* at the Weather Station repo. Then use your serial wire debugger/programmer to flash BFree-core to the Metro M0 board, following the instructions at github.com/TUDSSL/BFree-core/blob/main/QUICKSTART.md. We recommend using the debugger, not the Metro M0 bootloader, because BFree-core is still in development, and you'll want the debugger to recover from a broken CircuitPython state (if it ever happens).

3. TEST YOUR BFREE SHIELD

Attach the BFree shield on top of the Metro M0 (Figure A). The pins of the shield correspond one-to-one with the headers of the Metro.

Next, connect the Metro's USB port to your PC. The Metro should show up as a mountable device in your operating system as usual.

Now we'll verify that BFree works as intended, using the Test Code program from the Weather Station repo:

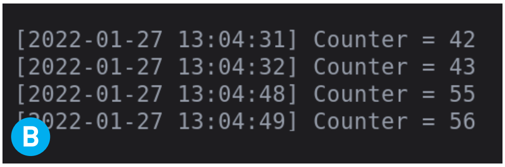
```
import time

# Setting the counter to 0 will only
# happen the very first boot
counter = 0

# The battery-free program should
# continue counting somewhere in the
# while loop
while True:
  counter += 1
  print('Counter =', counter)
  time.sleep(1)
```

This simple CircuitPython program increments a variable counter indefinitely. In a typical solar-powered system, the battery will deplete when there's no sun. At this point, the counter will be reset to the initial value of zero. However, in the BFree-based solar-powered system, the counter will continue increasing from where it left off, once the system recharges after a power outage. To see this effect in action, upload the Test Code to the Metro M0 board, replacing the original *main.py* program pre-installed on the Metro with

Vito Kortbeek and Przemysław Pawełczak

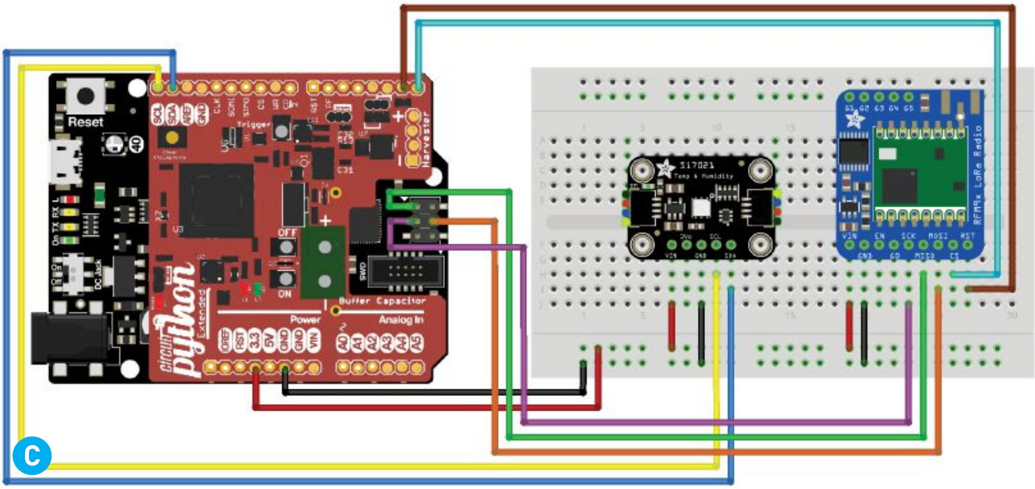


this new one. Do not disconnect the Metro from the USB port, and don't forget to keep the BFree shield connected on top of the Metro M0.

Now monitor the serial port, letting the code run for several seconds. (If you're not sure how, check out learn.adafruit.com/welcome-to-circuitpython/kattni-connecting-to-the-serial-console.)

Unplug the Metro M0 from the USB port (cutting off power) and plug it back in again. When the Metro is plugged back in, the counter should continue where it left off instead of resetting back to zero. It's sustaining the computation state despite power failures!

Figure B shows the serial connection monitored by Minicom (type **`sudo apt install minicom`** to install it) with 1-second timestamps. You'll see that the counter does not reset to zero when the system is unplugged, and that there's a gap between **`Counter = 43`** and **`Counter = 55`**. This is because the Metro M0 with its BFree shield is already continuing the CircuitPython program execution (incrementing the counter) before the USB serial port is even completely initialized.



4. CONNECT SENSORS TO METRO THROUGH BFREE

Now let's set up the weather station. Follow the wiring diagram (Figure C) to connect the Si7021 temperature and humidity sensor module (black) and the RFM9x LoRa transceiver (blue) to your BFree shield on top of the Metro M0.

Before running your weather station from the solar panel, let's test that everything works on constant power. Connect the Metro to your computer, and upload the Battery Free Transmitter code from the Weather Station repo. This new *main.py* program accumulates temperature and humidity samples, averages them, and sends them as a LoRa packet in a continuous, non-breakable loop.

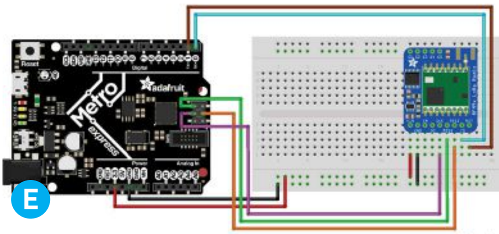
Now monitor the serial port as you connect and disconnect the Metro from your computer. Whenever the station broadcasts a LoRa message, it will also print a message to the serial port containing all the information sent in the LoRa frame and the number of samples collected since the start of the program (Figure D).

5. SET UP THE LORA RECEIVER

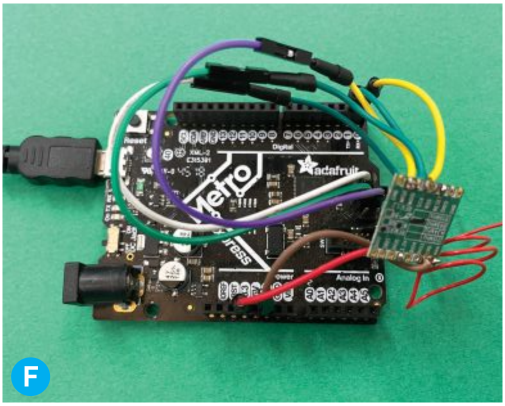
Now that your LoRa transmitter is working, you need a receiver. Connect the second RFM9x LoRa transceiver directly to the second Metro M0 Express board, using the same pins as before (Figures E and F). This receiver will be permanently connected to a PC via a USB port and continuously listen for LoRa frames sent by your weather station.

```
[2022-01-27 13:27:59] Sending LoRa message completed
[2022-01-27 13:27:59]   Power-failure count: 3
[2022-01-27 13:27:59]   Samples collected: 120
[2022-01-27 13:27:59]   Transmitted packets: 12
[2022-01-27 13:27:59]   Average temperature: 22.5585
[2022-01-27 13:27:59]   Average humidity: 49.989
[2022-01-27 13:27:59]
```

D



E



F

```
[2022-01-27 14:04:46] Raw packet: 5,1903,22.78,50.33
[2022-01-27 14:04:46] Message content:
[2022-01-27 14:04:46]   Reboot count = 5
[2022-01-27 14:04:46]   Transmitted messages = 1903
[2022-01-27 14:04:46]   Average temperature (C) = 22.78
[2022-01-27 14:04:46]   Average humidity (%) = 50.33
```

G

Vito Kortbeek and Przemysław Pawełczak

Upload the Receiver code to the Metro M0, from the Weather Station repo. Now whenever your weather station has power and decides to send a message, your receiver should be ready to receive the message, parse it, and print it to the serial terminal.

6. TEST THE LORA COMMUNICATION

Before you go battery-free, you should test whether your transmitter and receiver are working as expected on constant power. Connect them both to your PC through individual USB ports, and monitor the serial port that belongs to the receiver. You should see the received messages as shown in Figure G.

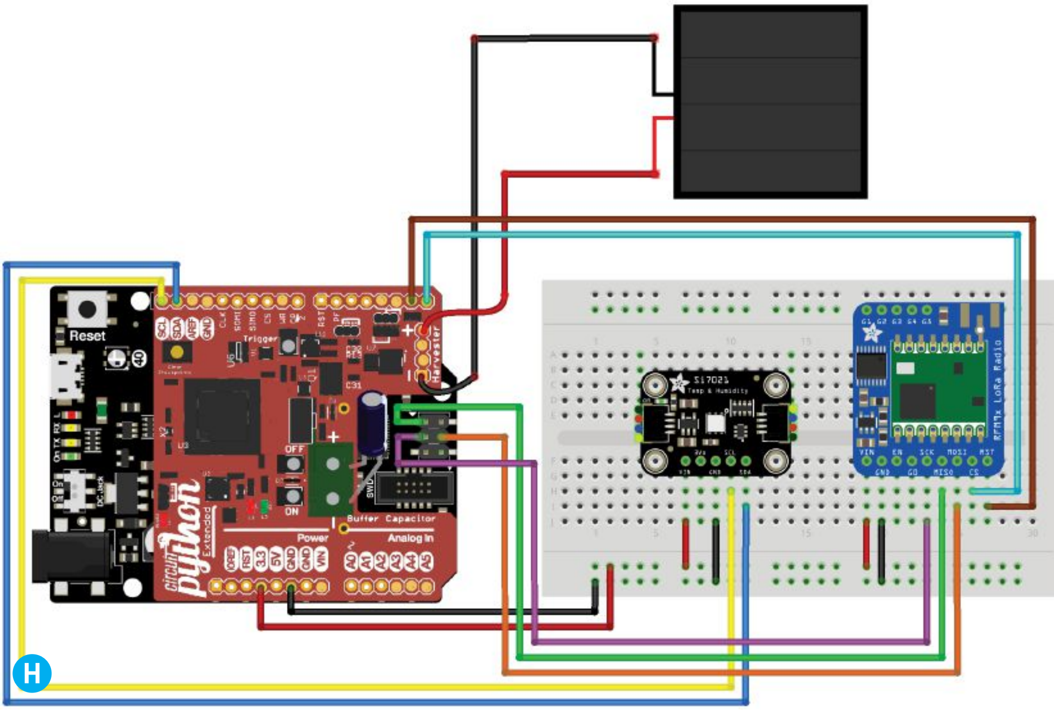
7. MAKE IT BATTERY FREE

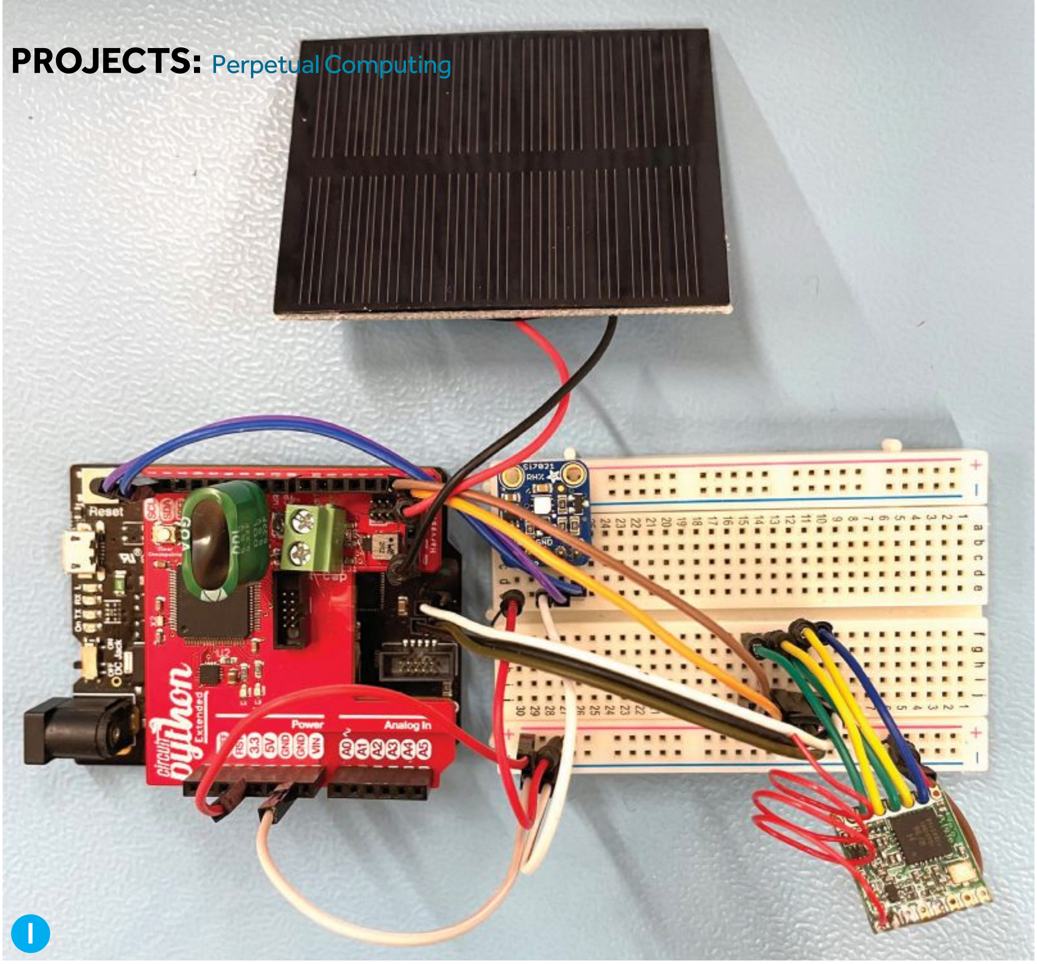
Now that everything works on continuous power, you can make your weather station battery-free! You'll use a solar panel to harvest the required energy and buffer this in a supercapacitor until it gathers enough energy to run a portion of the code.

Multiple factors come into play when choosing the size of the solar panel and supercapacitor. How much energy a solar panel generates dramatically depends on the available light. The same panel can generate 200mA of current when placed in direct sun, but only 0.5mA under office lighting. So if you plan to use your weather station outside, pick a reasonably small solar cell; use a larger one if you use it indoors. Any surplus energy, once the supercapacitor is full, is dumped into a large power resistor on the back of BFree, so make sure your solar cell doesn't exceed 1.5 watts or this resistor might get too warm.

The capacitor determines how much energy your weather station can store. A larger capacitor can keep the station operating for longer, but also takes longer to charge, so the time between two successive intervals where BFree executes code is longer. If you choose to use a supercapacitor instead of a normal capacitor, check the ***equivalent series resistance (ESR)*** value. You ideally want to use a capacitor with an ESR below 5 ohms (5Ω). We chose a 0.22F supercapacitor with an ESR of 2.5Ω for our setup.

Connect your supercapacitor to the terminal block on the BFree shield, shown in dark green in Figure H. Make sure to pay attention to the capacitor polarity. Then connect your solar panel to the header labeled Harvester.





Your weather station is ready to go (Figure I)!

SET IT AND FORGET IT

Deploy your perpetual weather station somewhere that receives light, and it should run virtually forever. When the capacitor reaches its threshold voltage, the system will turn on for a couple of seconds. During this time, the CircuitPython code will continue to either collect sensor data, process that data, or transmit a LoRa message. How often a message is sent greatly depends on the available light and can vary between once per second when the sun is intense and once every 15 minutes when there's only office lighting available.

GOING FURTHER

In this project we connected the solar cell directly to the BFree shield. For better harvesting efficiency, you could connect a ***maximum power point tracking (MPPT)*** charge controller between the solar cell and the shield's harvester input.

Solar cells are not the only form of energy harvesting that can be used. It's also possible to harvest power from radio waves, kinetic energy, piezoelectricity, heat energy, or other ambient sources (see sidebar).

We hope you enjoy building this weather station, and we hope you're convinced now that battery-free electronic devices are possible with intermittent computing! Of course this is just a beginning. Battery-free remote control? Battery-free stock price display? You name it! We would love to hear about your experience and your ideas. Please send all of them as Github feature requests via github.com/TUDSSL/BFree/issues.

BFree was developed by Vito Kortbeek and Przemysław Pawełczak at TU Delft, Netherlands, github.com/TUDSSL; Kasim Sinan Yildirim at TU Delft and the University of Trento, Italy; and Josiah David Hester, Abu Bakar, and Stefany Cruz at Northwestern University, USA, kamoamoa.eecs.northwestern.edu.

Vito Kortbeek and Przemysław Pawełczak

DEDICATED ENERGY HARVESTING CHIPS

As energy harvesting has become more prevalent for low-voltage IoT and smart devices, chip makers have integrated the discrete components required to efficiently harvest the most energy possible onto a single chip to optimize size and performance. Now, anyone can buy chips and breakout boards from Digi-Key, SparkFun, and Adafruit that can harvest solar, piezoelectric, thermal, and even radio wave energy. These ICs range in sophistication (and price) from simple step-down or step-up voltage regulators to much more sophisticated chips with built-in rectifiers or ***maximum power point tracking (MPPT).***

What is maximum power point tracking? It's a complex topic, with significant research continuing across industry and academia. The problem is that the efficiency of power harvesting of any source is affected by the environment (i.e., amount of sunlight, device temperature) and the load (i.e., how much power is being drawn). An MPPT tries to dynamically change the load that the harvester sees, so that the maximum power is extracted. This is extraordinarily hard to do well!

One of the more common (and older) of these chips is the **Texas Instruments BQ25504** (ti.com/product/BQ25504), available on various breakout boards. It has a built-in MPPT, buck-boost regulator, and in some variants, internal circuitry to manage the recharging of a battery or a supercapacitor. **Linear Technologies LTC3588** (found on SparkFun's breakout, sparkfun.com/products/9946) has also been around for a while (Figure J). It combines a rectifier circuit and a buck converter to harvest piezoelectric or solar sources that produce a high voltage (10V–40V) and low current.

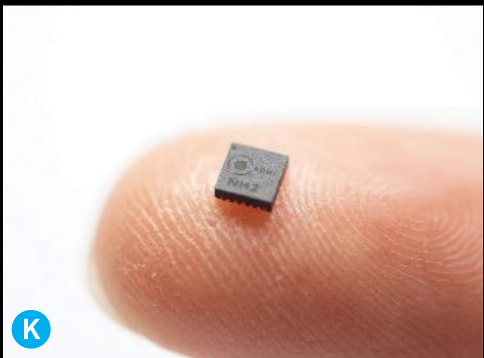
Some exciting directions are being explored by startups who are tackling the unique constraints of mobile devices and ultra-low-power systems. For example, newer harvesting ICs like the **Nowi Energy NH2D0245** (Figure K) optimize for higher MPPT efficiency and conduct a much faster calculation of the maximum power point, which means they can harvest more energy in dynamic environments, for example, on a wristwatch. You can buy the bare chip from Digi-Key or request a breakout board at nowi-energy.com/evaluation-boards.

Other startups are fine-tuning chips for emerging harvesting sources. **Matrix Industries' Mercury boost converters**, available from Digi-Key and Mouser, are custom-built to harvest energy from tiny ***thermoelectric generators (TEGs)***, aka Seebeck generators, which generate an electrical current based on the difference in temperature on the top and bottom of the TEG. These have notoriously low output voltages, which have to be boosted to be of any use. Matrix's Prometheus modules (matrixindustries.com/prometheus) are designed to harvest from thermoelectric sources even at insanely low voltages (6mV).

The emergence of these custom chips, many available for makers and hobbyists in nicely designed breakout boards, make it an exciting time to be making energy harvesting projects!

—Josiah David Hester

J



K

SparkFun; Nowi Energy

Custom Fabrics

Design your own fantastic fabrics and have them specially printed or woven

Written by David J. Groom

DAVID J. GROOM loves writing code that you can touch. If he's not hacking on wearables, he's building a companion bot, growing his extensive collection of dev boards, or hacking on 90s DOS-based palmtops. Find him on Twitter at @IShJR.

Textile printing — the application of colored patterns to fabric — is not a new phenomenon. Woodblock-printed fabric dates back hundreds, perhaps thousands of years, and has been widely available in forms such as chintz and calico since before the Industrial Revolution. New printing techniques developed during that period, however, brought elaborately decorated fabrics to the hands — and bodies — of the masses.

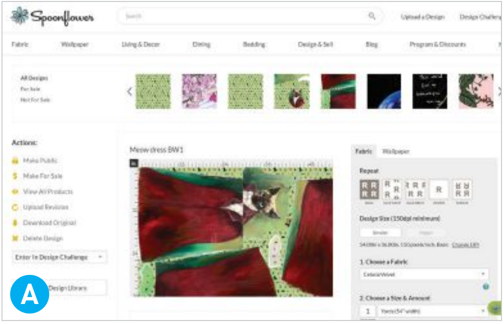
But not everyone wants to look like the masses. Modern direct-to-fabric printers can produce ultra-short runs of custom, colorfast, washable designs on a variety of fabrics, and websites such as Spoonflower (Figure A), Contrado, and Jo-Ann MyFabric put mass customization in the hands of designers, artists, technologists, and makers and crafters like you.

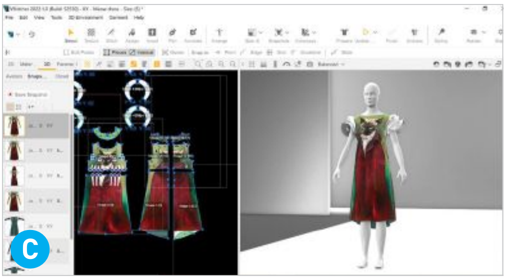
SHARING THE MEANS OF PRODUCTION

Although digital textile printing has been around for decades, it was the internet that finally democratized the process, availing to individual designers and crafters a methodology that was once the province of large factories and design houses. After websites for creating custom T-shirts, mugs, and calendars appeared, the trend spread into more specialized areas, such as 3D printing services, printed circuit board fabrication, and custom fabric production. Just as you might create a keepsake for a friend by uploading a photo to Shutterfly, you can now upload your original design to Spoonflower for printing, or Wovns for weaving, and receive your custom fabrics in just a few weeks.

WARDROBE BY PHYSICIST

Dr. Kitty Yeung (Figure B) started using the Spoonflower service for her *Art by Physicist* line in 2016. Since there is no minimum order quantity, it allows her to experiment and create all kinds of custom pieces without having to worry about production volume. One bonus of the digital process is that it is also more eco-friendly than traditional dyeing and screen printing. Alarmed by the amount of waste produced by the fashion industry, Yeung has adopted custom digital printing wholeheartedly to promote ethical and sustainable production.





Silvan Reiser, Kitty Yeung

DIGITAL DILIGENCE

Yeung uses ordinary digital design tools like Photoshop and Illustrator to create her graphics. One unique concern with fabric, as compared to printing a logo on a T-shirt, is the need for designs to repeat seamlessly across the material. This is easily accomplished using Photoshop, and Yeung has gone further and taken her entire process digital, using Browzwear VStitcher (Figure C) to drape and preview her patterns, eliminating further waste. She even prints sewing patterns directly on the fabric, and uses the spaces between pieces for little bonus odds and ends to ensure that nothing goes to waste.

NOT ALL ROSES

Custom printing fabric is not without its challenges. You're limited to fixed sizes based on the capability of the machines, and to single-sided color with a white back. Depending on the application, this can be overcome by using two layers, but you'll still want off-the-shelf fabrics for linings and interfacing. Overall, the technique is perhaps best suited to one-offs and prototypes. Mass-produced fabrics are still cheaper and more immediate to source, and there's no risk of the pattern ending up 10 times bigger or smaller than expected because you made a mistake while ordering.

It can also be scary, given the amount of design theft in the fashion industry, to send your original designs off to an anonymous factory, so it's important to choose a reputable company that you can trust. Some sites even let you share your original designs in their marketplace and earn commission from their sale. It is important to note too, that you may only print artwork that you have rights to or permissions to use — you can't just borrow someone else's design or logo or face to create your own knockoffs.

CODING THE SEEDS

Creative technologist **bleeptrack** uses custom fabric printing to manifest her generative coding projects in the physical world. Her Overflower project — an ingenious portmanteau of the computer science term *overflow* and the horticultural term *flower* — uses procedurally generative JavaScript to literally sow the seeds of imaginary flowers, based on nature's own Fibonacci spiral (Figures D and E).

These fictional florae were scripted to create a full Overflower "bed" — blooming to fill the available area afforded by the digital printer. Shuffling through a palette of several colors, or even progressing through the full spectrum across the length of the print, bleeptrack creates entirely unique pieces of fabric with no repetition or duplication. She then uses the material —

The individual cats on Kitty Yeung's "Meow" pattern were crowdsourced via social media, and the large, stately fellow was drawn by Judy Wang.

Kitty Yeung, Silvan Reiser, Jen Costillo also from Spoonflower — to hand-sew pouches, backpacks, even a winter coat. The full spectrum progression even stood (hung?) on its own as art in an exhibition (Figures F and G)!

SONIC WEAVE

Firmware engineer, choreographer, and podcaster **Jen Costillo**'s fabrics transform the sounds that are all around us into the visual spectrum. Costillo (they/them) first experimented with wearables and LEDs, imbuing dance costumes with electronics to create multimedia performances. Using the free Processing environment's digital signal processing (DSP) capabilities, Costillo made a spectral analysis of Yma Sumac's "Malambo No. 1," then made it tangible using the Wovns custom woven fabric service (Figure H).

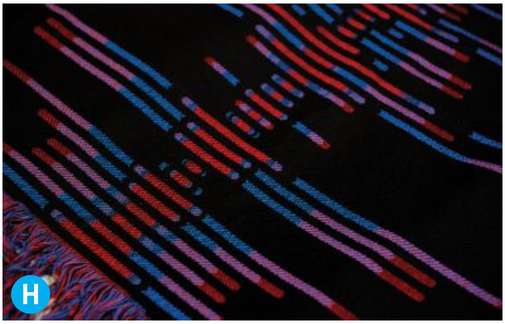
Collaborating with Kyle Chan for their next piece, Costillo envisioned a modern friendship bracelet of sorts, transforming four songs that were special to their group, entwining memories into "cybergoth" cloth. Again using Processing to transform frequencies, this time radially, the result became "Industrial Plaid"(Figure I).

COMPUTATIONAL TEXTILES

Costillo credits the extensive tutorials on the Wovns site as having helped spur their creative use of the service — in particular, "Designing Computational Textiles with Processing." Unlike printed fabric, woven textiles are limited to specific palettes, since the colors make up the warp and weft of the material itself, versus being applied on top. Costillo plans on using the fabrics for tote bags, and possibly skirts or dresses. Although the process is more complicated and expensive than printing, Costillo recommends woven fabric as a great next step, claiming it to be "way easier than you think!"

BUILD A FASTER FABRIC

Textile printing has come full circle — from a completely handmade process, to mass production, and back to highly personalized individual pieces — thanks to digital technology. The ability to create a unique design, click a button, and have it arrive a few weeks later as durable, colorfast fabric which can then be turned into anything, is a real game changer for designers and makers. As with so many other creative and technical pursuits, fashion tools and methodologies are evolving at an explosive rate, enabling unprecedented creativity and inventiveness, as the gap narrows between production and the speed of inspiration.



- Subscribe to be notified when the *Meow* line is available, at kittyyeung.com
- Generate your own unique Overflower at overflower.bleeptrack.de
- Listen to Jen Costillo's reverse engineering podcast at unnamedre.com

Get Barreled

Emergency water storage is an easy project, from 2 liters to 55 gallons

Written and photographed by Forrest M. Mims III

Most of us have experienced power outages. While brief interruptions are unpleasant, lengthy outages that can occur after severe weather, forest fires, and earthquakes can cause loss of food stored in refrigerators and freezers unless a backup generator is available.

While water outages are less common than power outages, drinkable water becomes much more important than food after a few days. That's because a healthy person can survive for a week or more without food but only a few days without water.

The Red Cross and the Federal Emergency Management Agency (FEMA) both recommend that households store at least a three-day supply of drinking water, one gallon per person per day. While that's not enough for bathing or flushing, a gallon is enough for drinking, limited food preparation, and teeth brushing.

Storing drinking water for emergency use requires ***food-quality*** containers. These can be purchased — 5-gallon water jugs are common — or drink containers can be cleaned and reused, such as 2-liter soda bottles. Don't use milk or juice jugs; they can harbor bacteria.

While people can store water in their bathtubs when an emergency occurs, it may not be safe to drink. A good alternative is to purchase a ***bathtub water bag*** that fits in a tub and can be easily filled. When sealed, the water in the bag will be drinkable. A WaterBOB bathtub bag will hold up to 100 gallons, which is enough for a family of five for up to 20 days.

If your residence has space, you might want to consider storing drinking water in one or more food-quality 55-gallon (208 liter) barrels. These barrels measure about 35" (88.9cm) high and 23" (58.4cm) in diameter. They weigh around 22lbs (10kg) when empty.

Figure A shows a non-food quality 55gal barrel I plan to use to drip irrigate my garden. Note the spigot I installed near the bottom. For drinking water, I recently bought two new food quality barrels from a friend for $60 each. One of the least expensive online sources, BayTec, charges about $70.

If you'd like to store drinking water in a barrel, be sure you have an appropriate place to store and access it. A 55gal barrel will hold 460–470lbs (209–213kg) of water, so select a location that can support that much weight! Also, be sure a clean water outlet is accessible for filling the barrel.

You will need to determine how to remove water from the barrel when it's needed. Simple siphon pumps are available, or you can install a spigot near the bottom of the barrel (see Step 3 below to decide where to install it).

Drinking water barrels have sealed lids with two 3" (7.6cm) access ports (bung holes). Two kinds of spigots are available for these barrels. One has a nut that must be installed inside the barrel. The other is installed by dropping a bulkhead fitting into the barrel through an open bung hole; the rest is installed outside. The second kind seemed more leak proof, so I selected a Rainpal RBS022 rain barrel spigot.

HOW TO INSTALL A SPIGOT

1. Use a bung wrench (about $10) to open one of the bung holes. Or twist it open with the open ends of a pair of water pump pliers.

2. While it may not be necessary, you may want to sanitize your new barrel. Pour a gallon or so (3 or 4 liters) of water with a few ounces (around 0.06 liter) of chlorine bleach into the barrel through one of the bung holes. Swirl the water around in the barrel and then pour it out through the open bung hole.

3. Decide where the water barrel will be placed when full. If the barrel will be stored on a floor, the spigot hole should be drilled high enough to allow easy access to the spigot using a pitcher. If the barrel will be installed on a raised surface, the spigot hole can be closer to the bottom of the barrel.

Drill a 1¼" (64mm) access hole for the spigot near the bottom of the barrel, in line with one of the bung holes; I selected the hole closest to the gallon markings on the side of the barrel.

The boring bit I initially tried did not work

TIME REQUIRED: 1–2 Hours

DIFFICULTY: Easy

COST: $90–$150

MATERIALS

» **Drinking water storage barrel, 55gal** I used BayTec Containers WB55NEW, bayteccontainers.com

» **Rain barrel spigot, lead-free brass** Rainpal RBS022 or similar, Amazon B00NX697C0

» **Raised platform** may be required; see text

TOOLS

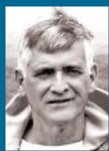
» **Drill**

» **Hole saw bit, 1¼"**

» **Safety glasses**

» **Tongue-and-groove pliers** aka water pump pliers, Channellocks, etc.

» **Bung wrench (optional)**



FORREST M. MIMS III is an amateur scientist and Rolex Award winner, was named by Discover magazine as one of the "50 Best Brains in Science." He has measured sunlight and the atmosphere since 1988. forrestmims.org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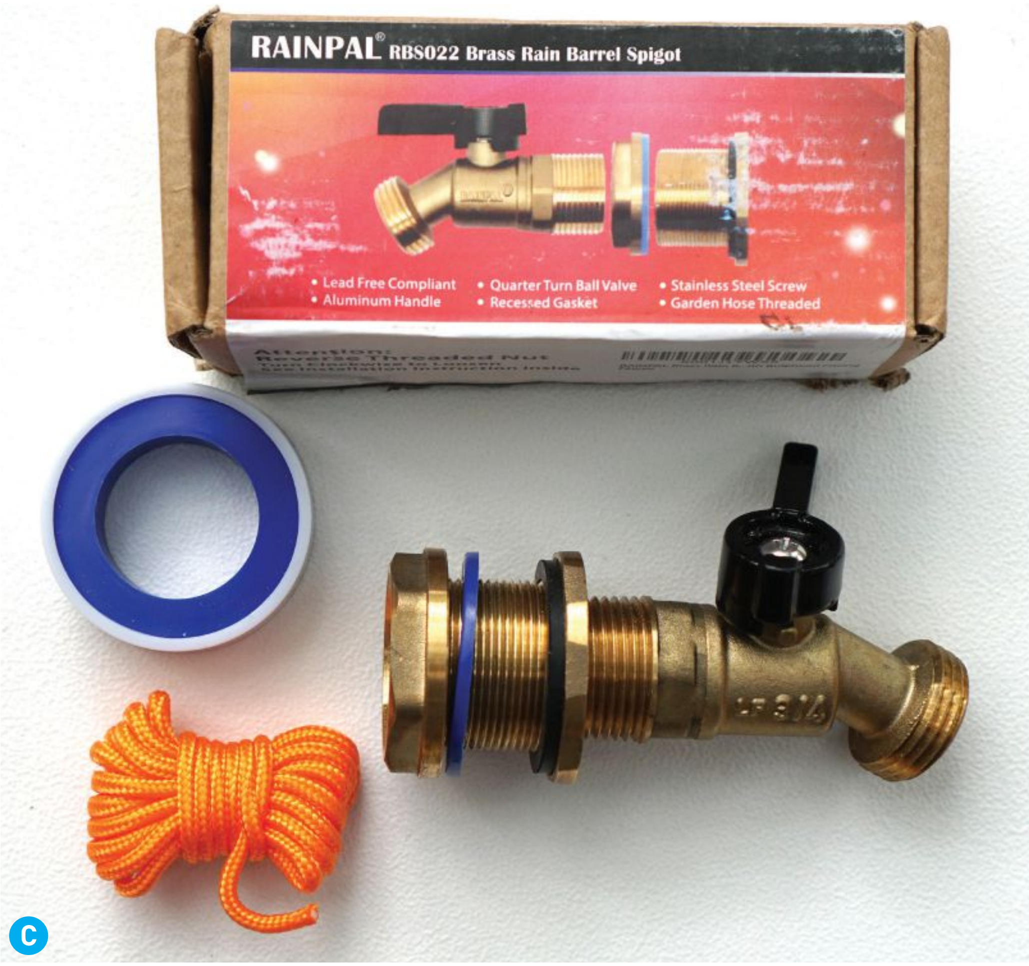

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properly. So I purchased a 1¼" hole saw for my drill, and it worked well (Figure B, previous page). Be sure the barrel is pushed against a wall or corner when drilling. Wear eye protection, hold the drill firmly with both hands, and push gently for best results. Carefully use a small knife to remove any remaining burr from the edge of the hole.

4. Figure C shows a spigot kit made by Rainpal. Separate the spigot from its two brass fittings. Hold the large bulkhead fitting in one hand and remove the small fitting by rotating it clockwise.

5. The large fitting has a rubber gasket and a hard plastic washer. Remove the plastic washer and set it aside.

6. Tie or tape one end of a cord to the top of the barrel and drop the other end through the open bung directly above the drilled hole. Insert your index finger through the spigot hole and grab the cord. Tilt the barrel if necessary. Gently pull the cord through the hole and tape it to the side of the barrel.

7. Untie the top end of the cord and thread it through the large brass fitting with its threaded end facing down (Figure D). Retie the end of the cord and drop the fitting down the cord so that it slides straight to the spigot hole. Insert your index finger and pull the fitting through the hole (Figure E).

8. While holding the bulkhead fitting with your index finger, carefully place the hard plastic

washer over the threaded portion of the fitting emerging through the spigot hole. Then install the small fitting nut onto the threads and turn it counterclockwise until it's hand tight. Note that this fitting is turned *counterclockwise* instead of the usual clockwise. Remove the cord and use a wrench to tighten the nut a quarter of a turn.

9. Wrap the threads of the spigot with three layers of plumbing tape, supplied with the spigot (Figure F). Install the spigot onto the fitting nut and hand-tighten it by rotating it clockwise. If the spigot output is pointed within a quarter of a turn from straight down, tighten it one-quarter turn with a wrench. Otherwise loosen and readjust the spigot until it is pointing within a quarter turn from straight down before tightening it (Figure G).

FILLING THE BARREL WITH DRINKING WATER

Runoff rainwater from your roof might be fine for watering a garden, but it should not be used for drinking water. Instead, fill the barrel by pouring water from a pitcher filled with municipal water that's been treated with chlorine. A much faster way is to use a recreational vehicle hose designed for use with drinkable water. Connect the hose to a nearby tap, and the barrel will be full in a few minutes. If you plan to use the water only during an emergency, it might be best to fill the barrel completely to keep out any algae that might be suspended in the air. While the rated capacity of the barrel is 55gal, mine holds nearly 60gal.

After the barrel is full, replace and tighten the bung cap. Dry the hose and attach protection covers to both ends to keep it safe for future use. Coil the hose and store it on top of the barrel.

If you want to store drinking water from a well or other non-municipal source, it's necessary to sterilize it. The Red Cross and FEMA recommend "adding two drops of non-scented liquid household chlorine bleach to each gallon of water" (makezine.com/go/red-cross-water). This resource also has good suggestions about water storage containers and emergency food storage. Much more information is available online.


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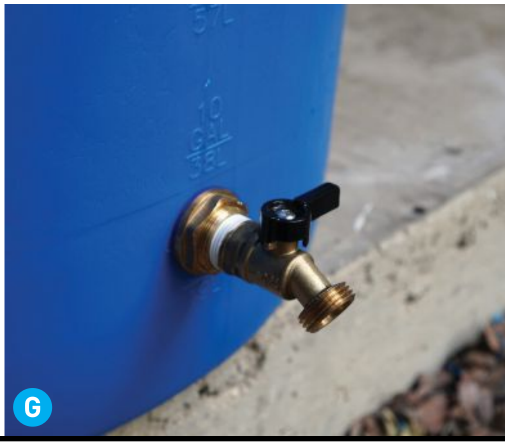
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Open Smart Cam

Free yourself from the corporate camera cloud with this motion-sensing Raspberry Pi/Arduino mash-up

Written and photographed by Eben Kouao

EBEN KOUAO makes DIY projects and prototypes, from delivery robots to electric skateboards and more. Watch his tutorials at youtube.com/ebenkouao.

Security cameras can be a great way to monitor and protect your home while you're away. However, with the proliferation of cloud-based solutions on the market, you may feel uneasy about the idea of your own video footage being handled by a corporation's cloud service. Moreover, some of their useful features such as recording or screen capture are typically hidden behind a subscription plan. What if you could build your own security camera with a Raspberry Pi, an Arduino, and motion sensors?

In this guide, you'll build a DIY security camera that you have full control of, without the need for a subscription plan. You can include as many features as you want — after all, this is an open-source project!

INTRODUCING THE PI SMART CAM

The Pi Smart Cam is an open-source DIY camera designed for you to view live footage from your phone — or any device — remotely (Figure A). It can detect motion and send you alerts, like a Nest security cam, but privately on your local network.

This project builds on my previous "Live Streaming with Raspberry Pi" tutorial in *Make:* Volume 76, makezine.com/projects/beginner-project-a-remote-viewing-camera-with-raspberry-pi. (If you're new to working with a Raspberry Pi, it would be best to explore the previous tutorial first.) In this guide, we're taking things a step further by entering the world of microcontrollers.

HOW IT WORKS

Pi Camera stream — The Pi Smart Cam captures live footage from the Raspberry Pi Camera Module and uses Flask (a Python web framework) to create a live stream to any client device connected to the same network (Figure B). Flask provides the "bridge" between Python and an HTML web page, which supports Motion JPEG video — essentially a sequence of independent JPEG images in a video compression format.

Arduino — An Arduino microcontroller sends values to the Pi via USB serial connection. With this setup, we can make the Pi trigger an action when the PIR sensor detects motion, such as sending emails, turning lights on, or sounding an alarm.

TIME REQUIRED: 4–6 Hours

DIFFICULTY: Intermediate

COST: $120–$150

MATERIALS

Check the GitHub repo for the latest parts list: github.com/EbenKouao/pi-smart-cam

» **Raspberry Pi single-board computer** with power supply; model 4B recommended
» **Raspberry Pi Camera Module** v2 recommended
» **microSD card, 32GB+**
» **Arduino Nano microcontroller board**
» **PIR sensor, HC-SR501**
» **Breadboard, half size**
» **Jumper wires: male/female and male/male**
» **Resistor, 220Ω**
» **LED**
» **Cable, USB-A to Mini-B**

For the hardware chassis (optional):

» **3D-printed parts** free 3D files at the GitHub repo
» **Screws, self-tapping, M3×40mm (4)**
» **Braided cable sleeve**

TOOLS

» **3D printer (optional)**
» **Computer with Arduino IDE** free from arduino.cc/downloads

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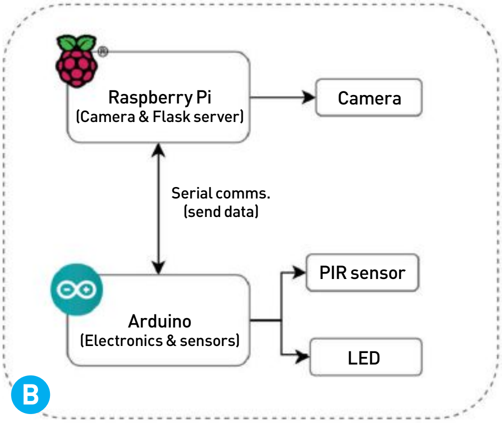

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PIR sensors — Passive infrared sensors are used in a wide array of sensory equipment, from automatic floodlights that turn on when motion is detected, to CCTV cameras. In our case, the HC-SR501 PIR sensor (Figure C) acts as an additional sensory input working with the camera to detect the presence of a human within the sensor's range, even in complete darkness!

BUILD YOUR PI SMART SECURITY CAMERA

Before you start, check my YouTube channel at youtube.com/ebenkouao. I've created a video tutorial complementing this article to help you visually build along.

1. SET UP YOUR RASPBERRY PI

This project assumes you have already created an image on the microSD card using the latest version of Raspbian, and that your Raspberry Pi is ready to go. For more details, read the previous Live Streaming tutorial referenced above.

1a. Enable Pi Camera module

Plug your camera module into its connector on the Raspberry Pi board. Open a terminal window on the Pi and type:

```
sudo raspi-config
```

To enable the camera, select Interface Options → Camera Port, and select Enabled (Figure D).

To enable VNC Viewer for remote access to the Pi, select Interface Options → VNC, and select Enabled.

Restart your Pi to apply the updates.

1b. Verify camera setup

Once you've rebooted your Pi, verify that your camera works by entering this command into your terminal:

```
raspistill -o ~/Desktop/image.jpg
```

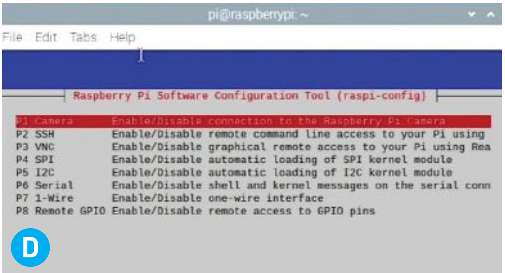
This will take a picture and store *image.jpg* on your desktop.

1c. Install/update packages

In terminal, type:

```
sudo apt-get update
sudo apt-get upgrade
```

C



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2. SET UP THE SMART CAM SOFTWARE

2a. Install Pi Smart Cam from GitHub repo

Now that you've updated packages and verified that the camera module is working, you can proceed to install the Pi Smart Cam's dependencies.

Open a terminal and clone the Pi Smart Cam Repo:

```
git clone https://github.com/
EbenKouao/pi-smart-cam.git
```

See the repo's *readme* file for further installation dependencies and notes.

2b. Launch Pi Smart Cam

Once the repo is cloned and dependencies are installed, you can navigate to the *code/examples/pi-camera-stream-pir-sensor* directory, and run the Video Streaming application in the terminal:

```
python3 main.py
```

Now devices connected to the same network can view the Pi camera's live stream (Figure E) by accessing this URL on port 5000: *<your_raspberry_pi_ip>:5000*, e.g. 192.168.0.103:5000

> **NOTE:** You can find your Pi's IP address by entering **ifconfig** into your terminal command and looking for the `inet address`.

3. BUILD THE ARDUINO CIRCUIT

Connect the LED and the 220Ω resistor to the Arduino Nano's pin D5 and ground, as shown in Figure F. Connect the PIR sensor to Arduino pins D8, power, and ground, as shown. This sensor helps our Pi Smart Cam detect movements, even in the dark.

4. SET UP ARDUINO SOFTWARE

Follow the general Arduino setup guide at arduino.cc/en/Guide/ArduinoUno. Then upload the motion sensor code from the Github repo, *pi-motion-sensor.ino*, to your Arduino board.

The code snippets shown here demonstrate how the Arduino microcontroller receives values from the PIR sensor. The PIR sensor input is set as digital pin 8, or D8 (Figure G).

The `loop()` function (Figure H) runs continuously while the Arduino is powered on. In it,

- The Arduino receives the input readings from the PIR sensor on digital pin 8.
- The current PIR sensor state is stored as `pinStateCurrent`. Where **1** is `HIGH`, and `0` is `LOW`.
- If the PIR sensor detects motion, and the current state is different from the previous state, then the Arduino writes the value of **1** (representing motion detected) to the serial output, which is sent to the Raspberry Pi.

You can verify that you're all set up by viewing the Arduino Serial Monitor. You should be able to hover your hands in front of the sensor and view the value of **1** appearing on the monitor, representing motion detection!

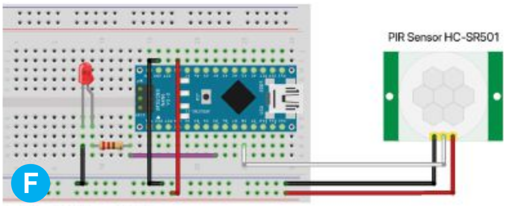
5. CONNECT ARDUINO TO RASPBERRY PI

For your smart cam to achieve the scenario of receiving a "motion detected" event and triggering an action such as sending an email, you'll need to connect the Arduino to the Raspberry Pi and send data between them. Plug the USB cable into both the Raspberry Pi USB port and the Arduino's USB B mini port (Figure I).

How Does a PIR Sensor Work?

It detects heat energy in the surrounding environment. The PIR includes a pair of pyroelectric sensors and a lens to enhance the sensing range. The two sensors are next to each other, and when the signal differential between the two changes (e.g., a person walks into a room) the PIR sensor will change state. (You can learn more at arrow.com/en/research-and-events/articles/understanding-active-and-passive-infrared-sensors.) This low-cost and very practical technology makes it an ideal sensor, especially when the camera is in the dark. No one can hide!

As a result, we can take advantage of the PIR motion sensor to trigger an action when an event has occurred.



Breadboard: PIR Sensor & LED

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```
int pirSensor = 8; // Arduino Digital Pin 8
```

```
void loop() {

  pinStatePrevious = pinStateCurrent; // store previous state of motion sensor
  pinStateCurrent = digitalRead(pirSensor);

  if (pinStatePrevious == LOW && pinStateCurrent == HIGH){

    Serial.write("1"); // Send message to the Raspberry pi - Motion Detected
    digitalWrite(ledPin, LOW);

  }else if (pinStatePrevious == HIGH && pinStateCurrent == LOW) {

    Serial.println("0"); // Motion stopped - Send message to the Raspberry pi
    digitalWrite(ledPin, HIGH);
```
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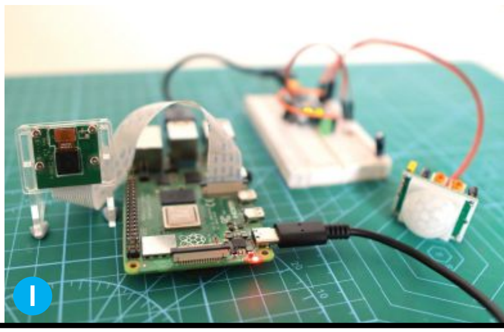

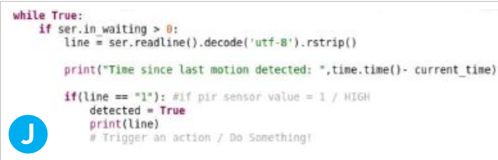

```
while True:
    if ser.in_waiting > 0:
        line = ser.readline().decode('utf-8').rstrip()

        print("Time since last motion detected: ",time.time()- current_time)

        if(line == "1"): #if pir sensor value = 1 / HIGH
            detected = True
            print(line)
            # Trigger an action / Do Something!
```

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```
ser = serial.Serial('/dev/ttyUSB0', 9600, timeout=1)
ser.reset_input_buffer()
```

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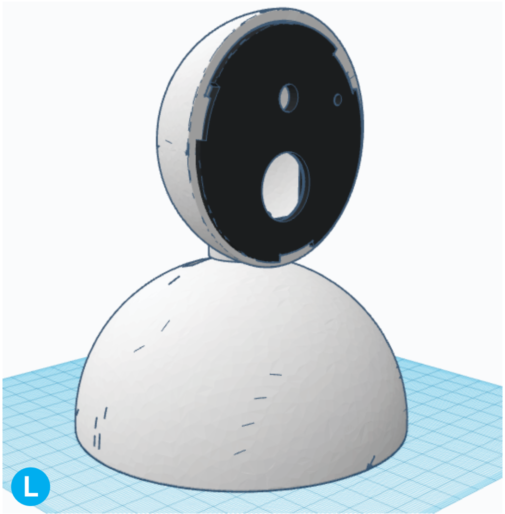

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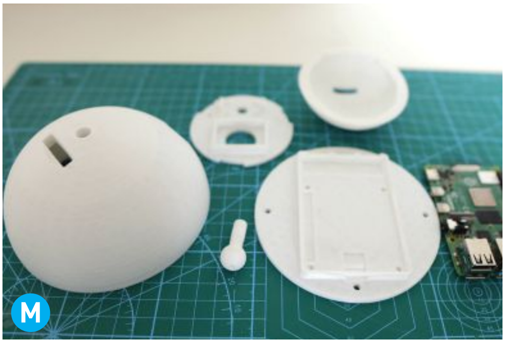

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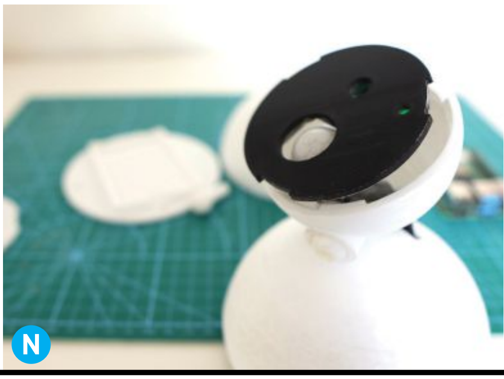

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On your Raspberry Pi, the Arduino board should now appear as */dev/ttyACM0 or /dev/ttyUSB0*. You can verify this by typing **`ls /dev/tty*`** into the Pi terminal.

Now run the Pi Smart Cam code, *arduino_comms.py*. This Python application receives data via serial comms from the Arduino (Figure J). The output seen in the terminal prints the value **1**, representing the PIR sensor state being **HIGH**, meaning motion is detected!

Note that the baud rate is set to 9600 (Figure K).

6. 3D PRINT THE CAMERA HOUSING

If you have access to a 3D printer, you can optionally build your own camera chassis (Figures L, M, and N) to house the camera, PIR sensor, Arduino, and Raspberry Pi. You can find the 3D parts and assembly details on the GitHub repo. Please feel free to contribute any modifications or accessories to the repo!

SOMEONE'S AT THE DOOR!

Your Pi Smart Cam is ready to keep an eye on things, indoors or out the window (Figures O and P). Now let's set up an action.

SENDING A NOTIFICATION VIA EMAIL

In this example, we'll send a notification to our email with a camera frame capturing the exact motion detected (Figure Q).

The example code *email_notification.py* (Figure R) sends emails to a target address including the attached camera frame, subject line, and message as part of the body using the SMTP Python library. SMTP is a protocol that handles sending emails between mail servers.

To configure your email notification, the following fields can be found in *main.py*:

```
pi_email = "<from-email>"
pi_app_password = "<app-password>"
pi_port = 465
pi_host = "smtp.gmail.com"
notification_recipient = "<to-email>"
```

NOTE: If you want to send email notifications via Gmail, enable 2FA and use App Passwords instead of storing the password as plain text. Find the latest information on the GitHub repo.

PERFORMANCE AND SECURITY

The Pi's stream latency depends on your Wi-Fi network performance; expect a latency of 1–2 seconds, and in some cases as low as ~500ms.

Avoid using the camera in compromising spaces, and consider adding credentials/encryption if you would like to expose your camera stream beyond your local network. (Learn more about cyber security on page 58.)

MORE FEATURES

If you're interested in adding more features, check out the GitHub repo:

- Ring chime pushbutton — allows a user to press a button to ring and notify the user that someone is at the door.
- LED lights up — as visual feedback when a button is pressed or motion is detected.

IMPROVEMENTS TO MAKE

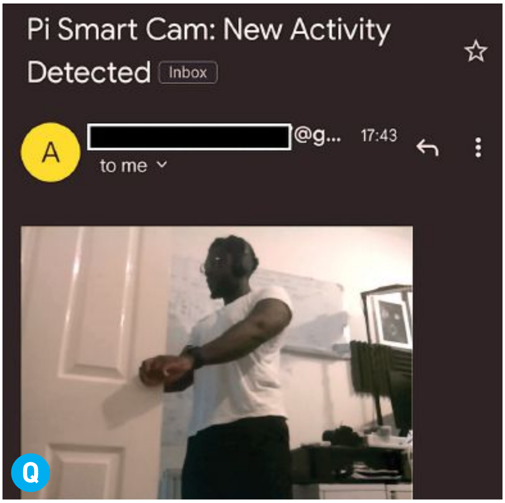
Here are some improvements you may want to explore:

- Create a PCB, reducing the form factor further!
- Upgrade your camera module to use an HD camera/webcam.
- Build your own dedicated server using SSH tunnelling and view your stream from outside the home.
- Add face detection!

Whether you're a web developer, 3D printing wizard, or Pi enthusiast, I hope you'll consider contributing to this project. The option for an open-source camera stream with motion detection and picture capture capabilities provides a DIY alternative to the tightly coupled Big Tech security systems. With your Pi Smart Cam, you're in full control of your data.


O

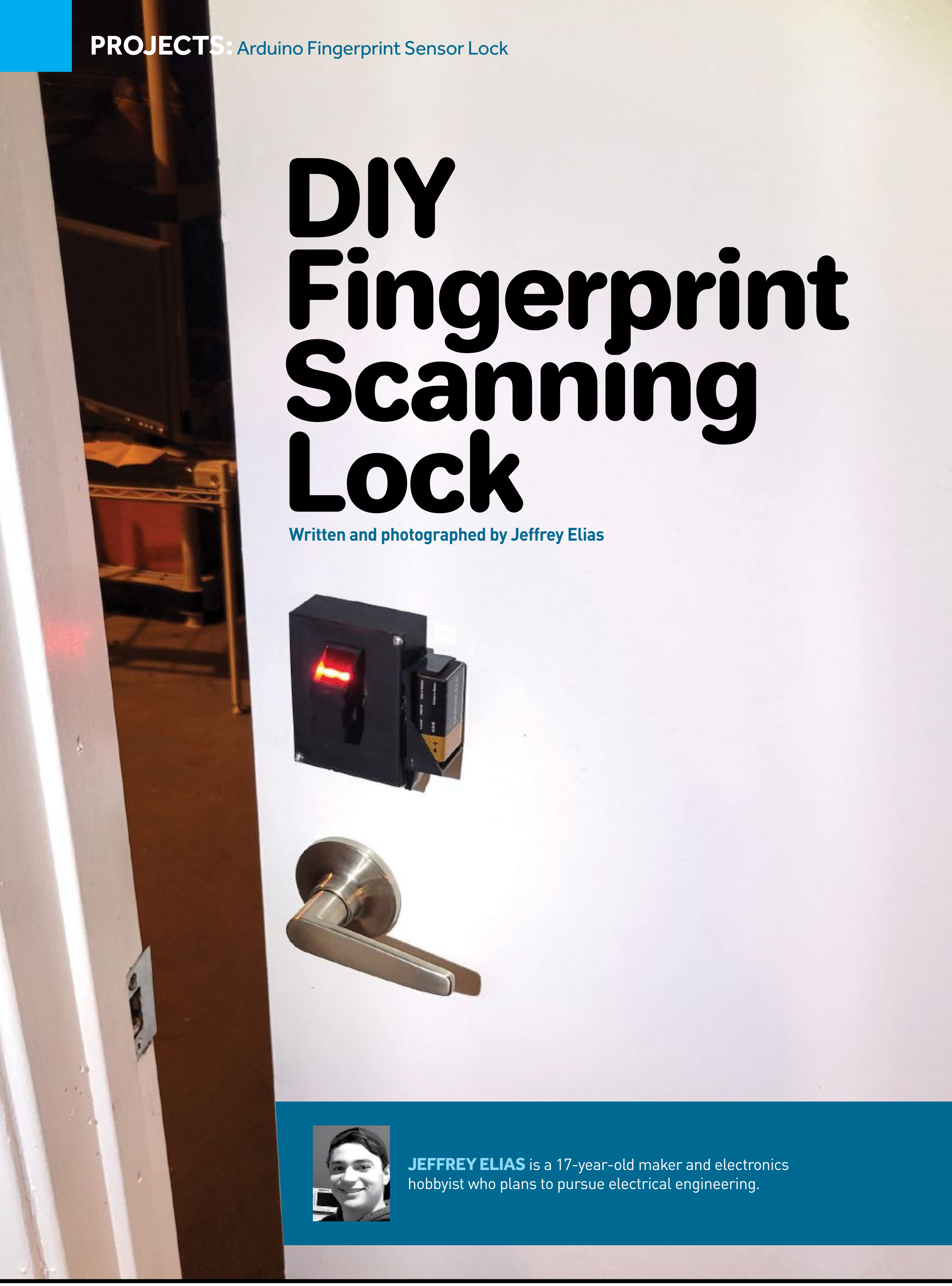

P



Q

R
```
# only send email notification if motion is detected after X seconds
if(int(time.time() - current_time) > sensitivity_timer):

    current_time = time.time()
    print(line) # print output from Arduino Comms
    if(detected == True):
        detected = False
        take_picture(pi_email, pi_app_password, pi_port, pi_host, frame)
        print("email sent")
```



DIY Fingerprint Scanning Lock

Written and photographed by Jeffrey Elias

JEFFREY ELIAS is a 17-year-old maker and electronics hobbyist who plans to pursue electrical engineering.

TIME REQUIRED: 2–3 Hours

DIFFICULTY: Easy/Intermediate

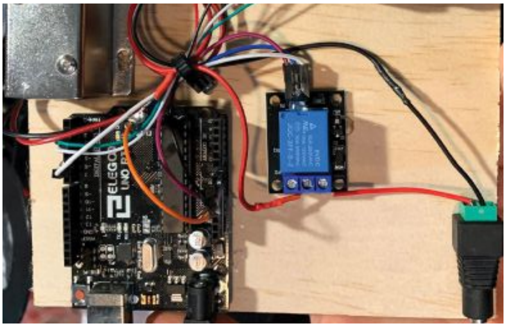
COST: $80–$90

MATERIALS

- **Optical fingerprint sensor module** ZhianTec ZFM-20, Adafruit #751
- **Solenoid lock, 12V DC, less than 1A**
- **Arduino Nano microcontroller board**
- **Blank PCB** aka proto board
- **Relay module, 5V**
- **Hookup wire, 22–24 AWG**
- **Heat-shrink tubing** for 22–24 AWG
- **Battery, 9V**
- **Battery connector, 9V**
- **Power supply, AC/DC 12V 1.5A–2A, with male barrel connector**
- **Matching female barrel connector** Get both with Amazon B07HNL5D56 or similar.
- **Micro slide switch, on-off**

TOOLS

- **Soldering iron with solder**
- **Wire cutters/strippers**
- **Screwdrivers**
- **Heat gun or lighter** for heat-shrink
- **USB Mini-B cable** for programming the Nano
- **Hot glue (optional)**
- **3D printer (optional)** for an enclosure



Here's my original design from two years ago.

Here's my new and improved design.

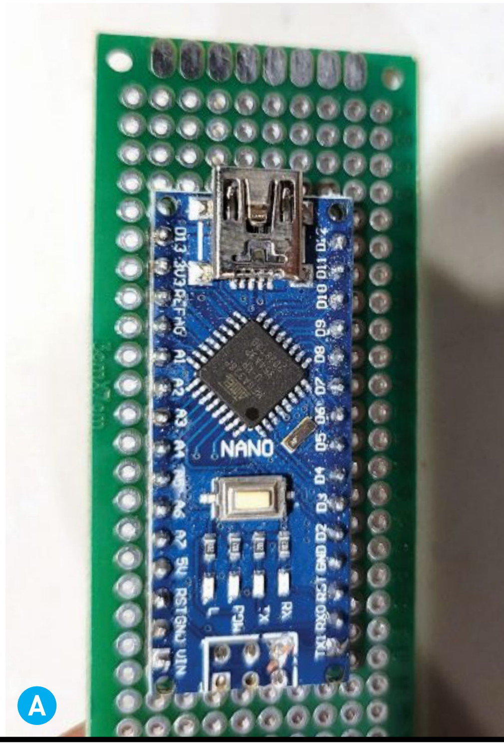
Add some real biometric security to your doors and drawers

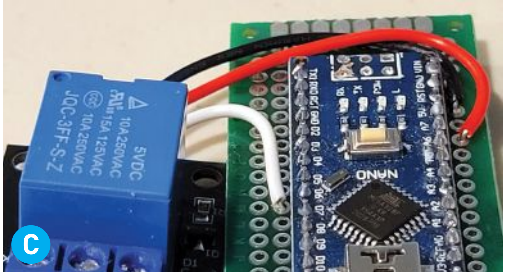
This is my Arduino Fingerprint Door Lock using an optical fingerprint identification sensor from Adafruit. Whether I decide to secure my room or limit access to my tools, this project can easily fit onto doors, cupboards, and drawers.

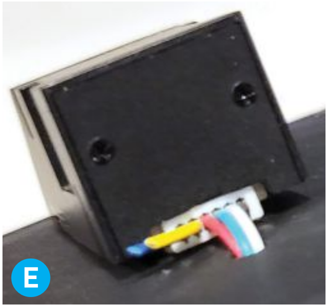
I first built this door lock two years ago. For this redesign, my goal was to see how my engineering skills have changed over the past two years. I've successfully miniaturized it, but I'm still using two power sources. Maybe you can improve it!

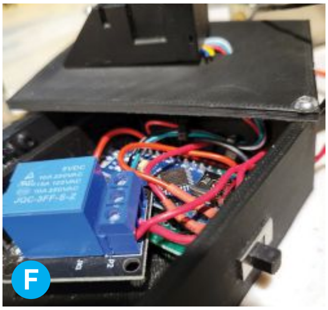
1. SOLDER THE ARDUINO NANO TO A BLANK PCB

Be sure to leave enough space for the mini USB cable (Figure A).









2. SOLDER THE RELAY PINS

Following Figures B and C, solder three wires to connect the relay control pins:

- Signal pin (S) on the relay to digital pin 5 (D5) on the Arduino Nano
- Positive pin (+) on relay to 5V on Arduino Nano
- Negative pin (–) on relay to ground (GND) on Arduino Nano

3. ADD THE FLIP SWITCH

Solder two lead wires to the micro switch pins as shown (Figure D). Use appropriate heat-shrink tubing where there may be wire exposure.

Solder one wire to voltage input (VIN) on the Arduino Nano. Leave the second wire to be connected to the battery later (in Step 6).

Also add a ground wire to any GND pin on the Arduino Nano. (Keep this wire long, as it will go to the battery too.)

4. CONNECT THE SENSOR

We only need to use four of the six available pins on this fingerprint sensor (Figure E): 5V (red), GND (black), Tx (green), and Rx (white). Solder these as follows:

- 5V to the 5V pin on the Arduino Nano
- GND to any GND pin on Arduino Nano
- Tx to the D2 pin on Arduino Nano
- Rx to the D3 pin on Arduino Nano

5. WIRE THE RELAY TERMINALS

The relay's middle screw terminal is the COM (common contact) that will be connected to the second terminal when the signal pin is set to HIGH. Connect the positive wire from the solenoid door lock to this COM terminal.

The second terminal used is NO (normally open); this represents the status of the terminals when there is no signal coming from D5. Attach a relatively long wire to be routed later (Figure F).

6. ADD THE 9V BATTERY

Using the wires from Step 3, solder Arduino GND to the battery connector's negative terminal, and solder the flip switch pin to the battery connector's positive terminal (Figure G).

7. ADD THE BARREL CONNECTOR

Connect the negative wire from the solenoid to the negative terminal of the barrel connector. Finally, connect the NO (normally open) wire from Step 5 to the positive terminal of the barrel connector (Figure H).

8. SET UP THE FINGERPRINT SENSOR

The Adafruit Fingerprint Sensor setup process can be found at learn.adafruit.com/adafruit-optical-fingerprint-sensor. After you've added ("enrolled") the desired fingerprints, you need to add some lines to the Adafruit sample code.

9. MODIFY THE CODE

This step allows us to change the status of the solenoid after a successful reading from the fingerprint sensor. When the solenoid is given power, it will retract.

Add `int lock = 5;` before `void setup (){`
Add `pinMode(lock, OUTPUT);` after `void setup (){`

Where the code returns a successful attempt to the serial monitor, add the following lines:

```
digitalWrite(lock, HIGH);
delay(5000);
digitalWrite(lock, LOW);
```

Upload the code to the Arduino and test the lock.

10. TEST THE LOCK

Give the sensor a few test runs. Don't be discouraged if it doesn't work the first time. Every attempt is a key part of the learning experience! I used the Adafruit tutorials but have since found YouTube to be a great source of ideas.

SCAN FOR ACCESS!

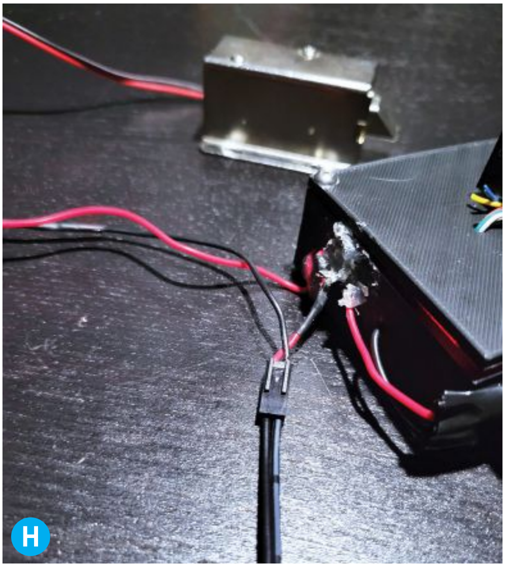
Your finished fingerprint lock can be used on doors, cabinets, drawers, or other projects

Whether it's just for show or put to use, this project can be modified as needed. If you're up to the challenge, here are some ideas for going further:

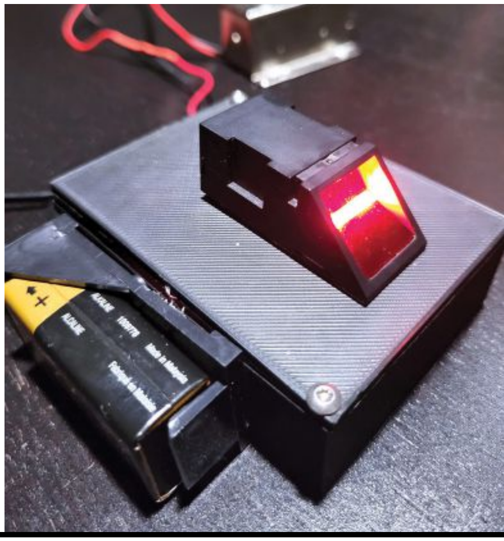
- Add an LCD screen to display the status of the lock
- Make your own enclosure for the project
- Try a solenoid with a lower operating voltage to eliminate the need for a relay module
- Figure out how to get rid of the additional power source! Page 104 shows the lock unplugged from the DC barrel connector, but it's got to be plugged in to use it.

Since so many makers have made projects similar to this one, there are a multitude of designs out there that may inspire your next modification.

G



H



Mini Glowboard

A light-up message board that gleams in the dark

Written and photographed by Bob Knetzger

TIME REQUIRED: A Few Hours

DIFFICULTY: Easy

COST: $10–$15

MATERIALS

- **Acrylic sheet, ¼" thick** clear for the glowboard, color of your choice for the base. Download the free vector files for cutting, from makezine.com/go/glowboard.
- **MEK solvent with applicator** or other glue for acrylic
- **LED, 5mm, 3V ultra bright**
- **Coin cell battery, 3V**
- **Dry erase markers, fluorescent/neon** aka window markers or glow board markers

TOOLS

- **Laser cutter (optional)** or send the files out to a service for cutting

Make a toy-sized light-up message board that glows in the dark, using ordinary neon dry-erase markers. Stand it up, hang it on a wall, or dangle from a doorknob. Easy, fast, *fun!*

The design is simple: a stack of laser-cut ¼" acrylic shapes form the base to hold a single LED and a clear panel (Figure A).

1. BUILD THE BASE

Visit the project page at makezine.com/go/glowboard to download the *.svg* files for laser cutting. Or create your own. None of the dimensions are critical. Just be sure to form a friction fit to hold the 5mm LED when you solvent-bond the two middle-layer parts D (Figure B). Hold the LED in place on top of the adjacent layer C and then tack on parts D with a drop of solvent. Adjust the fit of the LED, then when snug, remove the LED and add more solvent.

Continue bonding each layer together to build the A-B-C-D-C-B-A stack (Figure C).

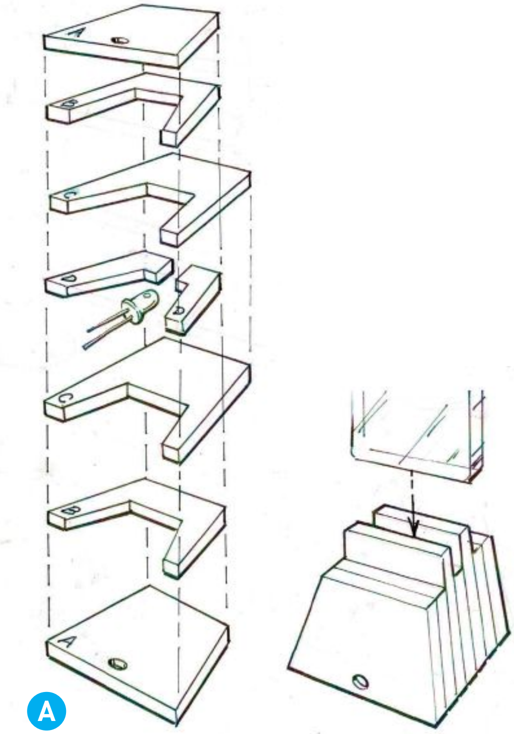
2. MAKE MESSAGE BOARDS

Also cut out several small ¼" clear acrylic panels of various sizes and shapes, for your mini message boards. I used Glowforge's Proofgrade acrylic to get perfect results without any "flashback" defects. The special Green Glass Proofgrade acrylic gives a very finished looking edge (Figure D).

3. ADD LED AND BATTERY

Insert an ultra-bright 3V LED in the base, and add a coin cell battery to make a super-simple light source. Just slip the 3V cell battery between the LED's leads and tape it on, like an LED "throwie" without the magnet (makezine.com/projects/led-

BOB KNETZGER is a designer/inventor/musician whose award-winning toys have been featured on *The Tonight Show*, *Nightline*, and *Good Morning America*. He is the author of *Make: Fun!*, available at makershed.com and fine bookstores.



A

throwies). Remember: The long leg of the LED is the positive lead (Figure E).

4. GET CREATIVE!

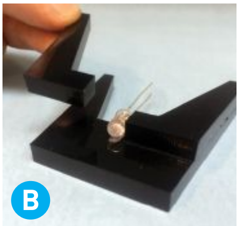
Use dry-erase glow board markers to draw and letter your own glowing messages and gleaming designs (Figures F, G, H, and I). Place the clear panel over a drawing or picture to trace. You can also decorate both sides of the panel for a 3D effect. The message boards friction-fit into the base without glue, so they're removable. Wipe them off and do it again!

Your designs glow brightly in the dark. Place a piece of black paper behind the Mini Glowboard panel for daylight viewing.

MORE FUN

- Use the small holes to hang up your Mini Glowboard anywhere (Figure J).
- Loop rubber bands through the mounting holes and hang it on a doorknob for a glowing nighttime "Keep Out!" warning (Figure K).
- Make multiple bases and combine them to light up bigger panels.

You can also change out the LED for other variations: Try different colors, blinking, flame-flicker, or UV LEDs. Glow for it!



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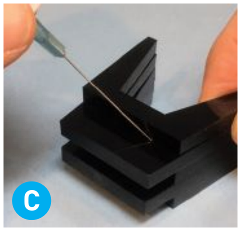

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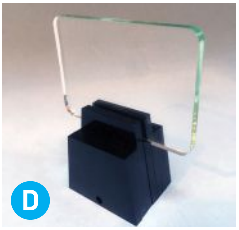


D

E

F

G

H

I

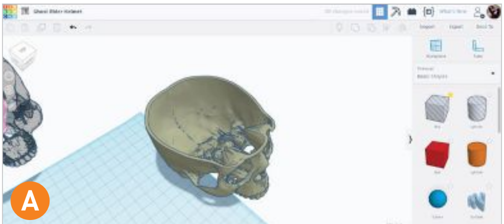
J

K

En Fuego!

Written and photographed by Mike Warren

Add awesome smoke and fire effects to this Ghost Rider — or any costume — using an e-cig and flicker LEDs



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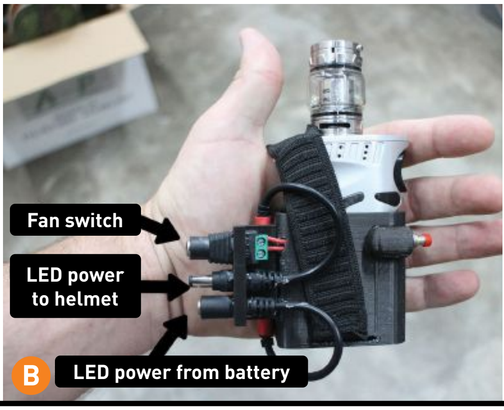


B

Adding smoke and flame effects to your costume is easier than you might think, using a vaping e-cig loaded with vegetable glycol and pumped using a small aquarium pump. This effect, combined with some flickering LEDs tucked into inconspicuous places, can give a realistic fire and smoke look to your next costume. See it in action at youtu.be/xBAWGbv2XRY and I'll show you how to build it here!

I made this Ghost Rider costume by 3D printing a skull that I found on Thingiverse (free) and modified in Tinkercad (also free), then painting it. The electronics and controls are incredibly simple, controlled by a cluster of buttons held in one hand and operated by momentary switches. The whole thing costs less than $100, assuming you already have black clothes, a motorcycle jacket, and a 3D printer.

1. PREPARE YOUR SKULL

I found a 3D skull model at thingiverse.com/thing:43591 and brought into Tinkercad to perform a few simple edits: I hollowed it out (Figure A), scaled it up a little larger than my head, and removed the back so I could wear it like a mask. Once I was happy with the shape, the model was exported as an STL for printing. See how I did it at instructables.com/Ghost-Rider-Costume.

You can use Tinkercad to modify this skull model, or just use the skull mask I created (it's open source), or substitute your own mask.

2. 3D PRINT THE PARTS

Download the parts from tinkercad.com/things/bwyUgKgfm2i and print them. There's the skull face, cap, and mandible, a housing for the controls, hose barbs for the air tubing, an LED holder, and a standoff for the electrical connectors. If you're using a different mask, you can skip the skull and just print the other parts for the smoke/fire effect.

Knowing that I was going to cover the entire mask with putty to smooth out the shape of the skull, I used low resolution setting for this print. Each section took ~10 hours to print. Plenty of artifacts, and some gnarly voids I missed filling in when I was in Tinkercad, but an easy fix when the putty goes over.

3. FINISH THE MASK

After printing, I sanded all the parts with 80 grit, smoothed the layer lines with Bondo putty, mated the cap and face, and smoothed with Bondo again.

I primed and spray painted the skull parts in ivory satin finish, and then painted the "lowlights": I thinned some black paint with water, rubbed it into all the divots and scratches, then wiped it off quickly, leaving behind black paint in only the low areas. This effect gives the skull a much more textured appearance. Again, you can get more details at the Instructables page.

Finally, a wide sewing elastic was sewn onto the back of the mask so I could wear it.

4. ELECTRONICS

The e-cig is placed inside the controller housing and the electrical connections are placed on the standoff, to make removing the controller easy when putting on the costume (Figure B). A momentary switch mounted in the controller operates the aquarium pump.

The flame LED arrays that I bought are controlled by a small 3-button setup. Power comes from the 12V battery pack into the LED buttons, mounted onto the end of the controller (Figure C on the following page), then back out

TIME REQUIRED: A Weekend

DIFFICULTY: Intermediate

COST: $100

MATERIALS

For the smoke/fire effect:

- **E-cig vape kit, large capacity** I used the Smok 225W Mag model, with 8ml tank.
- **Batteries, Li-ion 18650, 2500mAH (2)** for the e-cig
- **Vegetable glycerin** for vape smoke, such as Amazon B0019LWU2K
- **Mini aquarium pump, 12V** Amazon B011C0X328
- **Flame effect flicker LEDs** such as Amazon B07HVCX4VP
- **Battery pack, Li-ion 12V** for the pump and LEDs, Amazon B07HVCX4VP
- **Air tubing, vinyl**
- **Hookup wire**
- **Momentary switch**
- **DC barrel jacks/plugs** with screw terminals
- **3D printed parts: hose barb and splitter, housing for controller, etc.**

For the Ghost Rider costume:

- **Skull mask** I modeled and 3D printed my own mask, but you can adapt this project to any costume that's got room for the LEDs inside.
- **Bondo putty** Amazon B0007ZHTTS
- **Sewing elastic** Amazon B01KWRM6YI
- **E6000 craft adhesive**
- **Foam padding** I used an old mousepad.
- **Black face mask or balaclava** Amazon B00PJV02WQ
- **Jet black pantyhose** Amazon B001CI941A
- **Black dungaree work pants** Amazon B000JJKG7Y
- **Leather jacket**
- **Plastic costume chains** Amazon B077MXJR3DI, or metal chains if you want
- **Cowboy boots**

TOOLS

- **Soldering iron**
- **Wire snips**
- **Sanding supplies**
- **Paint supplies**
- **Sewing supplies**
- **3D printer**

MIKE WARREN is a mad scientist and best-selling author based in San Francisco. Fluent in sawdust and CNC, he is equally comfortable with CAD design and hand fabrication. Since 2005 he's been producing digital and physical prototypes to turn crazy ideas into tangible reality. michaelsaurus.com

and into the helmet (Figure D).

I mounted the two LED flicker arrays around my nose, but wanted more light above my eyes, so I added a simple LED holder that's installed along the brow line. You can connect your components by following my wiring diagram (Figure E).

5. AIR TUBING

The top of the e-cig is attached to a removable mouthpiece which goes into vinyl tubing and into the small 12V pump. Figure F shows what the setup looks like when placed inside the jacket. The vape "smoke" is drawn from the e-cig and into the pump, which then pushes the smoke through a barbed splitter into two tubes: one up into the helmet and another attached to the collar of the jacket with a 3D-printed clip.

FIRE IT UP

Now your Ghost Rider costume is set to scare the neighborhood!

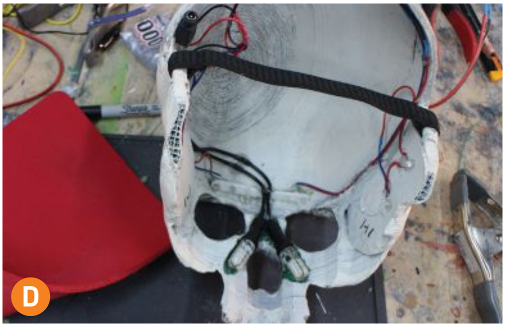
To hide my face while wearing the mask, I cut off one leg of the pantyhose and stretched it over my face, obscuring my eyes but still allowing me to see. Then I put the balaclava over, to cover the rest of my face.

The two different LED arrays, combined with a judicial use of vapor from the e-cig, create an amazing effect. With the controller in one hand, the e-cig is ignited and the pump activated, drawing the smoke from the e-cig through the costume and up out the skull mask and jacket. To clear out the smoke effect, the e-cig trigger is released and the pump left on.

The vapor cloud is from vegetable glycerine, which is the main component in most e-juice vaporizers. Vegetable glycerine is food safe and contains 0% tobacco or flavorings. *Do not* use tobacco e-juice as it will stink and you'll smoke yourself out! Even with vegetable glycerine this device can only be used in short bursts. Be smart about how you use this effect.

The effect is striking in person, and from a distance looks incredibly believable! I found the combination of pantyhose and thick smoke almost impossible to see out of, so I could only perform the smoke trick when standing still. Happy making! :)


C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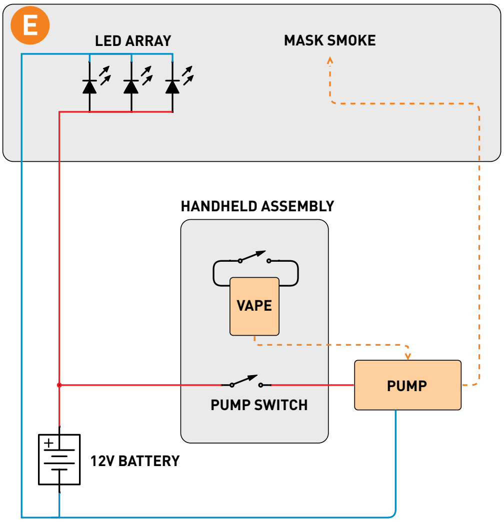
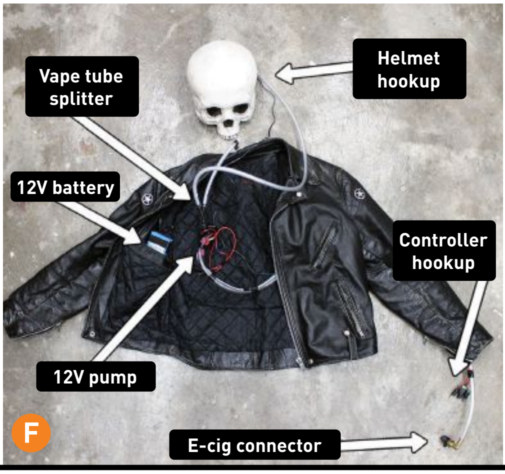
MASK ASSEMBLY

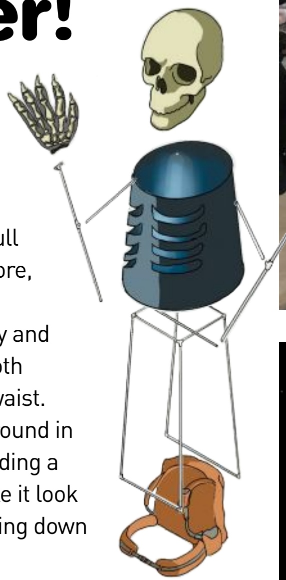




F

1+2+3 Floating Specter!

Written by Tom Heck



I designed and built this 10-foot-tall costume for Halloween 2020. The head is a giant plastic skull I found at a Halloween store, and I downloaded creepy scary sounds from Spotify and played them on a Bluetooth speaker attached to my waist. Although you can walk around in this costume, I decided riding a Segway would really make it look like the specter was floating down the road or sidewalk.

1 MAKE THE FRAME Using ½" PVC pipe, build a tall structure to hold the head. Mount the skeleton hands on the ends of two pipes that you will wave around.

2 MOUNT TO BACKPACK Attach the tall PVC pipe frame to a backpack. Wrap it with a cardboard tube, with cutouts for the ribs, to make the body. A camping lantern inside the ribs can provide a nice glow.

3 COVER IT UP Drape the whole thing in white linen to obscure your figure and make the arms appear to be attached.

It took a little practice to wear the costume without crashing — it's very top heavy — and riding the Segway was a challenge: turning, starting, stopping, moving the arms, watching where I'm going, etc. But with 20 minutes of practice during daylight hours I was ready for Halloween!

Caleb Kraft, Tom Heck, Adobe Stock - Vjom

TIME REQUIRED: 2–4 Hours

DIFFICULTY: Moderate

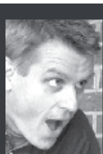
COST: $100

MATERIALS

- **LED Light Up Skull with Sound, battery operated** I bought this at a temporary Halloween "superstore" tent in the parking lot of our local shopping mall. You can also find them online, model MR123238.
- **Segway miniPRO transporter (optional)**
- **PVC pipe and fittings, ½" diameter**
- **White linen material** I found some in the scrap bin at the local fabric store.
- **Camping backpack** to attach the PVC frame. One with a rigid structure is best.
- **Halloween skeleton gloves, large**
- **Cardboard** to make the ribcage
- **LED camping lantern**
- **Glue, fasteners, etc.** whatever works best for you
- **Scrap wood (optional)** to mount the skull
- **Portable Bluetooth speaker (optional)** to play your favorite spooky sounds

TOOLS

- **PVC pipe cutter**
- **Cordless drill**



TOM HECK is a longtime maker, *Make:* contributor, and Maker Faire presenter and exhibitor. He volunteers at a local makerspace and enjoys creating impractical and whimsical things, especially if they are interactive. tomheck.com and makezine.com/author/tom-heck

TIME REQUIRED: 1 Hour

DIFFICULTY: Easy

COST: $5–$10

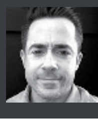
MATERIALS

For about 30 eyeballs:

- **Shiratama flour (400g)**
- **Soft tofu (560g)**
- **Food coloring** powdered or liquid for the eyeballs; liquid for drinks

TOOLS

- **Rubber gloves** to handle the food coloring
- **Large plates (3)** to work on
- **Large pot** to boil water
- **Large bowl** to cool the eyeballs
- **Ice** enough to make ice water in the large bowl
- **Freezer bags** to store the eyeballs



BRYAN HARPER is a builder, artist, and teacher in Japan.

Edible Eyeballs

Elevate your spooky libations with these easy treats

Written and photographed by Bryan Harper

These edible eyeballs are made from a popular traditional Japanese snack called *shiratama*. They're fun and spooky and also not too gross looking, perfect for Halloween! Why should you make them? Hey, they're cheap, easy to make, and something fun to do with kids.

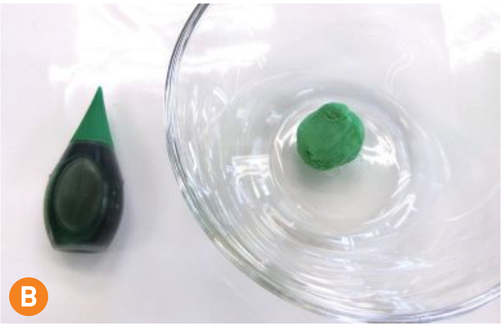
All you need is shiratama flour, soft tofu, and food coloring. Shiratama flour is available on Amazon, or at Walmart and Target. It's also called *shiratamako* or *shiratama powder*. Be careful, because there's a difference between shiratama flour, mochi flour, and glutinous rice flour. These are similar, but they cannot be substituted for each other.

Normal shiratama is just shiratama flour and water, but I use tofu because it keeps the shiratama softer much longer. They turn hard faster when using water.

1. MAKE THE SHIRATAMA MIX

- Put 400g of shiratama flour in a bowl, then add 560g of soft tofu, and mix with your fingers. No utensils required.
- Form a ball, or *dango* in Japanese, for the main eyeball. You should be able to make 30 balls, each about 3cm–4cm in diameter (Figure A).
- Using the rest of the mixture, separate pinches of dough for the irises and smaller pinches for the pupils. You'll want an equal number of eyeballs, irises, and pupils.

A



B

C

D

E

2. ADD FOOD COLORING

It's best to roll out all the eyeballs, irises, and pupils before adding color, so you have an exact count. Then you can combine the food coloring into the iris and pupil balls to color them. Add a bit of coloring to each iris and pupil and reroll in your hands until the coloring is thoroughly mixed (Figures B and C).

TIP: Wear gloves when you color the shiratama. Some food coloring is difficult to wash off.

3. MAKE THE EYEBALLS

Once the shiratama are dyed, you can take off your gloves to make the eyeballs.

- Flatten out an iris in the palm of your hand using a finger.
- Place the flat iris on the eyeball.
- Place the pupil on the iris (Figure D).
- Gently press and roll all the pieces together to make an eyeball (Figure E).

4. COOK YOUR EYEBALLS

- Prepare a large bowl of ice water and set aside.
- Bring a large pot of water to a boil.
- Gently drop the shiratama into the boiling water. They will sink to the bottom of the pot.
- When all of the shiratama are floating, continue to boil for another 2 minutes.
- Strain the shiratama and then transfer them to the ice water to cool.
- Once they are firm and not hot, you can eat them or freeze them for later.

NOTE: Freeze them in a way that they're not touching, otherwise they'll fuse together permanently. This is very important!

HERE'S LOOKING AT YOU, KID

Now let's make some drinks!

MOCKTAIL: Add 3 frozen eyeballs to a wine glass, and fill with cider or a clear soft drink. Add a few drops of grenadine and 1 drop of red liquid food coloring.

COCKTAIL: Same as the mocktail, but add vodka! Blueberries complement shiratama well, too.

Cursed Objects

Written by Caleb Kraft

Jumpstart the season with these spooky builds

Make your Halloween the spookiest it can possibly be! There's no way we could include all the wonderfully inspiring projects that we loved this year. Here are just a few that stood out.

Wicked Makers, Makr Komus, David Sarlls, Alicia Williams, Jonathan Pfeiler, Adobe Stock - Vjom

A SCARY HAUNTED MIRROR

makezine.com/go/haunted-mirror

Combining a TV, motion sensor, one-way mirror, and some simple video editing, you can pull off the very impressive effect of a mirror that suddenly shifts from your reflection to a spooky ghost or ghoul. This project is easier than it looks and is sure to keep your Halloween visitors on their toes.

B JUMP SCARE TOMBSTONE

hackaday.io/project/182367-jump-scare-tombstone

This little tombstone will detect your proximity and display a creepy skeleton on the screen while playing spooky sounds. The concepts here are rock solid and the documentation is great; you could take this project much further by scaling things up and creating a bit more atmosphere and really scare some folks!

C BIKE-RIDING SKELETON

instructables.com/The-Bike-Riding-Skeleton

An impressive display doesn't have to be expensive or super complicated. David Sarlls shows how to build this bike-riding skeleton for under $400, if you can be resourceful and scrounge a few things. Considering many cheesy store-bought decorations cost more than that, we think David did a fantastic job.

D GARAGE DOOR MONSTER

makeprojects.com/project/garage-door-monster-mouth

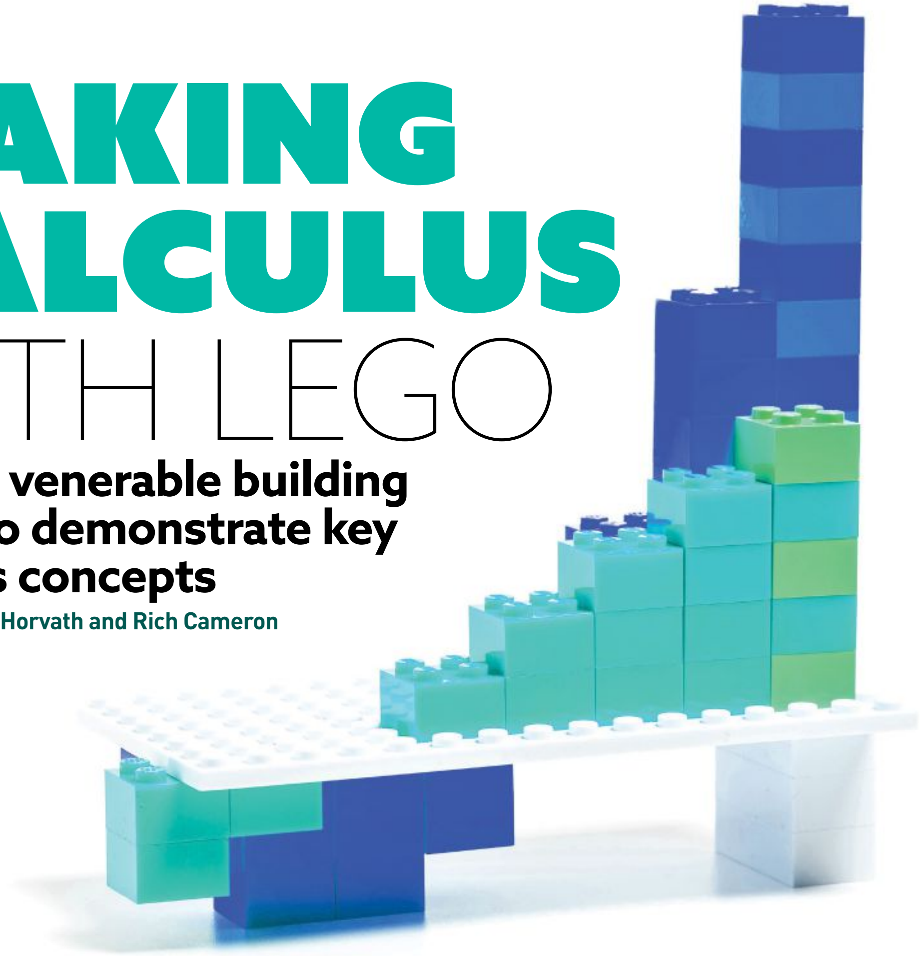
Want more bang for your buck? This garage makeover turns your house into a giant monster with a gaping maw! Alicia Williams (*Make:*'s very own web developer!) and family created this spooky setup using mainly cardboard and paint.

E ZUUL ON YOUR ROOFTOP

makeprojects.com/project/there-is-no-danaonly-zuul

If you have a little artistic ability, tap into pop culture for a prize that nearly everyone will recognize. The giant demon dogs from the movie *Ghostbusters* are almost universally known and we promise that having your very own Gatekeeper of Gozer perched on your roof will certainly draw a crowd.

MAKING CALCULUS WITH LEGO



Use the venerable building bricks to demonstrate key calculus concepts

Written by Joan Horvath and Rich Cameron

JOAN HORVATH and **RICH CAMERON** are the co-founders of Nonscriptum LLC (nonscriptum.com). They are the authors of many books, including *Make: Geometry* and *Make: Calculus*.

TIME REQUIRED 1 Hour

DIFFICULTY Easy

COST About $30 for Lego bricks

MATERIALS

» **Identical construction toy bricks (80) and baseplate** 2×2 Lego bricks are ideal

» **Paper model printout (optional)** or 3D print one

Isaac Newton developed calculus back in the mid-1600s as a tool to explain physical phenomena, in particular the motions of planets. As it turned out, it was also a way to encode how things move and change more generally, from economies to populations of rabbits and foxes. When Newton did it, his reasoning was mostly geometrical, not so much based on the large amounts of algebra and symbols we associate with calculus today. Those were mostly the brainchild of his contemporary (and competitor) Gottfried Wilhelm von Leibniz.

There is a lot of scary-sounding terminology that puts people off calculus, like *derivatives* and *integrals*. Too often, it is thought of as something to survive, be tested on, and never address again. However, these concepts are not all that hard, and can give insight into just about anything that changes or moves. A few basic relationships

Rich Cameron

underlie everything else in calculus, one of which is so central that it is usually called the *Fundamental Theorem.*

As it turns out, Lego bricks are a perfect medium to do a very basic geometry-first demonstration of this theorem. We think Newton would have approved. If you want to follow along at home, you'll need a base plate and some 2×2 square bricks.

After that, we'll try a more accurate way of looking at a smooth curve, instead of a blocky one made of columns of Lego bricks. We'll give you some downloadable models to 3D print or to print on paper to play along there, too.

The Curved Wall

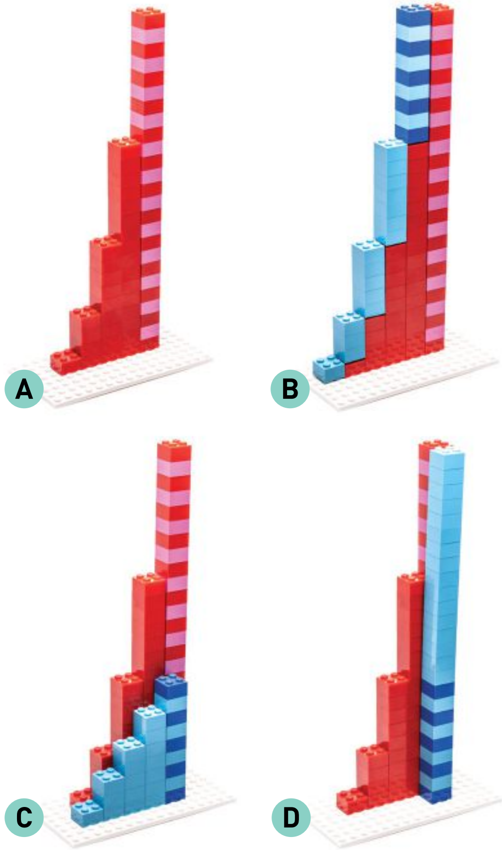
Let's make a wall of red Lego bricks using columns. For the first column, leave a space with "zero bricks." Then, place 1 brick in the next column, then 4, 9, 16, and finally 25, as shown in Figure A. The height of each column in the red wall contains bricks corresponding to the *square* of its position. We alternated colors in the tallest one, just to help you count them.

Now, let's take some blue bricks, and look at the *differences* from one red column to the next (Figure B). As we go along this curve, the differences get bigger, too.

Next, let's move those differences to make a wall of their own, putting each blue brick in-between the columns of red ones (Figure C). That signifies that the blue brick is the difference between those two red columns (including the red "column" of zero bricks). There are 1, 3, 5, 7 and 9 bricks in the blue wall.

This blue wall made up of all the differences of the original wall has some interesting properties. It is climbing up by two bricks per column. In algebra you may have learned about the *slope* of a wall (sometimes expressed as *rise/run*). A straight line (like the one made by the blue wall) will have a slope that is some constant number. In this case, the blue wall has a slope of 2; it rises two bricks for every column.

Remember that the blue wall represents how the red curve is *changing*. In calculus, we call this more-general version of a slope the ***derivative*** of the original curve. From here on out we will call the blue wall of differences the "derivative wall."



(There are technicalities we are passing over here, because our wall is stair-stepping rather than being a smooth curve, but we'll ignore all that for now.)

Now, about those interesting properties of the blue derivative wall. Suppose we added up the bricks in that wall. The number of bricks in the first blue column is 1. That's the same as the number of bricks in the first nonzero column of the original (the difference between 0 and 1). If we now add up the first two columns of the derivative wall, we get a column the same height as the second (nonzero) column in the original wall. This is true all the way to the end (Figure D) where we get a blue totaled-up column equal to the tallest red column.

You can prove to yourself that this will always be true. If you start off with the first value in the original curve and keep adding the differences between subsequent points as you go along, the running total of blue bricks is the same as the number of red bricks at that point in the original curve. It is also proportional to the *area* under the blue derivative curve, since each Lego brick contributes one rectangle of area we can add up to get the whole.

In calculus, adding up a quantity represented by a curve is called *taking its integral.* Generally speaking, an ***integral*** is what you get when you add up what is underneath a curve: the area under a curve, or the volume under a surface.

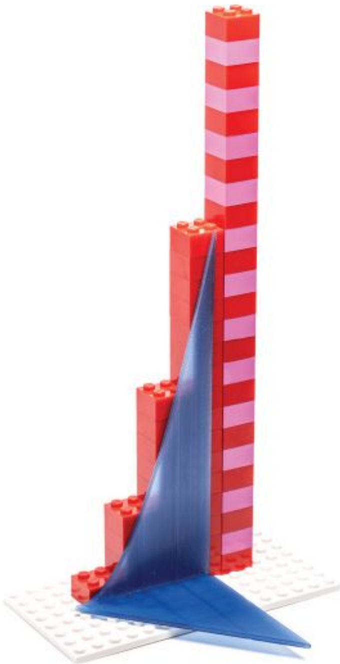
Let's recap what we did.

- We started with a red wall that was 0 bricks high, then 1, 4, 9, 16, up to 25.
- Then we created a new blue wall made up of the differences from column to column in the original wall. This new wall, we discovered, could be called the *derivative* of the first one.
- Next, we added up the number of bricks in our derivative wall. We discovered that the running total (integral) of the derivative is just the number of bricks in the original curve at that point!

To put it another way, finding derivatives and integrals are what mathematicians would call ***inverses*** of each other, or operations that cancel each other out. This is similar to the relationship between multiplication and division, or squaring and taking a square root. The fact that the derivative of an integral gives you back the original curve you started with, and likewise the integral of the derivative, is called the ***Fundamental Theorem of Calculus***. And no equations required (so far)! In more complicated cases, the integral may have a constant offset, but we constructed our examples to avoid that.

Continuous-Curve Model

As we just saw, the brick model works for curves that can be easily chopped up into a small number of whole bricks. But what if we had a smooth curve, that was changing in big swoops in some places and barely changing in others? Isaac Newton's big "aha" moment (one of them, anyway) was that you could create ways of figuring out the slope of a curve instantaneously, between two "columns" that are incredibly close together. We could imagine that we create a zillion columns of teeny bricks and do the same exercise.



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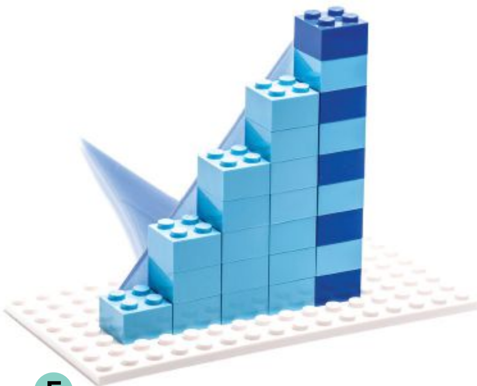

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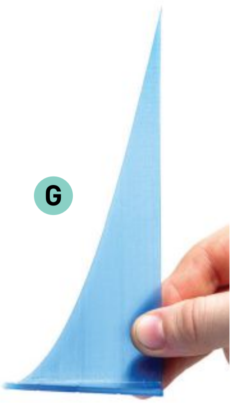

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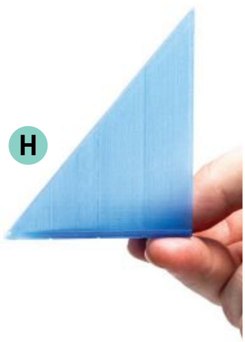


H

Rich Cameron

Since that's not very practical, we have created a 3D-printed model to think about this (Figure E) and put it in front of our red wall to show that it, too, is a curve that rises as the square of its position. (It's a little shorter because the size of our print bed did not allow us to go all the way to 5^2.) We will give you a template to make a paper one instead, but it is a little easier to see what is going on with this translucent model. We can see there that the smooth blue model is crossing through the center of the top brick in each stack.

There is a part of the smooth blue model sticking out toward us in Figure E. Let's rotate the model and see how that part fits our blue wall (Figure F). Yes, it lines up perfectly.

So, we can see that one part of this 3D print (Figure G) follows the original (red) curve, and if we rotate it away from us, we follow the derivative (blue) curve (Figure H). Thus, we take this model (all of which is visible in Figure E) and rotate it away from us to get a derivative.

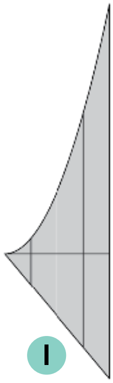
If instead we started with Figure H and wanted to know how the area of the shape accumulates as we move from left to right, we could rotate it the other way, to get Figure G, the integral. In this case, we can see that the integral grows faster and faster, because as the line slopes upward, more and more area is added for each tiny step to the right. So, the exact same pair of curves can show us a curve and its derivative, or an integral and the curve it integrates — another hands-on view of the Fundamental Theorem. We rotate one way to find a derivative, and rotate back the other way to get an integral.

Purists will note some details here that we are ignoring. As we mentioned earlier, there is a constant floating around we will need to deal with to get numerical answers in general, but let's enjoy our victory for a moment!

Making the Right-Angle Model

Our new book, *Make: Calculus* (available soon in the Maker Shed and other retailers) details how to make a 3D printable version of this model and many others. This model was created in OpenSCAD, and will be available in the book's open-source GitHub repository.

Meanwhile, if you'd like to play with it, we have provided both a 3D-printable STL and a paper-printable PDF file (Figure I) that is scaled to match models made from 2×2 Lego bricks, just like the ones in the photos. You can download these at makezine.com/go/make-calculus. For the paper version, be sure to print it out at 100% size. Cut it out and fold it along the fold line. Then think about how one side represents how the other side is changing or accumulating, respectively. (If you use different construction toys, you'll need to scale these accordingly.)



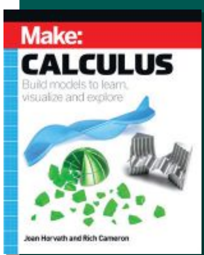
Why a Right-Angle Model?

People often plot a curve, its derivative, and the equation for its integral on the same 2D graph, since all of them are just functions of some variable. Often, we think of a variable as "dimensionless" and not having any units. But, in real life, variables are measured in feet or meters or bricks or dollars. Their derivatives will have units like bricks (high) per brick (long) in the case of the wall.

Integrating quantities of bricks with respect to other bricks will result in units of $(\text{bricks})^2$. We feel that plotting derivatives, curves, and integrals together on the same 2D graph is misleading at best. That's why we came up with this right-angle way of looking at curves. In these models, the independent axis (usually labeled *x*, or sometimes *t* for time), is shared by the two graphs.

The Bottom Line

We hope these models have given you some intuition about some of the fundamental principles of calculus. There are a lot more cool things to learn about calculus. We hope you are inspired to learn more!



Our new *Make: Calculus* book explores calculus concepts with hands-on explorations and a minimum of calculation. It also links key topics with traditional approaches so that it can be used either stand-alone to learn intuitively, or as a companion to a traditional textbook to give more insights.

SPEED UP YOUR 3D PRINTS

Change one slicer setting to take *hours* off your long 3D prints

Written and photographed by Bryan Vines

A

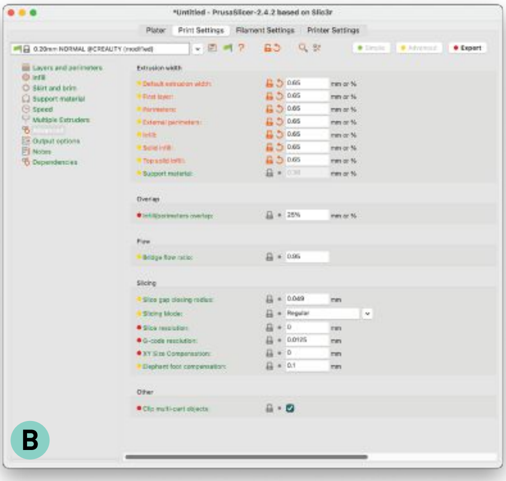
Hello 3D printing friends! Today I want to share a handy trick to get faster prints from your 3D printer, just by changing a setting in your slicer. It all started when I wanted to reduce the print time for this Neutron Tube model (Figure A) from Clockspring (patreon.com/clockspring3D). You can watch my full 8-minute video about the process at makezine.com/go/speed-up-prints, but I'll distill the steps for you here.

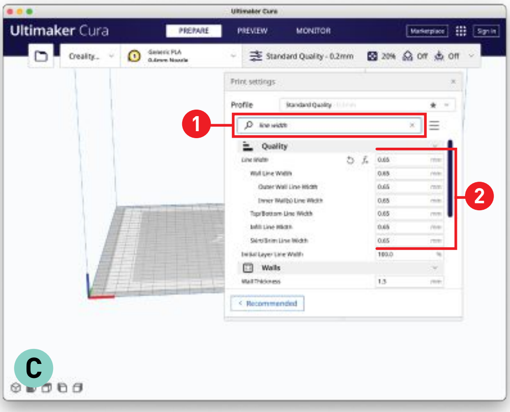
The Neutron Tube is a cylindrical container, about the size of a 12oz soda can, with a hinged lid and a threaded retaining ring. It's designed to print as one complete piece, instead of separate parts which are then assembled. Both the captive hinge pins for the lid and the threaded retaining ring print *in place* on the finished model. This is known as a ***print-in-place*** model, and it highlights one of the benefits that additive manufacturing processes such as 3D printing can provide.

Slicing the Neutron Tube with PrusaSlicer's standard 0.2mm Normal settings, the model took a little over 18 hours to print. One of the things I noticed about PrusaSlicer is that it has its ***extrusion width*** set a little bit wider than the diameter of the nozzle's orifice. So for a 0.4mm nozzle, PrusaSlicer has most of its extrusion widths set to 0.45mm. Since PrusaSlicer already uses an extrusion width larger than the nozzle's bore, I figured I could add another 0.2mm, making the extrusions 0.65mm wide.

In theory, with everything else being the same — layer height, number of perimeters, number of top and bottom layers, and printing speed — using a wider extrusion requires fewer printing moves per layer, which should result in less time spent printing. Think of it in terms of a paintbrush: A wider brush requires fewer

BRYAN VINES is a 3D printing enthusiast and host of The BV3D Channel on YouTube. He lives in San Antonio, Texas.





Prusa Reasearch, Ultimaker

Watch a video walk-through at makezine.com/go/speed-up-prints.

brush strokes to cover a surface with paint.

And in practice, it works! The longer a model would take to print with the Normal settings, the more time you can save.

Here's how to do it:

1. Click over to PrusaSlicer's **Print Settings** tab (Figure B).
2. Click the **Expert** button to expose additional settings.
3. Select the **Advanced** category from the list on the left side of the window.
4. In the **Extrusion width** group, set all the available values to **0.65mm.**
5. Then, return to the **Plater** tab to slice the model, export the G-code file, and move the file to your printer for printing.

NOTE: If you use Cura, search for **Line Width** and make the changes there (Figure C). This technique should work in any slicer which gives you control over extrusion width. Simplify3D, IdeaMaker, SuperSlicer, and even the browser-based Kiri:Moto slicer have settings for line width, though it sometimes goes by a different name.

For the Neutron Tube model, the time estimate was reduced from about 19 hours to 14 hours. And when printed, the model sliced with unmodified settings finished in about 18 hours, while the model with the wide extrusions finished in about 13 hours — about 5 hours faster! I couldn't see much of a difference in quality or precision between the two, either (Figure D). The hinged lid and the threaded ring work equally well on both.

What are the downsides? The time savings on smaller models may only be a few minutes. And while I had no issues with the Neutron Tube, some print-in-place mechanisms may not work if the moving parts fuse together during printing. You may also notice small gaps where the wider tracks meet corners. But it's worth experimenting with, and it's a handy tool to keep in your 3D printing toolbox that can save time on longer prints.

Monport Fiber Laser $2,945 monportlaser.com

Lasers are awesome, and this is doubly true when it comes to fiber lasers that can actually engrave metal. Where your typical CO_2 or diode laser can only leave a surface mark with the help of an additional coating, a fiber laser actually ablates the surface of most metals. You can engrave copper, aluminum, steel, gold, nickel, and much more. This really opens up the possibilities when it comes to making products for resale or art that will last a long time.

Fiber lasers have typically been in the financial realm of serious industrial equipment: tens of thousands of dollars. In the past few years the price of a desktop unit has dropped considerably to be cheaper than many of the popular CO_2 lasers we see on the market!

This unit has few bells and whistles, but gets the job done admirably. Your Z-focus is done manually, and there just isn't much else to operating the machine physically. The build quality on this is superbly solid. I feel like I could knock it off my workbench and it would still function. I won't do that though. I'll just keep engraving brass with friggin' light.

—Caleb Kraft

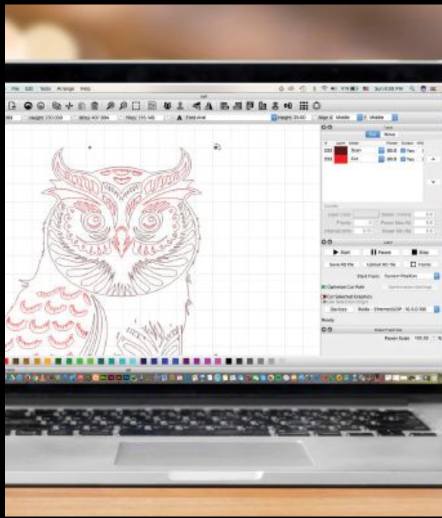
Nomad Sculpt on iPad

$15 nomadsculpt.com

For years the investment to get into digital sculpting has been pretty steep. You needed to shell out considerable cash to begin to tackle the industry goliath Zbrush. Even with free alternatives, you had invest in a graphical tablet, preferably one with a built-in display.

Nomad Sculpt has come along and brought digital sculpting to mobile devices like phones and tablets. With Android and Apple versions available, testing this out on an iPad has been an absolute delight. A responsive touch interface that you can carry around with you and sculpt on the go? What's not to like? There's still a bit of a learning curve, but at $14.99, it's easier to swallow.

The software can handle incredibly complex scenes with millions of polygons, and outputs in a variety of formats, including ones that can be 3D printed. New features are being added all the time, such as the recent addition of texture mapping, a missing feature that previously kept this software a hobbyist toy and has now opened it up to being an industry competitor. *—CK*



Lightburn Software

$60 lightburnsoftware.com

With the laser market swelling like crazy due to low prices, we're seeing diode lasers, CO_2 lasers, and even fiber lasers becoming more common in makerspaces and people's homes. One pain point that keeps coming up, though, is that the software for these is either extremely buggy or old, missing modern niceties such as anti-aliasing and drag-and-drop features.

Lightburn has stepped in to create a software package for controlling these machines that feels like modern software and has an active team of developers updating it.

Some features are worth the cost alone, like the circle center finder, perfect for centering designs on round things — a notoriously difficult task. Other tools will increase the utility of your laser, like the ability to use a cheap portable diode laser, unmodified, to engrave something many times the size of the work area, like an entire floor. *—CK*

3D Gloop

$20 (PLA), $25 (PET), $30 (ABS) 3dgloop.com

3D Gloop makes specialty glues formulated specifically for 3D prints. If you've been printing for a while, you know that needing to glue parts together is somewhat common. This stuff really is effective, and my tests gluing various PLA and PETG pieces together turned out much better than typical CA glue. It doesn't leave a haze like you'd get with CA and it holds fantastically.

For items like PLA, this is nice but not world changing. However, when you get into things like PETG, it's awesome. Gluing PETG used to be a serious problem for me as it seemed nothing wanted to hold it together well, but the 3D Gloop for PETG holds fast and strong without warping or discoloration. This alone will allow me to use a lot more PETG, which is fantastic because it is likely the most recyclable filament commonly available.

3D Gloop has another trick up its sleeve: it doubles as a bed adhesion material for those using glass beds. Having problems getting parts to stick? Not anymore. —*CK*

Qfun Digital Calipers

$30 amzn.com/dp/B09CL2HZQM

I was pleasantly surprised with the solid build on these calipers. At the price they were offered, I didn't have high hopes, expecting cheap plastic and loose fit. When I pulled them out of the box, my mind was instantly changed. They feel solid in your hand and the display is responsive.

There's a nice metric-to-Imperial conversion chart on the back, a handy thing when talking to American makers as we tend to jump from one to the other altogether too frequently. —*CK*

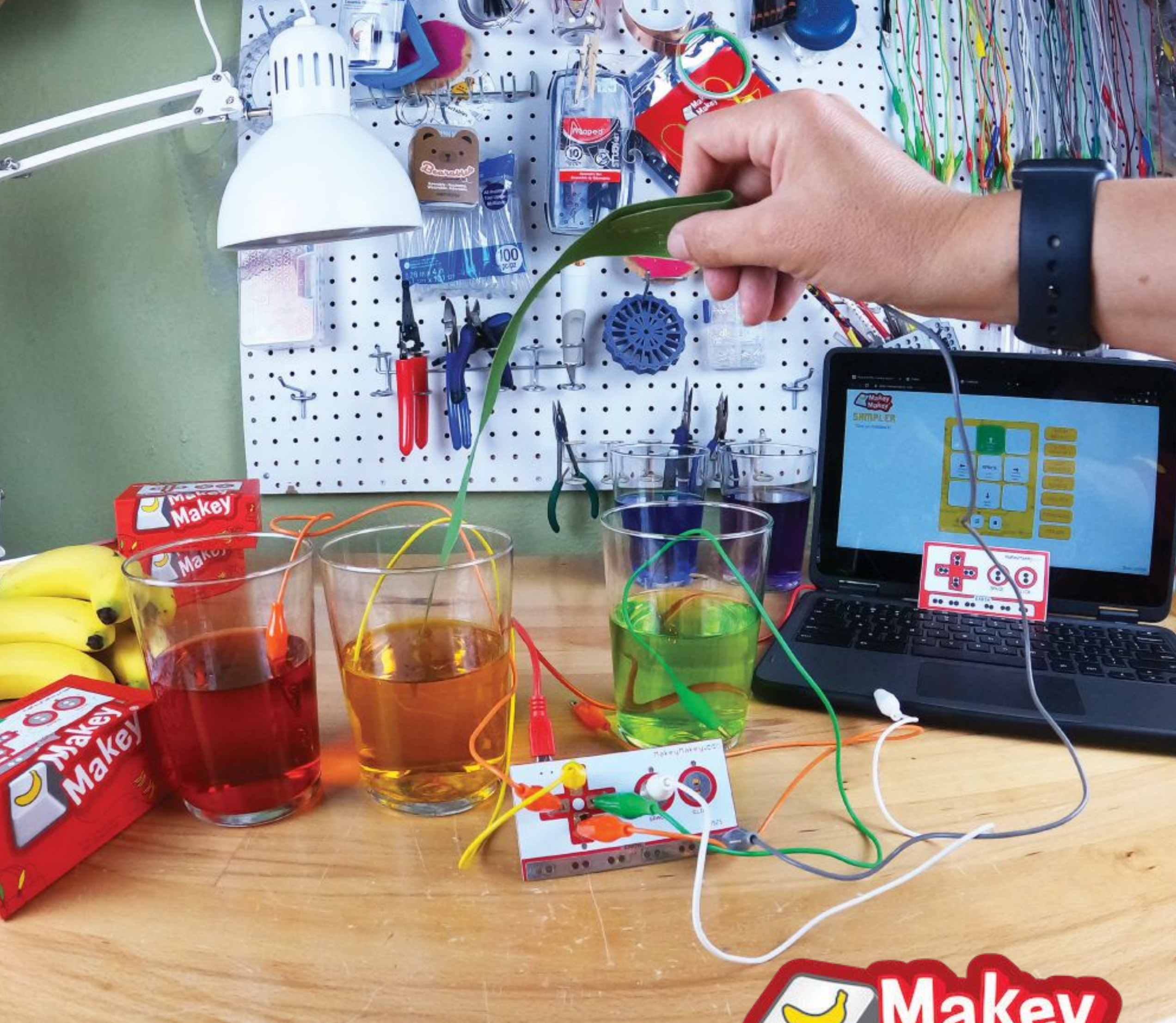
Tracy Norman

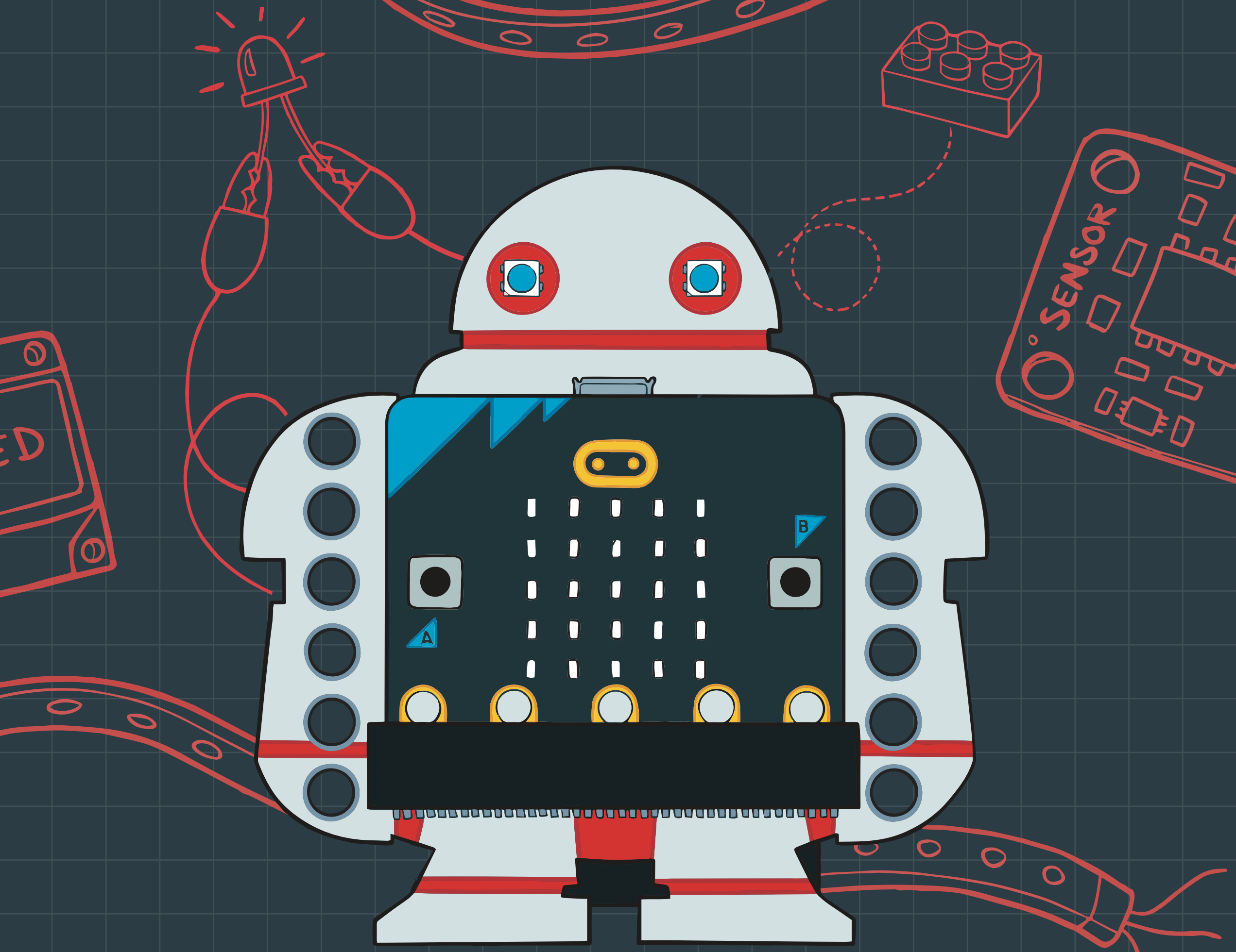
HUMPBACKS OF NOTRE DAME

It's rare to have fun with climate change but that's what Robert van de Walle and Team Pineapple accomplished with *Humpbacks of Notre Dame*, a human-powered vehicle that they entered in the 54th Annual Kinetic Grand Championship. They were recognized as 2022 Grand Champions by scoring highest in the combined categories of Art, Engineering, and Speed. This 50-mile race, with "have fun at all times" as its first rule, takes place over land, sand, and water in Arcata, California, on Memorial Day weekend.

What started as wordplay became, over three years, an amphibious pedal car weighing in at 500 pounds with all the art and gear onboard. *Humpbacks* has a whole backstory, told in an *Onion*-style newspaper named *New Planet News*, which was handed out by volunteers along the route. Dated 2069, this news from the future tells of the melting of Earth's last glacier, and how the Cathedral of Notre Dame, now underwater, is visited regularly by humpback whales named Quasimodo and Esmeralda.

Robert van de Walle wrote: "*Humpbacks of Notre Dame* is both a science fiction dystopia and an arrow pointing to a solution. We desperately need to stop burning fossil fuels traveling to work, school, and vacation. We model one way to adapt to a world when our energy use will be sustainable and shared equitably. We show the world, and our children, that the coming decades need not be feared. We work — and play! — towards a future where everyone gets to share in the glory." *—Dale Dougherty*

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