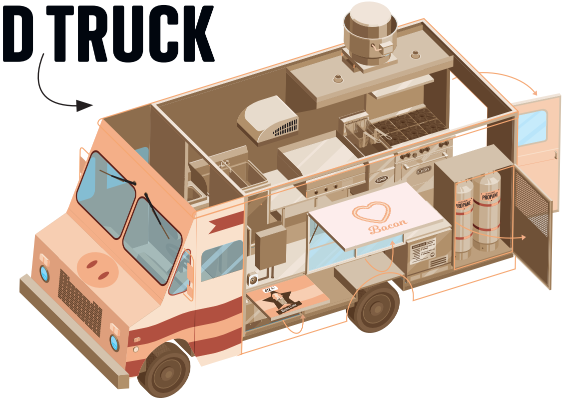
RASPBERRY PI **SKYCAM** // BUILD A **FOOD TRUCK**



Make:

ONE-DAY PIZZA OVEN BUILD!

HACK YOUR FOOD

\+ LIQUID NITROGEN FEAST

LASER-CUT SUSHI

COLD BREW COFFEE TOWER

CHEESEMAKING CHEMISTRY

PERIODIC TABLE OF SPICES

32 PROJECTS INCLUDING:

Arduino-Powered 3D LED GLOBE

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Vol. 53 October/November 2016

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Bernzomatic wants to feed your burning desire to make things that make a difference. That's why we host the Find Your Fire Community Grants program. Makers can submit community-minded project ideas to win up to $15,000 and have help from Nicole Curtis, self taught TV home rehabber, designer and author of ***Better Than New.***

Learn more at Bernzomatic.com/Grants

Entries judged by Nicole Curtis.

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BERNZOMATIC
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COMMUNITY GRANTS

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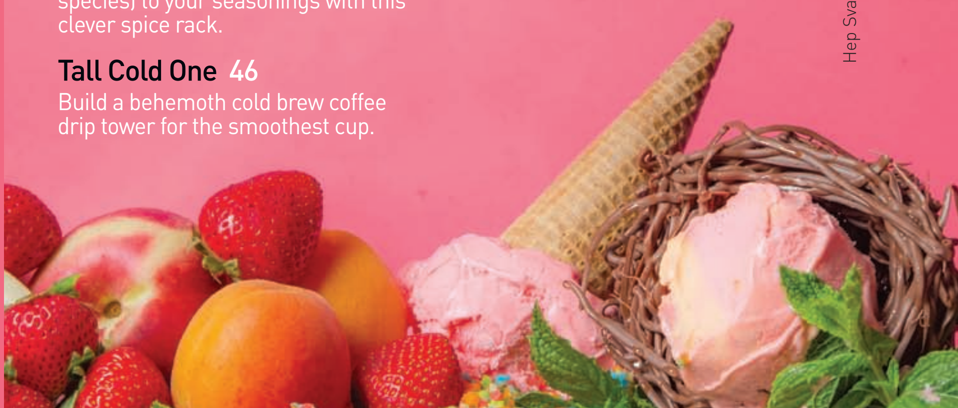

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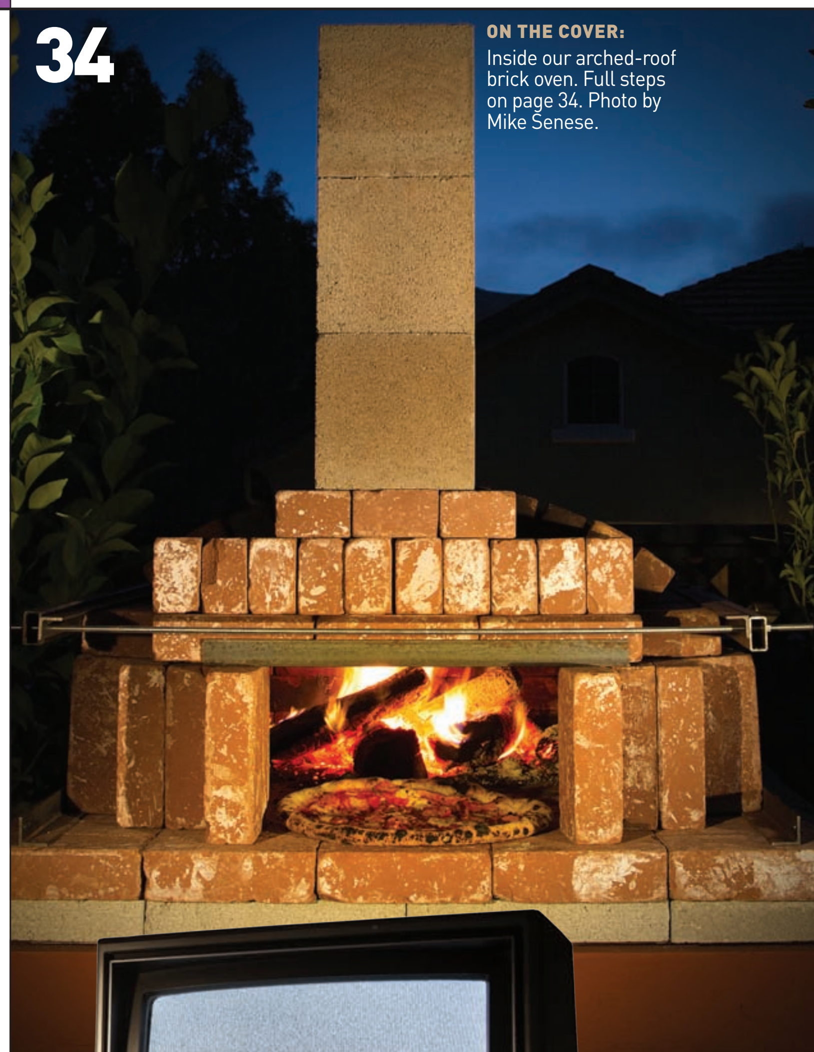

ON THE COVER:
Inside our arched-roof brick oven. Full steps on page 34. Photo by Mike Senese.

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Tools

You will need a computer with access to the internet. All the software and code needed can be downloaded for free from the Amazon Developer website **developer.amazon.com/ask**

Links

Everything you need to start your own app can be found on the Amazon Developer site **developer.amazon.com/make**

Skill Level

There is a fair amount of programming involved, but since we are using a supplied template, anyone with an intermediate level of programming experience should be able to complete this project in an hour.

Hep Svadja

HAVE YOU EVER WANTED TO TALK TO YOUR HOUSE? How about control your lights or one of your DIY electronics projects with your voice? Amazon Alexa can do just that, and if you have an intermediate knowledge of code, it's surprisingly easy to get started developing your own custom skills.

In this tutorial we will look at how you can develop your own voice-activated fact skill using the Alexa Skills Kit and supplied tools. It's a great place to start, only takes about an hour, and hosting on AWS Lambda is free for up to 1 million calls a month.

DID YOU KNOW? You can make your own Alexa-enabled device! Amazon has published code to easily connect a Raspberry Pi to their Alexa service: github.com/amzn/alexa-avs-raspberry-pi

1. CREATE AN ACCOUNT

Start by registering your Amazon developer account at developer.amazon.com.

2. GET THE CODE

Download the sample package at github.com/amzn/alexa-skills-kit-js. It includes a number of examples; we will be using the one called "SpaceGeek,"and then modifying it in the next part.

3. CREATE AN AMAZON WEB SERVICE ACCOUNT

Visit aws.amazon.com and create a free AWS account.

4. CREATE A NEW LAMBDA FUNCTION

In the AWS Console, create a new Lambda function making sure to set your location to US East — currently the only region that is free — in the upper right hand corner.

Click "Skip" on the Select Blueprint page.

On the Configure Triggers page, click on the empty box with the dotted lines and select "Alexa Skill Kit" followed by "Next."

Choose a name for your function, and select "NodeJS" as the runtime. Next, upload the code downloaded in step 1 by selecting the files "AlexaSkill.js" and "index.js" and creating a zip file.

Keep the Handler as "index.handler" and create a basic execution role. Now, copy the ARN from upper right of the screen. You'll need this when setting up your Alexa Skill.

TIPS & TRICKS You can edit the content of these two files in almost any text editor to create your own trivia facts. Just remember when uploading your code, be sure to compress only the two required individual files as a .zip, not the entire folder that contains those files.

5. CREATE A NEW ALEXA SKILL

Head back to developer.amazon.com, and click on Alexa, followed by "Create an Alexa skill now," then "Add a New Skill." Next, select "Custom Interaction Model," give your skill a name and an Invocation Name. Click "Next."

Enter the "Intent Schema" code which can be found in the "speechAssets" folder from the original GitHub link. Same goes for the "Sample Utterances." Click "Next."

On the Configuration page, select the Lambda ARN for the Endpoint and paste the ARN number you copied earlier from Lambda. Click "Next."

That's it! You can now test your new Skill on this page. Type in a phrase and you should get a Space-related response.

PROJECT: CUSTOM FACT SKILL

After you get the sample SpaceGeek code working on your Alexa-enabled device, it's really easy to go back and modify it with your own trivia content. Here's what I modified to create a Maker Faire Trivia Alexa skill.

1. ADD YOUR OWN FACTS

Using the same code as the SpaceGeek sample tutorial, download and edit the "index.js" file in your favorite text editor. Around line 30 you will see a line of code "var FACTS=". These are the responses to your voice requests. Go ahead and replace these facts with your own. Remember to use quotation marks, and to end each line with a comma.

2. CREATE A NEW LAMBDA FUNCTION

Compress the modified .index.js file and the AlexaSkill.js file as a zip and upload it to a new AWS Lambda function as described in the tutorial.

3. CREATE A NEW ALEXA SKILL

Create a new Alexa Skill using the Alexa Skill Kit. Follow the instructions as described in the tutorials, but in the Interaction Model setup page, change the Name of the Skill to your own. We used "Maker Faire Trivia." Next, select an Invocation Name, or the word that Alexa will use to identify the skill. We chose the Maker Faire mascot, Makey.

4. CHANGE SAMPLE UTTERANCES

On the Interaction Model page, you need to change the Sample Utterances to match what a typical user might say after the Invocation name. When thinking about how this works, in your head, not in the code, replace the "GetNewFactIntent" with the Intent word. For example: "Alexa, ask Makey for a Maker Faire fact"

That's it! You're ready to test out your custom fact skill on your Alexa-enabled device. Perfect for a party — have fun!

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"The only real stumbling block is fear of failure. In cooking you've got to have a what-the-hell attitude."
— Julia Child

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If you could design and make any kitchen implement, real or fantastic, what would it be?

Louella Hill
Staunton, Virginia (Funky Fromage)
I'm waiting for someone to design a home-scale cheese cave with temperature and humidity controls as well as proper oxygen flow. I'd be extra pleased if it could be integrated into home refrigerators.

Stephen Ritz
Bronx, New York (Hack Your Food)
We actually designed and made the product you described! The Green Bronx Machine Mobile Classroom Kitchen is a portable, lightweight, and USDA/NFS approved food truck on wheels!

Peter Strain
Belfast, Northern Ireland (Illustrator, Remaking History)
I'm not exactly the best in the kitchen so some sort of pan that intuitively knows when chicken or beef is becoming too well done/burnt before it's too late.

Ted Kinsman
Rochester, New York (Macro Magic)
My invention would be a combination passive and active stabilization system, like an upside down Segway, that would be able to deliver wedding cakes without messing them up.

Lisa Martin
San Francisco, CA (Frigid Feast)
I just want flat-pack versions of everything so they take up less space. Or pocket dimension cabinets.

On Safety and More

THE DANGERS OF PROPANE

There was a supreme irony as I came home from work today. I hadn't had time to read the latest *Make:* magazine, with "Play with Fire: a Propane Primer" (page 48) on the front cover, before going to work. My "day job" is as an EMT in a local city's 911 system. Last night, we had a fast-moving four-alarm fire that was caused by improper use of a propane grill.

So with all this fresh in my mind, I perused the article when I got home, and was dismayed by the almost dismissive attitude to the dangers inherent in fire — what warnings were there seemed added as an afterthought, and your designer did little to differentiate those warnings from the rest of the content on those pages.

Fire is unquestionably dangerous. It's never a plaything; indeed, it's a cruel master when things go awry.

Please do more to encourage safe making. *—C. Turner, via the web*

Author Tim Deagan Responds:

You have a point that we wouldn't ever want to skip over. I spent a number of years in a volunteer fire department and can completely corroborate the concerns that you express. I'm chagrined that you discern a dismissive tone towards safety since I desperately want to create an underlying commitment to safety in everything I do or write about as a maker.

I've gone back and re-read the three propane articles with an eye to the concerns you express, because your ultimate goal of protecting life and property is one that I want to hold above all others. I'm not able to immediately recognize the sections that you consider dismissive. It is, perhaps, the omission of additional warnings rather than the articles themselves. I'll think long and hard about what additional warnings could be included.

Shout-out to *Make:* readers Luke Pellegrini and Gonzo Ballesteros for correctly identifying our homage to Fritz Lang's iconic 1927 film *Metropolis* on issue 51's cover!

IN RESPONSE TO *MAKE:* VOLUME 52:

In assessing issues of *Make:*, I observe how many times I say things like:

- ARGH, I should have thought of that!
- THAT IS SO COOL!
- I'm so doing that.
- Hmmmm, I wonder if I should get one of those?
- I have to come back and read that later.

I said those things and more while flipping through Vol. 52. Many thanks for your efforts (and to the contributors).

—Robert Bass, via the web

I remember in 2001 or 2002 I went to a geography symposium in Toluca, Mexico, and Jean Parcher from the USGS gave a great presentation of the work they were doing with this new (for us) tech called lidar ("Laser Focus," page 16). It was so cool! I remember I thought "I wish one day it is accessible to any person. It just looks so distant in the future, now!" Awesome times to be alive, these are.

—Aristarco Palacios, via the web

Such a fantastic project ("1+2+3: Edible Paper," page 86). We're going to make a number of these incorporating edible flowers. Thanks!

—Laura Weldon, via the web

MORE EASY PROJECTS

I'm a major fan of your magazine, but I've noticed that most of the projects featured tend toward the electronics and programming end of the spectrum and often require CNC machines, laser cutters, and the like. Speaking as a maker who often can't afford to drop a hundred bucks on a new project, it would be great if there could be some examples of more skills within reach of the more cash-strapped or isolated makers.

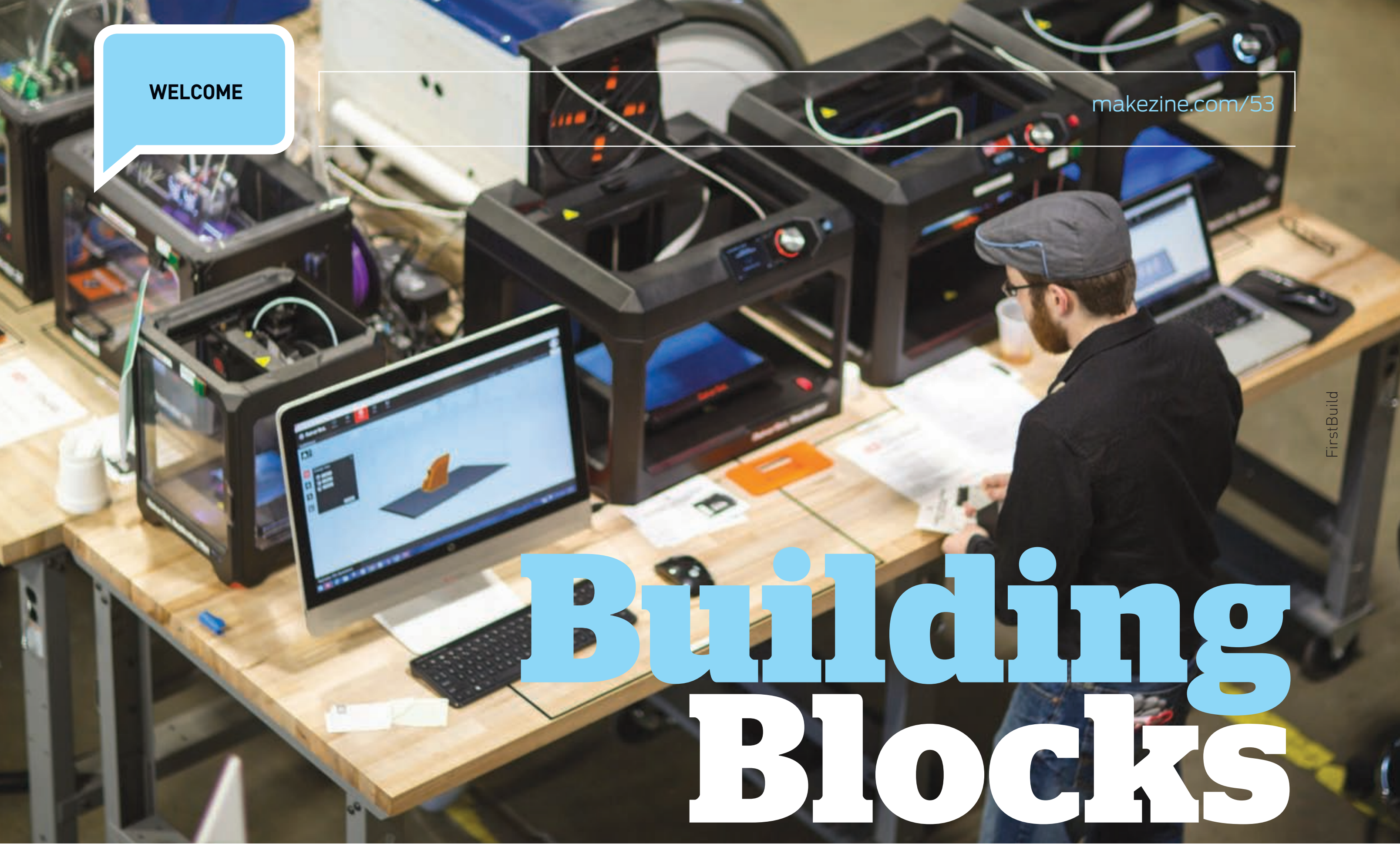
—Marcus Mann, Victoria, Australia

Editor Sophia Smith Responds:

Thanks for the thoughtful note, Marcus! Here at *Make:*, we celebrate all types of making, including craft, cooking, and homesteading. Technology, however, has always been a primary focus. Using new technologies to create plays a big part in how the maker movement is changing the world every day. But so does accessibility, and we will keep an eye on project cost and scope as we head into future issues.

Hep Svadja

Make: Asks What projects would you like to see in *Make:*? Let us know at editor@makezine.com


FirstBuild

Building Blocks

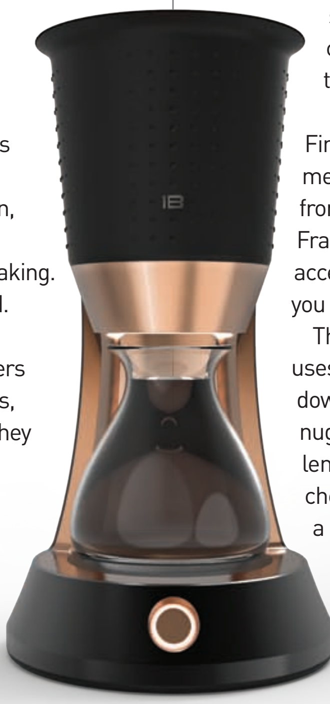
BY MIKE SENESE, executive editor of *Make:* magazine

FOR ALL OUR FASCINATION WITH NEW TOOLS AND TECHNOLOGIES, THE BASIC CATEGORY OF FOOD is by far the most widespread (yet maybe overlooked) maker pursuit. The tools in our kitchen are likely more used than those in our workshop, and nowadays are probably more advanced too. And, like building projects at makerspaces, food brings people together in magical ways.

We've covered food projects in past issues, from fast fermenting to beer brewing, so when we decided to do a full food-themed issue of *Make:*, ideas came quick. We aimed to highlight the kitchen projects and programs that had the same spirit of the maker community: innovation, experimentation, collaboration, and most of all, fun.

There are various groups that focus on food and making. One standout is Louisville, Kentucky-based FirstBuild. Launching two summers ago from General Electric's Appliance division, their initiative is to work with makers and enthusiasts to produce innovative kitchen gadgets, using new tools like hackathons and crowdfunding. They already have 9,663 community members registered on their site, according to Taylor Dawson, FirstBuild's Product Evangelist.

Early on, FirstBuild released the Green Bean Maker Module — a small interface board that lets users access some of the deepest programming elements of certain GE appliances. With it, someone can add the functionality to change their oven temperature via Raspberry Pi, or have their dryer tweet when finished with a load. FirstBuild uses the Bean in hackathons held in their community-accessible makerspace to help people make their appliance ideas come true. It's working; in just two years, "we've launched 16 or 17 new products, run three crowdfunding campaigns on Indiegogo, and accrued $3 million in crowdfunding alone," Dawson says. Their products span a variety of categories: countertop appliances, major appliances, and even totally new products like their in-home pizza oven.



Pizza oven settings are tricky, so for theirs, the FirstBuild team built a "digital pizza" sensor array to measure the cooking characteristics of iconic pizzerias from around the country, including Zero Zero in San Francisco and Paulie Gee's in Brooklyn. The oven now accesses this data, letting you dial in whatever pizza style you want to cook and get a facsimile of the real thing.

Their latest release is a cold-brew coffee maker that uses a vacuum system to cut the 24 hour cold brew wait down to 10 minutes. And their biggest success is their nugget ice maker, letting people make their own slushie lemonade anytime they want. The final products aren't cheap, but they push the envelope of what you can do in a kitchen, and leverage the might of makers to do so.

Coincidentally, we have pizza oven, slow-drip coffee, and specialty ice projects in this issue as well. We hope you test them out, improve on them, and share your results. Food is making. It's community. It's fun. It's magical.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Fleeting Thoughts GIJSVANBON.NL

A wheeled contraption pours aquarium sand onto the ground, scribing precise lines of poetry with a funnel that rolls back and forth across a gantry. It wheels forward dutifully as onlookers take care not to stomp out the pristine letters it leaves behind. Follow the words far enough backward, though, and they begins to smudge and scatter.

The Dutch say "*Wie schrijft, die blijft*," or, "those who write are those who stay." Dutch artist **Gijs van Bon** brings a temporal twist to the idiom with his Skryf Sandwriter robot — it's outlived everything it's ever written.

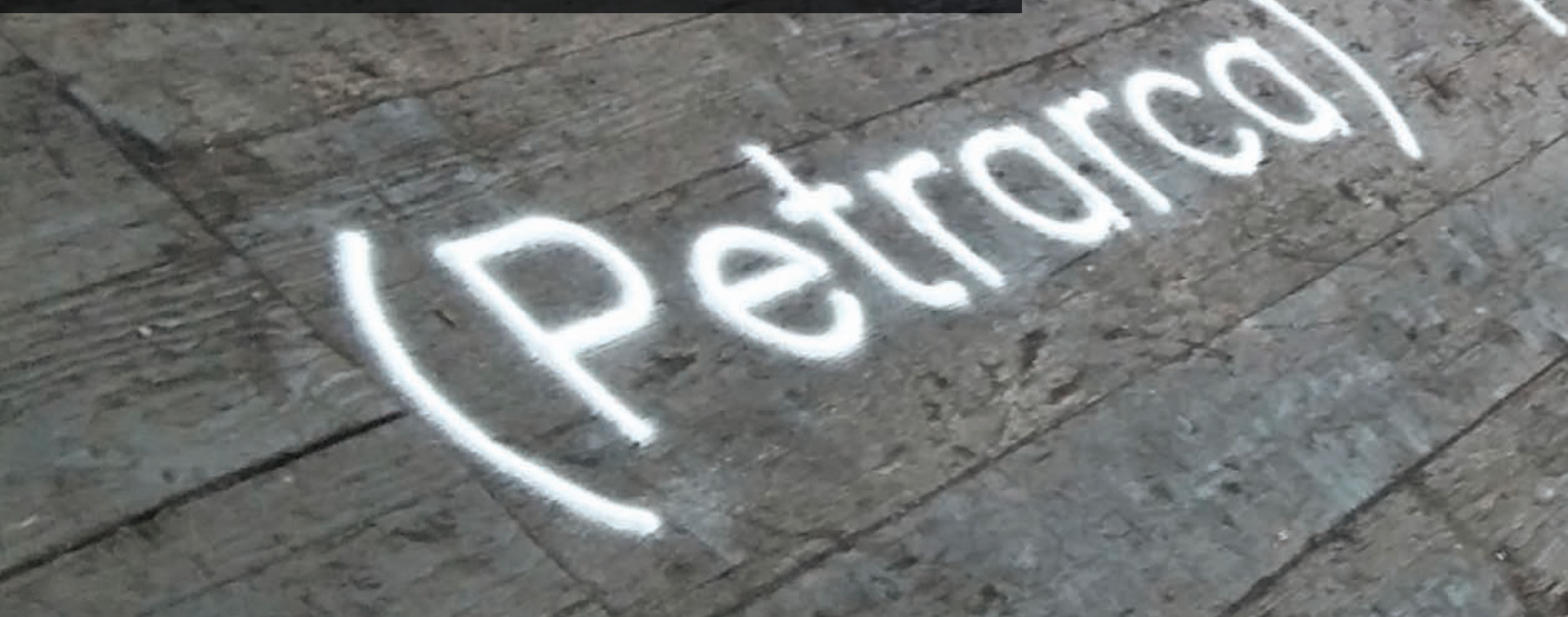
Van Bon uses a simple program that reads text letter by letter and feeds it to an industrial CNC controller, translating each letter into the plotter's movement. The x, y, and z axes that control the mechanics of the Skryf are based on a CNC milling machine. It's driven by stepper motors, which van Bon chose because they are "cheapest, easiest, and have the best torque."

Van Bon brought the first of his three Skryfs to Maker Faire Bay Area this year. One of its siblings has no gantry; instead it uses an arm that can rotate within a 2-meter diameter. The movements of the Skryfs are slow and methodical, but they have quite an appetite. Van Bon says he has to feed the robot roughly 25 kilograms (about 55 pounds) of sand over a four-hour period.

The Skryfs have written in over 10 languages, including Korean, Lithuanian, and Swedish, although van Bon says he's especially fond of Arabic. No matter what they're writing, van Bon says he hopes the Skryfs speak to people of the "transient, ephemeral nature of our being." Such things truly transcend language.

—Sophia Smith

Gijs van Bon



STRIKING SCULPTURES

RIVAMONTEROBOTS.COM

Miami-based sculptor and illustrator **Mike Rivamonte** has long been sketching ideas for robot sculptures. While roaming flea markets in New York City a few years ago, where he worked at a Broadway ad agency, an album of matchbook covers caught his eye and helped him bring his inspirations to life.

He built his first series of six robots, aptly titled "American Series," with a collection of United States matchbook covers dating from the 1920s to the 1950s. The colorful matchbooks — printed with ads depicting long-gone restaurants with 10¢ specials and orchestra-filled nightclubs — provided the iconic aesthetic he wanted for the bots. "Creating these sculptures is a wonderful experience for me and one of my greatest joys."

The robots stand about two feet tall and call for approximately 200 covers each. Rivamonte lays out the covers like a jigsaw puzzle to achieve the look he'd like for each sculpture. While it's time-consuming to sand the wooden pieces of the robots, apply the matchbook covers, and seal them with a UV protective varnish, the longest part of the process is simply the time it takes to collect the perfect assortment of pieces. "I like to find enough matchbook covers to create three to four robots at a time. That takes about a year or so of collecting," says Rivamonte.

—Krista Peryer

Mike Rivamonte

CLAIR DE LUNE

INCANDESCENTCLOUD.COM

As people spin the wheel below, the light above shifts. Inside this lunar globe of steel and 5,000 light bulbs (burnt and new alike) a mirrored LED plate rotates, casting both shadow and light. Depending on your perspective, *New Moon* by **Caitlind r. c. Brown** and **Wayne Garrett** looks as though it's waxing or waning.

"*New Moon* explores the whimsical and alluring nature of the moon, drawing on the familiarity of moonlight to all people," Brown said of the work. "By allowing viewers to see the moon at once in all phases of its cycle, the work emphasizes the personal relationship between each person and this celestial body, freeing the moon from time itself."

The installation, which took a month and a half to finish, builds off of their previous work creating illuminated clouds out of light bulbs. Local volunteers and welding students and teachers from the Bluegrass Community and Technical College assisted with the construction, and all the light bulbs were donated.

The nature of the work — which is both large and heavy, and nerve-wrackingly fragile — made it an especially challenging piece to finish. There were shattered bulbs, misaligned pieces, and the artists and their volunteers worked through the night to finish it before its opening reception.

— Lisa Martin

New Moon is currently between publicly viewable installations, but video of the artwork is available online at makezine.com/go/new-moon

Caitlind r. c. Brown and Wayne Garrett

PLAYING WITH PI CIRCUITBEARD.CO.UK

After building the ROMBUS3000, a Raspberry Pi-based mini arcade machine made out of a small Grandstand Scramble 80s-era desktop arcade game, **Matt "Circuitbeard" Brailsford** decided to take things one step further. For his second iteration, instead of starting out with an existing single-joystick design and modifying it to fit modern electronics, Brailsford designed the two-player ROMBUS-CT (short for "cocktail table") around the components he wanted to use.

At the heart of the design is a Raspberry Pi 3. An 8" TFT screen, 24mm buttons, and two joysticks provide user interface. Brailsford designed the build on Inkscape in order to fit his A3-sized (297mm×420mm) laser cutter, and after prototyping with plywood, cut it out of MDF. He then painted it with a roller for a smooth finish, and applied a beautiful wood-patterned vinyl from d-c-fix.

—Jeremy Cook

Matt Brailsford

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TRACES OF TECHNOLOGY

THEOKAMECKE.COM

Tucked away in the Catskill Mountains lies **Theo Kamecke**'s studio, home to an impressively well-stocked library of vintage circuit boards. Kamecke doesn't organize the boards by function or manufacturer, but with words like "serpentine" and "geometric" that convey their look and feel.

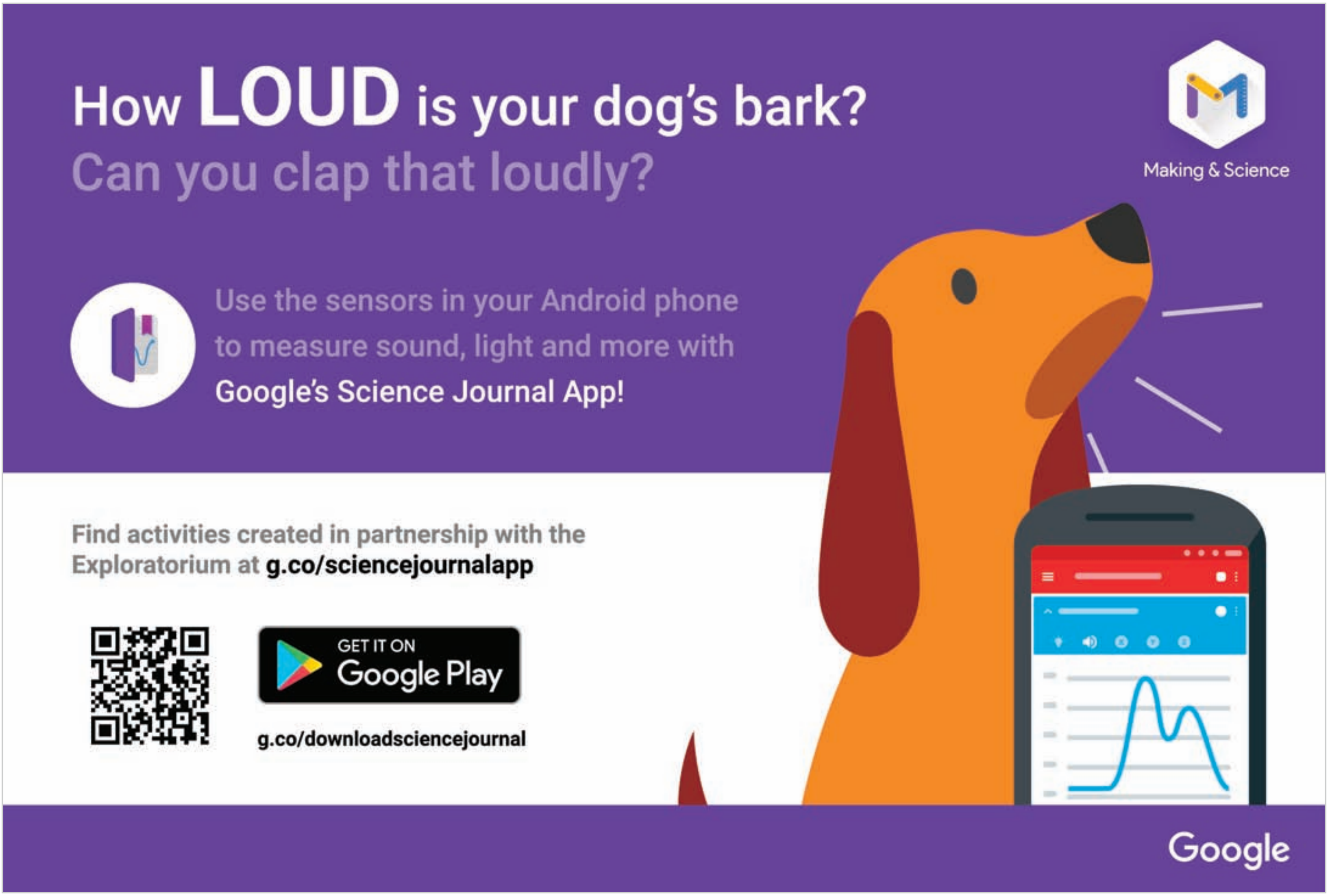
Decades ago, when miniaturization began to shrink the beautiful patterns to near invisibility, Kamecke realized these "fossils" of the electronic era would one day disappear. "I went to dozens and dozens of factories within hundreds of miles of [Manhattan] and talked them out of their obsolete or surplus boards," he explains. "They were very happy that someone was doing something creative with it."

To create contrast with the silvery lines of the circuitry, Kamecke dyes the boards so that the substrate appears like black stone. He lays them out in a design he likes, and then constructs hardwood frames onto which he overlays the dyed circuit boards. He makes the translucent pieces from acrylic sheets, illuminating them from within.

Kamecke upcycles scavenged boards — he does not make his own, because it goes "against the whole idea to be designing my own," he explains. "It would be like designing a leaf." Working within parameters like that can actually be very liberating for the creative process; "Limitations are very valuable," says Kamecke.

—Sophia Smith

Theo Kamecke


How LOUD is your dog's bark?
Can you clap that loudly?
Making & Science
Use the sensors in your Android phone to measure sound, light and more with Google's Science Journal App!
Find activities created in partnership with the Exploratorium at g.co/sciencejournalapp
GET IT ON Google Play
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More than a million ways to give your business a major competitive advantage!
Laser 1
CO2 10.6 µm
10 W 25 W 30 W 40 W 50 W 60 W 75 W 250 W
Laser 2
CO2 10.6 µm
10 W 25 W 30 W 40 W 50 W 60 W 75 W 250 W
9.3 µm
30 W 50 W
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Laser 2
Dual laser platforms offer the ability to use more than 100 laser power combinations, giving you unmatched system flexibility and capability.
Leverage our nearly 30 years of continuous innovation with market-first technology only available from Universal Laser Systems:
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SHOW & TELL

Dazzling projects from inventive makers like you

Sharing what you've built is half the joy of making. Send us your project photos and notes at makezine.com/contribute

1

1 Contained by a frame and illuminated by over 1,000 LEDs, **Bryan Sullivan**'s *Aurora Range* is a topographical landscape of electricity. Photo: Keith Brennan

2 Built by **Mike Fulkerson and San Dieguito High School students** to promote metal shop, the AR-Duo is a rolling telepresence bot with a pipe organ: makezine.com/go/AR-Duo. Photo: Austin Dilley

3 Curious folks can walk inside of and explore **James Peterson**'s *Dreamcatcher* installation, a textured cave with interactive lighting inspired by organic formations. Photo: Reid Godshaw

4 Gatobot, a 13-foot-tall wearable sculpture with LEDs, speakers, and a voice-changing module, was built by **Rhiannon Johnson and other Benicia High School students** to test the limits of recycled cardboard. Photo: Sheridan Lugo

5 **Carol Milne** knits strands of wax and uses a lost-wax casting process to create incredible glass sculpture. Photo: Carol Milne

6 **Jake Hudson of Hudson Forge Company** fuses reclaimed metal and wood into intricate sculptures like the fantastical post-apocalyptic *Regig Climber* seen here. Photo: Emily Fontaine Ho

7 **Katie Freeman**, maker of "creepy masks to sell to deviants on the internet," knit this eerily cozy *Alien* facehugger mask with aquarium tubing for structure. Photo: Jim Lafferty

8 **Børge Selbæk** constructed this engineering flowchart for his workshop. Not only is it a clever reminder of the golden rule of DIY, it provides storage for the two most important tools in your arsenal! Photo: Børge Selbæk

9 What's better than a board game? A life-sized one! **Emily McQueen and the "MakerSoul" Club** designed, laser cut, and finished this Monopoly board for Maker Faire Bay Area. Photo: Veronica Sam

10 **Brock Atchison** made some personal tweaks to Adafruit's Iron Man Arc Reactor tutorial for an appropriately illuminated Halloween costume. Photo: Brock Atchison

11 The artistic output of Spinbots, by **ArtBot Toys**, is much more than the sum of their laser cut parts! Photo: Adriel Olmos

12 With Steadcraft Jewelry, designer **Grant Diffendaffer** unites digital fabrication processes like 3D printing with traditional metalworking techniques. Photo: Grant Diffendaffer

13 **Arynne Elfenbein**'s Time Trinkets pack a punch of tiny gears and watch hands into custom handcrafted jewelry. Photo: Arynne Elfenbein

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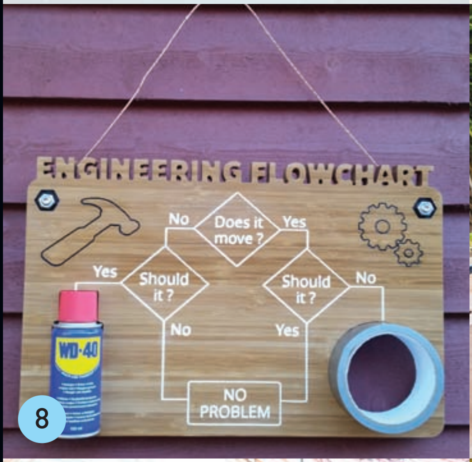

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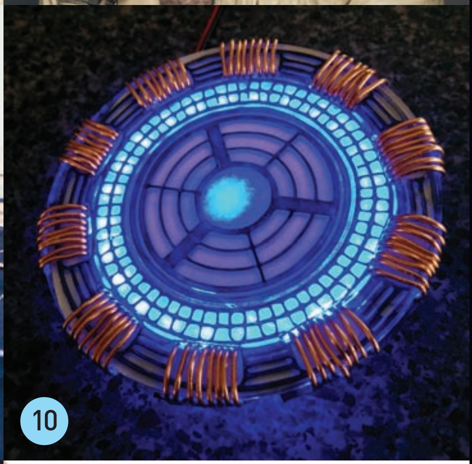
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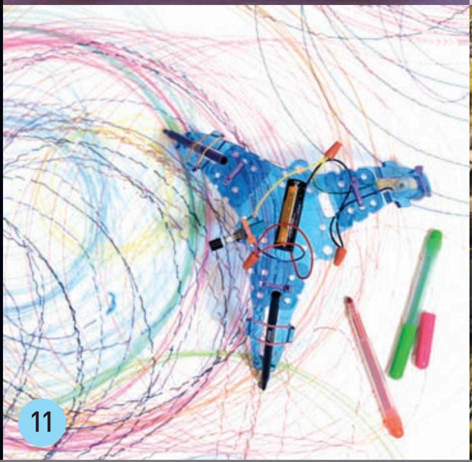
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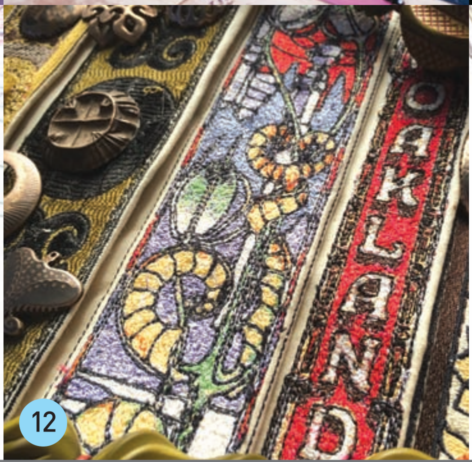

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13

These young Egyptian innovators are embracing technology and maker culture despite — or because of — political challenges

Written and photographed by Dale Dougherty

MAKERS IN THE ARAB WORLD

Crossing the street in Tahrir Square in Cairo is an adventure. There are no crosswalks or streetlights. You cross wherever you choose to do so, at your own risk. Drivers decide how best to avoid you without braking. That's what it is like to cross over to the Egyptian Museum where the treasures of King Tut's tomb are on display.

Tahrir Square was the epicenter of the Arab Spring uprising in 2011. It was a revolution that partially succeeded by toppling the government. Next to the rose-colored Egyptian Museum was once the burned-out headquarters of Hosni Mubarak's National Democratic Party, which last year stood out as a reminder of the revolution's fury, but which a year later had been completely demolished. Only sand and rubble remained in a fenced-off lot.

While Arab Spring did not bring about the kind of economic and political change that most people hoped for, those who participated in it felt that they had changed and their world was different. In the aftermath of Arab Spring, the maker movement has been on the rise, not just in Egypt but across the Arab world, particularly among young people who are exploring a newfound freedom to decide for themselves what the future holds. They are unhappy with their government, their education system and their economy but they are positive about what they can do themselves, even on a small scale. Even if their country appears broken, they are learning how to fix things. If the country does not offer them much opportunity, they are willing to create it. They are learning from each other and reaching out to share what they can do.

I visited Egypt in 2015 and 2016, both times for Maker Faire Cairo, held at the GrEEK Campus off Tahrir Square. I haven't met a group of makers more enthusiastic than those I met at these two events and my accompanying travels.

FAB LAB EGYPT

Dina El-Zanfaly witnessed Arab Spring from afar at MIT where she was getting her Ph.D. She grew up in Alexandria and was trained as an architect and practiced in Cairo before going to MIT, where she took Neil Gershenfeld's class, "How to Make Almost Anything." That class got her thinking about how to create a Fab Lab in Egypt. "For me, I realized that my life would have been totally different if I grew up with a Fab Lab in my city," she says. Her initial plans were interrupted by the events early in 2011. Then Neil forwarded her an email from Hisham Khodeir, a Cairo businessman who expressed interest in starting a Fab Lab. Dina met with him in the summer of 2011 and they got the ball rolling by reaching out to local makers they knew. "We had 3 more co-founders who donated money and effort to start," says Dina. "It was grass-roots funding." Hisham provided space for the lab in the same building as his business and Fab Lab Egypt opened in February 2012.

Hisham, like his wife, Nihla, has a computer science degree from the American University of Cairo. His company does localization of software and content into the Arabic language. Arab Spring of 2011 caused him "to want to leave the bubble I was in." He saw the problems more clearly, such as unemployment reinforced by a school system that does not develop students with valuable skills and abilities. He believed that the Fab Lab could teach skills and technology in a new way. Even more, he saw the need to inspire confidence and develop a sense of belonging.

Dina shared much of the same thinking. "The education system in Egypt lacks hands-on learning activities," she says. "Opening the lab in Cairo made me realize that learning the technical skills to use the machines and instruction-based approach aren't enough to make makers. This made me shift my Ph.D. research towards how people learn to make things, and what they learn from making, and the roles of computational tools, theories, and practices for understanding, describing, and enriching the making process and design learning."

Fab Lab Egypt is located in the Mohandessin district of Giza. (*Mohandessin* means "the engineers" in Arabic.) It is a modest space on the ground floor with beanbags, tool cabinets, and 3D printers. It serves as a social club at the crossroads of art, science, technology, and business. When a group of us stopped by on the Friday before Maker Faire, its worktables were occupied by makers finishing up projects for the event. I met a high school senior who loved making things at the space. He hoped to go to university in the United States but his grades weren't

good enough. He was frustrated that school didn't recognize any of the work he did at the Fab Lab. "They only care about testing," he says.

"We envisioned that someday we will have 'designed and made in Egypt' products," says Dina. "It's time to look at spreading and learning design and making as means for economic development." The lab has seen several startups develop. "The lab and the maker movement introduced a new approach of collaboration and diversity," she says. "Engineers now work with artists and medical doctors to create new projects, something we lacked in Egypt for so long. Instead of all the makers, hobbyists, and nerds working individually in their homes, they started to feel that they are part of a larger community of makers from different backgrounds.

"Our vision is to make and connect two million makers in the coming couple of years across Egypt," says Dina. Today, Fab Lab Egypt has expanded to the main headquarters in downtown Cairo and manages six more Fab Labs in six governorates.

With Hisham and Dina's leadership, the Fab Lab team helped organize both Cairo Maker Faires. The first year I met a young student who had a makeshift robot. I asked him what it did and he replied: "It's a bomb defusing unit." He explained that in his town there can be things in the street that one suspects could be a bomb but no police or military will come to inspect it. He built a cheap robot with a camera and claw that he could direct to do that task. The second year I met others with robots to detect mines in remote regions. The mines dated back to World War II; afterward I read a story in the local paper where several people had been killed by such a mine.

CHANGE OF CULTURE

Samar Hamdy attended Maker Faire Cairo for the first time this year. An engineer

Dina El-Zanfaly and Hisham Khodeir helped open Fab Lab Egypt in 2012.

Fab Lab Egypt serves as a social club at the crossroads of art, science, technology, and business.

Amr Saleh was the first to run a Kickstarter in Egypt. With a goal of $10,000, he raised $85,000.

who works in marketing at an engineering firm, Samar said that it was an opportunity for Egyptians "to prove that 'yes we can.'" She met entrepreneurs, students, kids, mothers, and "not only people from the engineering sector." What she liked was that Maker Faire encourages each person "to dream and reach for his/her goals."

"You can feel the excitement in the air," exclaimed Hoda Mustafa on Twitter during the Maker Faire. The excitement came from makers finding each other and getting connected. It's a young maker community that is forming here in Cairo and in the second year's visit, I had the feeling that the makers not only were participating, but they were able to articulate what coming together meant to them.

Sam Almahy was shooting video for Fab Lab Egypt at the event. I grabbed lunch with him, visiting a traditional *koshari* restaurant. Over our meal, he told me that what he found at Fab Lab and at Maker Faire was the support from others. "We don't have that in our culture," he says. He meant that the recognition and encouragement that makers received from each other was the most important thing. Just a pat on the back made a difference.

"What happens here will influence the rest of our world," Hisham told me, referring to the influential role that Egypt plays as a cultural center for the Arab world. Others from countries like Jordan, Lebanon, and Saudi Arabia were coming to learn about Fab Lab Egypt and Maker Faire, hoping to create versions in their communities.

NEW ENTREPRENEURIAL OPPORTUNITIES

During his final semester in an engineering program at Cairo University, Amr Saleh was down in Tahrir Square joining others, mostly young, in protesting. "I got a call from my supervisor at the university who said 'Dude, you need to get back to work,'" he tells me. The revolution impacted Amr in many ways but it wasn't the primary motivation for him to become an entrepreneur. He had already come to that conclusion on his own. "I wanted to do something different," he told me. He wasn't looking for a job; he wanted to make a product. With his university colleagues, he entered a competition for Egyptian Engineering Day and won a prize for a "smart breadboard." After graduation, he tried developing a commercial version but was unsuccessful.

Amr first learned about Arduino not in college, but by taking an Arduino workshop at Fab Lab Egypt with his CTO after working on their smart breadboard project. The course was taught by Omar El Safty, who was the lead organizer for the second Cairo Maker Faire and who must have been about 18 at the time. Amr's CTO developed their first Arduino project. "Its purpose was to prank me into thinking something was wrong" with the apartment they shared, Amr recalls. Their hands-on experience with Arduino led them to recognize the market need for a shield that connects to your smart phone, providing access to the onboard sensors. "We didn't think it made sense for people to have to buy a different shield for each project to add sensors and control to Arduino applications when those sensors already existed on your smartphone," he says. 1Sheeld was born.

Smart and friendly, Amr was the first to run a Kickstarter in Egypt. With a goal of $10,000, 1Sheeld raised $85,000. It was a big relief, as he would have had to close the business without the funds. About 50% of the backers were from the U.S. but there were people from 55 countries, including Egypt, Libya and Tunisia. Their first run of boards was 2,000 with 1,300 going out to backers. Soon, they had lined up 30 distributors.

He was surprised by who bought the product and began using it. "We thought we'd be selling it to students who were college age, but we saw much older users in our community," he says. One of them was using 1Sheeld to control a microscope with his cellphone.

Amr's intention is to keep building products that serve makers. "It's an amazing audience to serve, and there's a real market there," he added. Now, the company is profitable, though still small. They just launched a new product for home automation.

"The entrepreneurship community in Egypt is very supportive," says Amr who has started organizing Hardware Startup Meetups in Cairo. Yet there are real challenges on many levels. "Ordering wireless components and getting them through customs is difficult," he says. You can build drones but you can't fly them. Some of the challenges are even more serious. Two of his interns were riding a bus back home when they were stopped by police, who looked them over and found an Arduino, breadboard and wires. The interns were taken to jail and detained for 45 days. "This is what's wrong," says Amr. "It's not just that the police made a mistake in detaining them, but it took them 45 days to deal with it. I could understand if they were held overnight but 45 days! We couldn't find out anything about them for 45 days."


May El-Dardiry works as a teacher at Maadi STEM School for Girls.

12th-grader Nourhan A. Fooda shares her prototype sign language-translation glove.

Nonetheless, Amr reflects the optimism of this new generation of makers. He thought that the revolution had changed people so that "they were now more comfortable and confident expressing themselves" and he noted it at Maker Faire. "The most valuable thing really is understanding that you are not alone," says Amr. "I had so many people say that to me. You see everyone making connections. It's a place for nerds, crafters, jewelry makers," he adds.

TEACHING TECHNOLOGY

May El-Dardiry is the technical operations lead at Fab Lab New Cairo and works as a teacher at Maadi STEM School for Girls. "We are more of a community where we encourage each other to learn," she says, adding that she wanted them to think independently. There are 300 girls in the school and about ⅓ of them are in the lab. She said that the motto is "Eat. Study. Laugh." "I treat them like my sisters, my friends," says May. "I want it to be safe for them to make mistakes and learn. Some of them feel so afraid that if they make a mistake, they will fail." In talking with May, I thought how many intangibles are involved in learning, and in particular, for becoming a maker.

Nourhan A. Fooda, a 12th-grader and one of the Maadi STEM students, demonstrated her project "An Interpretive Hand for the Voiceless" at the second Maker Faire. It was a prototype of a glove that was able to detect a wearer using sign language and translate it into text messages or even text-to-speech. The prototype used Arduino and had lots of wires hanging off a rather large black glove.

Two of the most dedicated makers I met at Maker Faire Cairo were Mena Effat and Rabab Hassan, co-founders of the Karakeeb Makerspace in Alexandria. (*Karakeeb* means "junk" in Egyptian Arabic.) Mena and Rabab brought kits and demonstrations such as a Jacob's Ladder that they use in their programs with kids. They also brought two young "interns" to work their exhibit: brothers, Omar and Ali, ages 11 and 13. The day after Maker Faire, they had exams and needed time to study for them. They were worried about coming to the event, but they came anyway. It proved to be a full day and they didn't get back home to Alexandria until 1 am. Their understanding mother let them stay home from school the next day. She went to the school herself and said that the boys were not taking their exams. Mena tells me: "She said to them: 'They learned a lot that day. More than they learn in school. We are more than happy to present you with anything that shows you what they learned.'"

I visited Mena and Rabab at the Karakeeb Makerspace at the Jesuit Cultural Center in Alexandria. It's a tiny space off a library — a single central table, a cabinet and shelf with supplies, and unexpectedly, a large laser cutter. It is typically open for several hours in the evening. Mena and Rabab, who both studied engineering at Alexandria University and have technical jobs, come by after work. "We do it for fun," says Mena who is 31 and married with a young daughter. Rabab is in her late twenties. Together, they self-funded the space, which opened in 2013. They offer community workshops for local children and their parents. The first workshop was Aviation 101 — simple gliders. They like to see families come and start a project at the space and then take it home to finish. Recently, they worked with the U.N. and began offering workshops for Syrian refugees in three different places. Mena said that they offered children a chance to play. "They need that more than anything else," he says. "They are naturally creative kids." They began training Syrians and even the kids began organizing workshops for other children.

Mena told me a story of how they acquired their large laser cutter. One day, a man came to visit the makerspace and they told him about what they do. The man was about to be married and he told the guests that in lieu of presents, he asked for donations to buy a laser cutter. "We only saw him once," says Mena. "I didn't believe it when he said it, but several months later, a laser cutter showed up."

I visited Alex Hackerspace, founded by Amr El Shair with the help of a number of makers. The space was unfinished with bare light bulbs hanging from the ceiling and building materials set on the ground. We sat around in a circle and each of the makers told me about the projects that they were working on. Ibrahim Abdelkader is the founder of the OpenMV project. He ran the second Kickstarter in Egypt raising over $100,000. "My goal is to make machine vision more accessible for makers," says Ibrahim. He had just finished a thermal imaging shield. Ibrahim talked about the challenges any maker faces in ordering parts and then finding out after testing that some are defective. He said it was necessary for a project to allow for a "screwup margin." Another group presented a universal remote control device that they said used AI to understand signals from any infrared device. Mohamed Shalaby, the maker of the Atom Open Source 3D printer, gave me a demo and said he was focusing on getting 3D printers in schools.

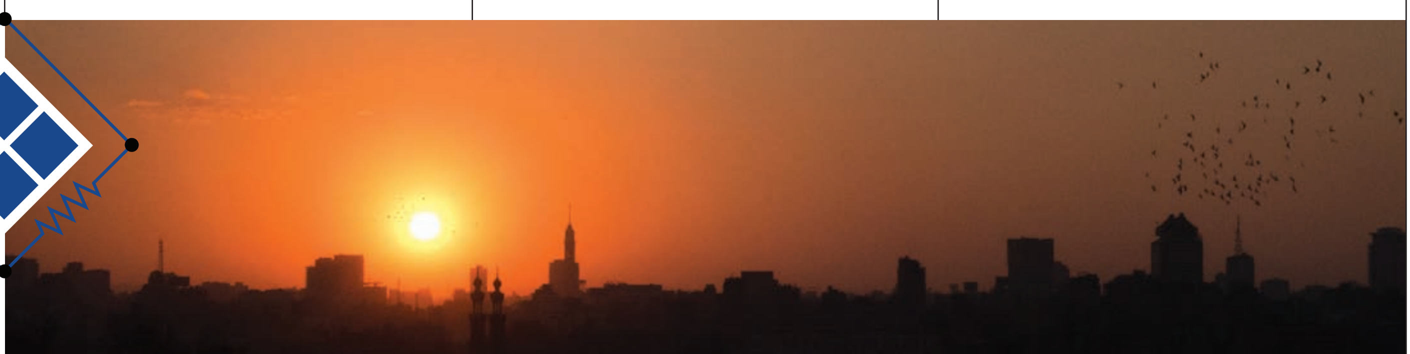
Rabab Hassan and Mena Effat self-funded Karakeeb Makerspace.

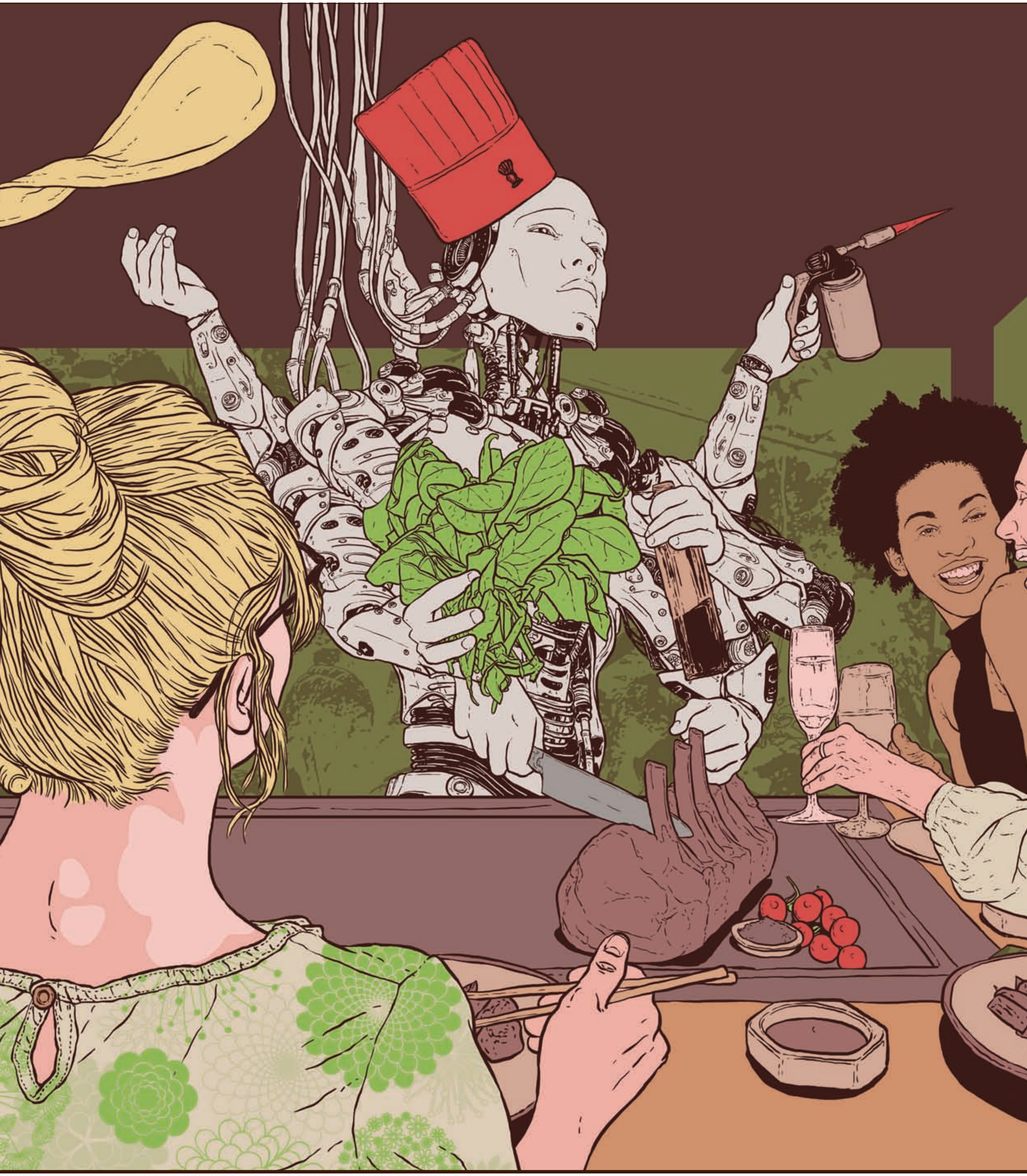

Brothers Omar and Ali helped out at the Karakeeb exhibit.

Amr dreams of changing education through Alex Hackerspace. He said that the labs in schools date back to the 1960s. He bought the space himself for about $40,000 and his local maker community is helping him build it out. He wants to change people's mindset, ignite their passion, and support them in pursuing a path to their own freedom and independence. He thinks they can do it by starting their own companies. "Everyone here believes in what we are doing," he says. "Not just me."

MAKING PROGRESS

On the day after this year's Maker Faire Cairo, there was a gathering for makers at Al-Azhar Park, with its beautiful public gardens set near the Mohammed Ali mosque. All of us who came as visitors to Cairo were transfixed by the sun setting over the busy city, as we could not only see the skyline but also the pyramids in Giza in the distance. Flocks of pigeons swooped overhead. After sunset, we turned our backs to the city to sit at tables for dinner, but then the air swelled with the amplified sounds of the call for prayer, rising from many different sources but combining in one voice that just filled me with wonder and delight. I didn't understand the words but I understood what they meant. Here was Cairo, a city of near-constant commotion, a multicultural city that blends Arab, Turkish, and western influences, a proud cultural center of the Muslim world, finding its own time of peace and its own expression of hope. Here was where the nascent maker community was coming together, enjoying each other and believing in the progress they are making together.


Meet more makers from my visits to Egypt: makezine.com/go/first-maker-faire-in-egypt and makezine.com/go/young-makers-on-rise-in-egypt



HACK YOUR FOOD

FIRST THE KITCHEN, THEN THE WORLD

Written by Stephen Ritz • Illustrated by Jan Feindt

NOTHING BRINGS PEOPLE TOGETHER LIKE A GOOD MEAL. But to eat without cooking is to consume without making — hacking your food is as maker-y as any craft.

Imagine a society where we grow and prepare our own food daily. Imagine a portable, affordable farm-on-wheels, accompanied by a plug-and-play commercial kitchen that can roll from one school classroom to the next at lunchtime. This is what we do every day at Green Bronx Machine, which operates in the poorest congressional district in the country. We're taking urban food production and distribution to a whole new level — growing food indoors 365 days a year, in the heart of the NYC housing projects in a 100-year-old building. And through maker innovation, we are growing community.

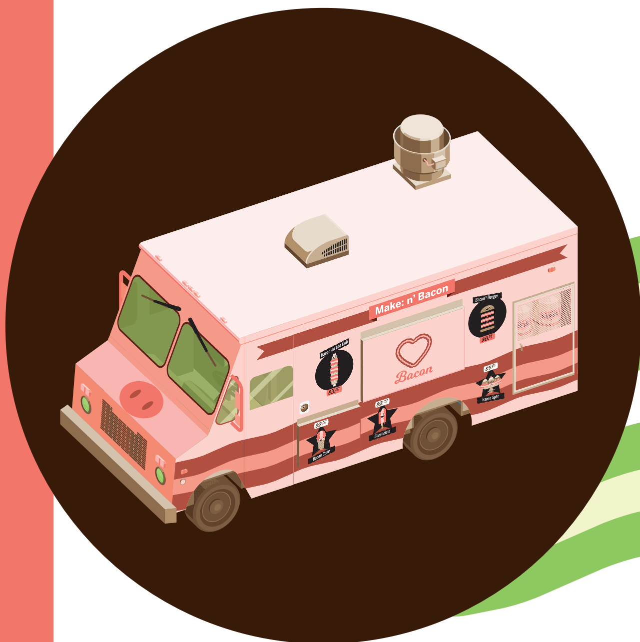
Even after harvesting 40,000 pounds of vegetables, our favorite crops are the organically grown citizens, graduates, members of the middle class, and kids who are growing and eating their way to spectacular school performance, all while using 90% less water and space. Healthy, nutritious food is a basic human right — our goal is to make it accessible for every community in the world.

What we're most excited about are the changes Green Bronx Machine is affecting in our daily lives and in a community with limited means and access. Not just food access, but also increased academic engagement, improved health, and the celebration of art and science we've come to associate with sitting around the table every day for delicious, healthy meals.

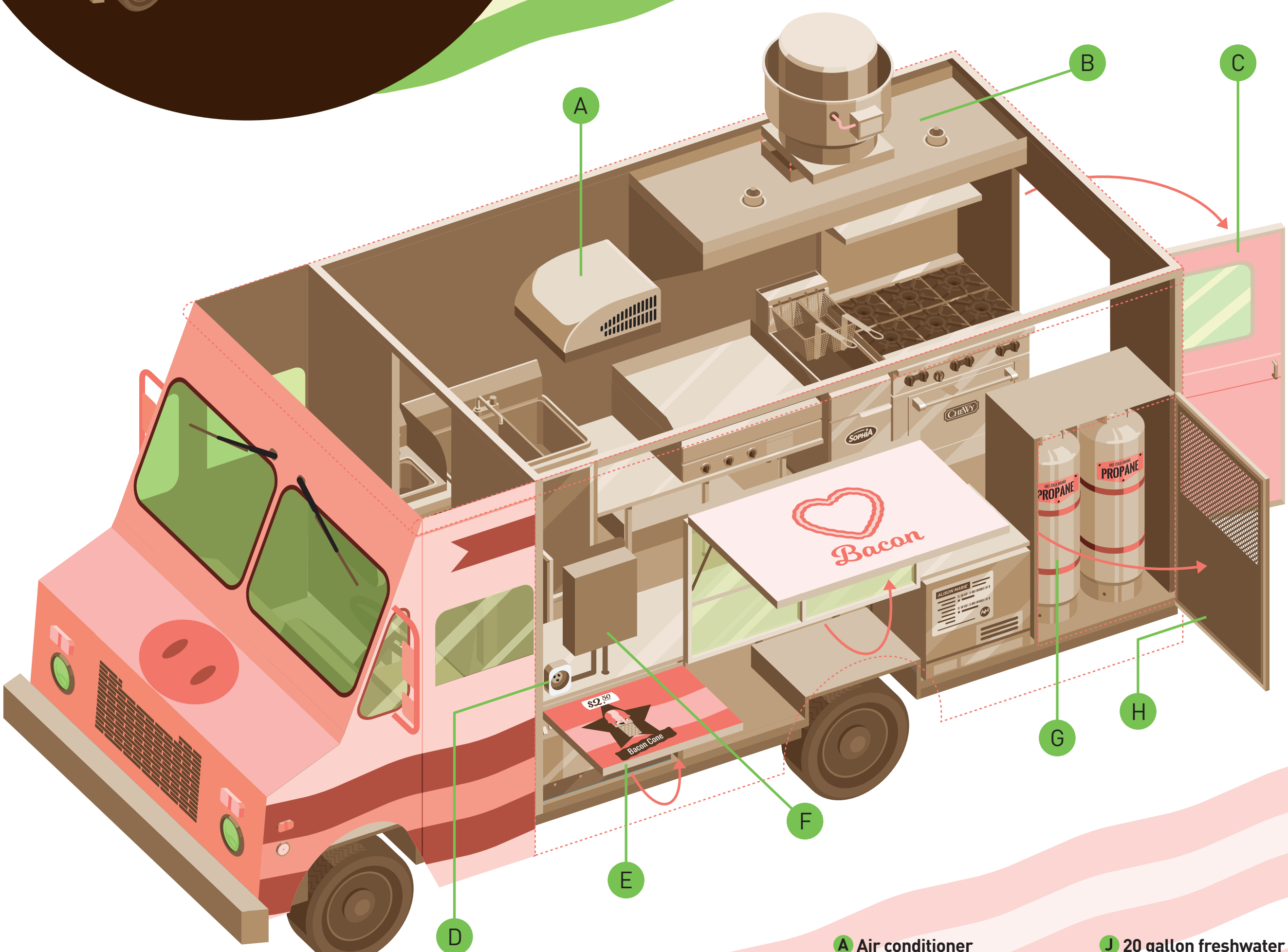
As populations grow and resources become sparser, the edible frontier — from farming and transportation to preparation and storage — presents the ultimate opportunity for makers to engineer solutions that benefit the whole world. Throw in the growing obesity epidemic and other global food- and nutrition-related crises, and you'll start to realize that it's imperative that we start innovating to help a world in challenged times — one farm, rooftop, basement, or backyard at a time.

The notion of a nonnegotiable item — food — aligned with something we all love to do — eat — somehow being made available and accessible in the least likely of places is indeed spectacular. This is evidence of what makers can do: Create a world of equity, opportunity, and abundance.

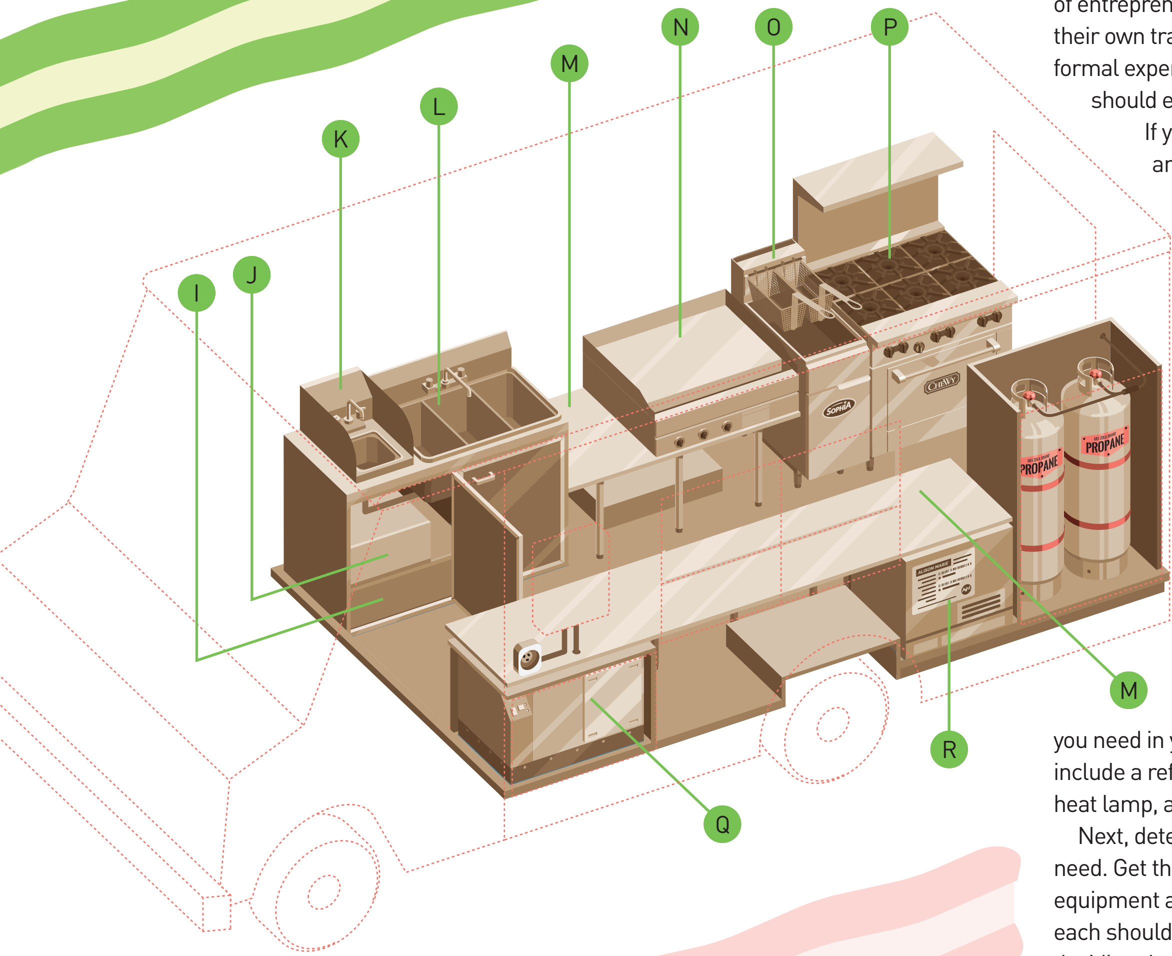
To get involved with the Green Bronx Machine, visit their site: greenbronxmachine.org



Written by Brett Lindenberg ■ Illustrated by Rob Nance



- **A** Air conditioner
- **B** Fume hood
- **C** Rear door
- **D** External power hookup
- **E** Generator cover panel
- **F** Circuit breaker
- **G** 100 lb propane tank
- **H** Propane housing door
- **I** 30 gallon wastewater tank
- **J** 20 gallon freshwater tank
- **K** Hand washing sink
- **L** 3 basin sink
- **M** Counter space
- **N** 36" gas griddle
- **O** 40 lb gas fryer
- **P** 6 burner gas range
- **Q** 6200 watt generator
- **R** Mini fridge



MEALS ON WHEELS

A SIMPLE HOW-TO GUIDE FOR BUILDING YOUR OWN FOOD TRUCK

SO YOU WANT TO GO THE DIY ROUTE AND BUILD A FOOD TRUCK ALL BY YOURSELF? The good news is there are many examples of entrepreneurs who have successfully built their own trailers and trucks without any formal experience. The bad news is that you should expect hiccups along the way.

If you have mechanical experience, an engineering background, and are really good at solving problems you can certainly pull this off. Plus, if you put the vehicle together yourself, you'll have in-depth knowledge on how to fix anything that might arise.

1. LAYOUT AND EQUIPMENT

Determine the type of food truck you want, along with the equipment needed to serve the food. A coffee truck will have very different space and equipment requirements than a burger bus. Write down everything you need in your future truck. This could include a refrigerator, deep fryer, freezer, heat lamp, and storage space.

Next, determine how much space you need. Get the specifics of each piece of equipment and design a layout of where each should be placed. Take your time when deciding the layout — building a food truck that's designed for efficiency is critical for maximizing profit.

2. FIND A VEHICLE

Be sure to conduct an inspection of the vehicle you're considering, and find out as much information as possible about its history prior to purchase. If you're buying directly from a business, you can be more certain of how the truck has been cared for in the past. If you buy from a dealer, it's more difficult to determine how the vehicle has been treated.

BRETT LINDENBERG is the founder of foodtruckempire.com, an online resource for starting a mobile food business that features hundreds of articles and podcast interviews with the world's most successful food truck entrepreneurs.

3. MARK THE LAYOUT

Clear out the interior of the truck, minus the driver's seat and steering wheel, until you get a big empty box.

Mark where the serving window will be within the truck. Use a Sharpie to outline where all the equipment will be placed. Identify the location of any outlets and fixtures, and determine the locations of the wall that separates the kitchen from the driver, the propane tank, and the generator.

4. SET UP THE ELECTRICAL WIRING

Wiring your truck correctly is extremely important because if the power goes out in your vehicle, you won't be able to serve customers. And it can be very difficult to determine what's wrong with electrical wiring after a vehicle is fully built.

Get an experienced electrician to help you with this if you don't know what you're doing. The electrician will run wire to all circuits and to the back panel. Electrical boxes may also need to be installed.

5. REINFORCING THE INTERIOR

Due to its light weight and durability, aluminum square tubing is recommended for framing the outside walls, around the serving window, the generator, the hood, areas of the A/C, and the divider wall.

6. CUT OPENINGS FOR WINDOWS AND A/C

Cut the side panel for the serving window. A typical opening is 4×3 feet. You'll also want to cut a space for the A/C unit on the roof.

7. FINISH THE INSIDE WALLS

The wall behind your cooking line must be made from nonflammable materials per most fire code requirements. That means wood should not be used in any area.

Insulate the walls using styrofoam panels (or nonflammable rockwool behind your cooking line), then install interior paneling on the walls and ceiling. Most food truckers recommend 100% stainless steel sheets for the walls. You also want to install non-skid flooring at this time.

8. GAS / PROPANE TANK

Check your local safety/fire regulations to ensure you're setting up everything correctly. Although it's very common to install propane tanks on the rear of a food truck, there are many cities that don't allow this. Ask your fire department for help positioning the gas tanks on your vehicle.

Next, install a gas manifold for your equipment, connect the manifold to the propane tank, and install the regulator. You will likely need to fabricate and install the tank rack to hold all this gear.

The Whole Cart operates a custom fleet of 25 food trucks that serve Bay Area corporate campuses.

The interior of the Rue du Falafel truck features rotating vertical spits for cooking shawarma.

A PowerTech 50kW generator serves up to 200 amps on the Red Triangle Coffee + Provisions truck.

9. SET UP THE INTERIOR HOOD

Interior exhaust hoods help to ventilate your vehicle. Before installing, check your local laws to confirm everything is up to code.

10. PRE-EQUIPMENT LOAD

Install the concession window and door, A/C unit, any general equipment tables, and cabinets and countertops.

11. COMPLETE ELECTRICAL WORK

Add light fixtures, outlets, switches, panels, and connect them to the breakers. Again, if you don't know how to do this, call a professional who has experience wiring food trucks or mobile homes.

12. LOAD COOKING EQUIPMENT

Load up the rest of the equipment: the refrigerator, kitchen sink, cash register, and other tools required to deliver memorable food moments to your future customers. If it goes onto the truck, install it now.

13. PLUMBING

At this point the plumber can connect the sinks to the fresh water tank, install a dump valve, and conduct other work that is required by your local ordinances. Hiring an experienced food-truck plumber is recommended. Anticipate actual costs to be 2–3 times the initial estimate.

14. SET UP THE GENERATOR

Confirm your generator is securely and firmly positioned. You'll need to connect the generator to the main panel and transfer switch. Also, make sure the generator is installed in a well-ventilated area of the vehicle. These things get hot!

15. FINISHING TOUCHES

Inspect the plumbing, gas connections, and electrical work, and test the generator.

Finally, you'll need to find someone to make and apply the truck wrap on the outside of the vehicle. This is not something you want to do yourself since the first thing customers will see is the outside of your vehicle. Make sure you look like a pro.

THE FINAL WORD

There will be some unique troubleshooting issues you'll need to figure out when building a food truck. Each is a little bit different and has particular equipment needs.

You shouldn't hesitate to reach out to experts along the way. You might even be surprised that any friends who are plumbers, electricians, or mechanics will be happy to help you out with this interesting project. Food trucks are fun! Fellow food truck owners can also be an incredible resource. They understand the local laws and may have built their own truck as well. Good luck!

More instruction and video guidance to help your food-truck dreams come true online: makezine.com/go/making-food-truck

Hep Svadja

Make: GUIDES

maker's guide to boards

makezine.com

guides updated monthly

CULINARY CONTRAPTIONS

QUELL YOUR HUNGER WITH THESE OVERSIZED AND AUTOMATED FOOD MACHINES

Written by Lisa Martin

You may have some go-to techniques for whipping up a meal, but have you considered adding some maker innovation to your routine? For inspiration, check out these over the top food-centric inventions.

1: GE, 2: Bistrobot, 3: Naveen Thomas, 4: FarmBot

1. BBQ Smoker … for Science

GE brought a 12-foot-tall smoker — built by our friends at Sheet Metal Alchemist in Oakland, California — to their Science of Barbecue Experience at SXSW 2015. While a local pitmaster took care of the meat, GE tricked out the inside of the smoker with sensors. Thermocouplers at the top, middle, and bottom of the stack report the temperature of the smoker, while two more monitor the meat itself. Humidity and velocity sensors in the smoke stack help measure the smoke's characteristics.

So what do you do with such refined sensors? Experiments! The pitmaster and pit chemist were able to precisely maintain variables to research which techniques made the best brisket.

2. Bistrobot, Make Me a Sandwich

This sandwich-making robot takes large-scale, conveyor belt-style food processing and tailors it for made-to-order lunches. After you customize your request, the machine sends your bread down a conveyor belt to get squirted with toppings, toasted, and neatly closed within a little box. Currently there's only one Bistrobot in the wild (at Andi's Market in San Francisco). It's worth a few bucks just to see the machine work its magic, though you'd be hard pressed to convince us to eat a sandwich with "the works," which currently would be a messy peanut butter with blackberry and strawberry jams, apple butter, Nutella, cinnamon, and chai powder.

3. Breakfast Goes BOOM

Cereal became the most ubiquitous breakfast staple of the American diet thanks to the puffing gun. Grains are loaded into the chamber of these cannon-like pressure cookers and rotated over heat until the pressure reaches 100psi, at which point the lid is literally hammered open and everything inside explodes outward.

Like popcorn, the pressure is too high to allow the boiling moisture inside the grains to escape until the gun is opened and the moisture releases all at once, puffing the grain. The Museum of Food and Drink in New York recently had a 3,200lb puffing gun built and mounted on a trailer for an exhibition on cereal. It is, after all, an important piece of culinary history. Plus, the big boom it makes sure can draw a crowd.

4. Green Thumbs Need Not Apply

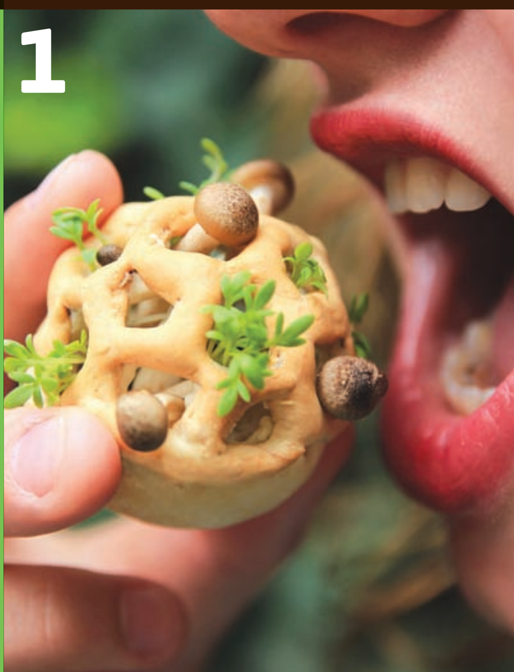
While lots of innovation happens in the kitchen, there's opportunity for growth in garden technology, too. One of the coolest backyard setups we've seen is FarmBot's Genesis, an app-controlled, planter-mounted x, y, and z plotter that can plant seeds and water them. It even has self-changing tool heads for checking the soil's moisture level and detecting and removing unwanted weeds. Reminiscent of desktop CNC machines familiar to many makers, the creators hope their open source system will facilitate iterative designs from the community.

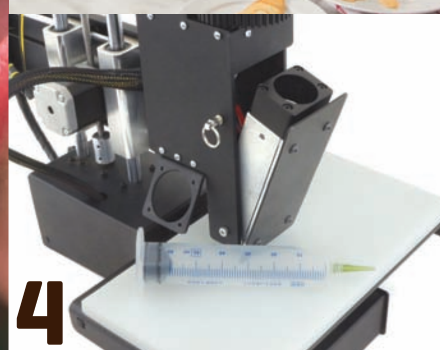
Written by Chandi Campbell

CUTTING-EDGE CUISINE

3D PRINTING ISN'T JUST FOR PLASTIC ANYMORE

These days it's tough to find an industry that *isn't* experimenting with 3D printing, and the food industry is no different. Printing customized meals certainly sounds entertaining, but other applications are pushing these bots beyond the simple novelty of robot chefs and into a whole new, well ... kitchen.





1: Chloé Rutzerveld, 2: PancakeBot, 3: BeeHex, 4: Dave Hays, 5: Katharina Jäger

1. Edible Growth

Just as petroleum-based plastics may soon be replaced with more sophisticated bio-plastics, 3D-printed food may evolve from direct extrusion to a more advanced process. The award-winning Edible Growth project by Chloé Rutzerveld demonstrates this with an edible geometric structure which houses a growth process for one or more organisms. This concept is not unlike 3D-printed bio-scaffolds for growing different types of organs. These "edible ecosystems" are printed whole and then allowed to grow.

2. Fabricated Flapjacks

The PancakeBot is a dedicated machine that allows you to design and print your pancakes. With their open source CAD software PancakePainter, you can import an image or draw your own. You can make pancake portraits of your friends! They probably won't think that's weird at all. Whether you love breakfast for breakfast, breakfast for dinner, or breakfast that looks like Chewbacca, you might have a lot of fun with this $300 machine.

3. Printable Pizza

Do you like pizza? How about pizza ... in space!? In the interest of their astronauts' nutritional and psychological wellbeing, NASA has researched food printing for long-term space voyages. Thus, the BeeHex printer was developed in 2013 thanks to NASA's SBIR (Small Business Innovation Research) grant. According to BeeHex's Founding CMO Jordan French, the company now focuses on printing Earth-pizza. They plan to hit the market in 2017 with pizza printing kiosks in stadiums, theme parks, and various retailers. The BeeHex features three nozzles (for three ingredients) and a pneumatic delivery system.

4. Plug and Play (with Your Food)

If you already own an FDM-style printer, you can swap out your plastic extruder/hot end assembly for a paste extruder. Printrbot sells a $330 mechanical extruder, designed for the Printrbot Simple.

While they warn that "installation is not trivial," due to disassembly, rewiring, and loading new firmware onto your Printrboard, the payoff is pretty sweet — you can print materials like chocolate or icing at a steady temperature thanks to the heated syringe.

5. More Accessible Than Ever Before

The PERFORMANCE project (Personalized Food using Rapid Manufacturing for the Nutrition of Elderly Consumers), funded by the European Commission, is an effort to help patients who suffer from dysphagia (difficulty swallowing or chewing) by providing fully customized meals.

Typically, sufferers of dysphagia are restricted to a liquefied food diet of unappetizing purees, but various printing methods, including FDM, SLS, and PBP, are being explored to create specially textured solid foods that look and taste like traditional meals.

Written by Mike Senese **Time Required:** A Weekend • **Cost:** $450–$600

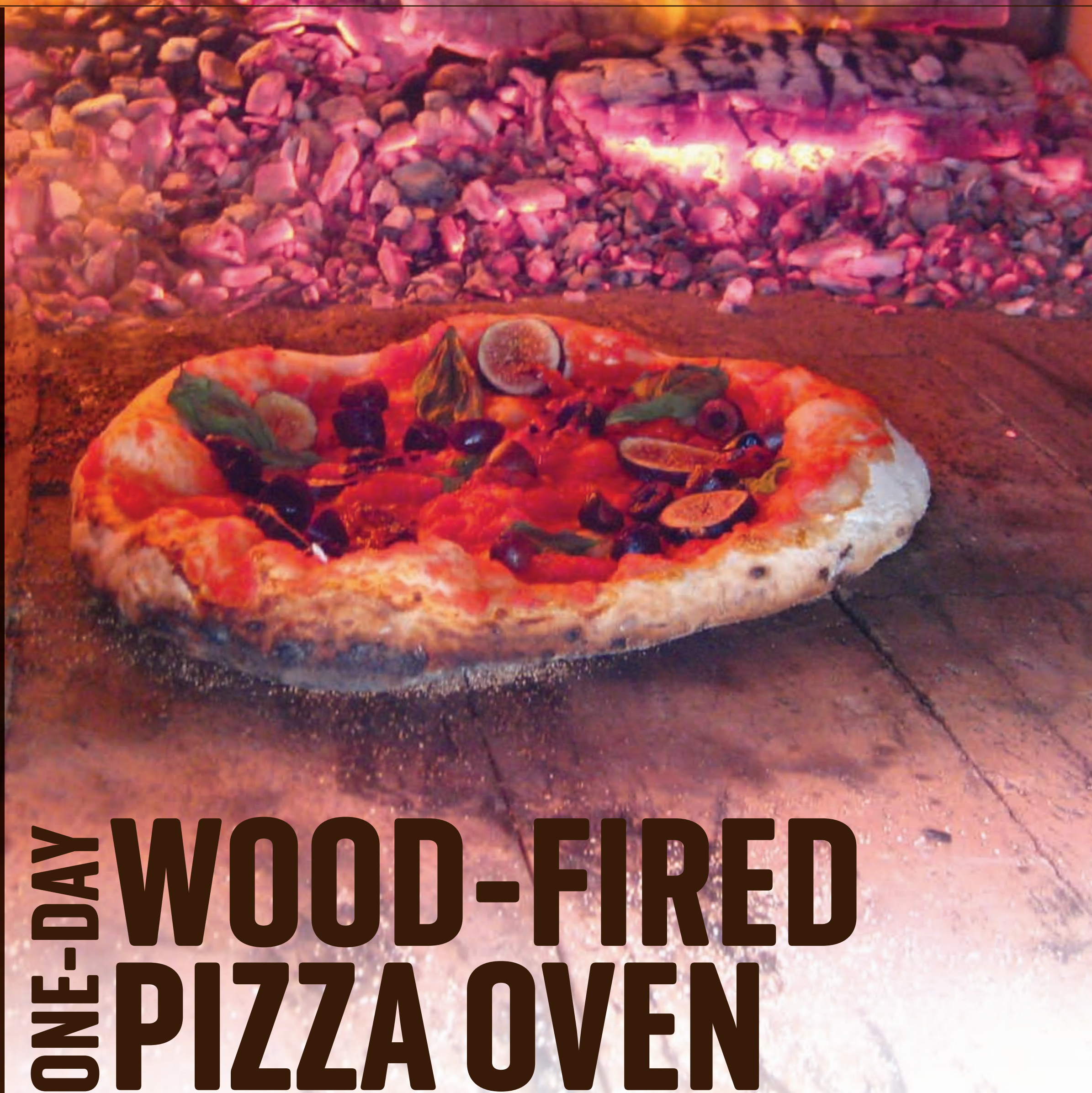
MATERIALS

- **Sturdy metal workbench** or make a platform from stacked cinder blocks and plywood
- **Pavers, 12" square (16)**
- **Firebricks, 9"×4"×2½" (190)** These are the biggest cost, so call your local masonry supply places for prices: $1.50–$2 per brick is reasonable.
- **Angle iron, 2" wide, 48" lengths (4)** for walls
- **Angle iron, 2" wide, 24" lengths (2)** for chimney
- **Threaded rod, ¼" diameter, 48" lengths (4) with nuts (8)**
- **Plywood, ½"–1" thick, about 34"×6" (2)** for arch jig
- **Lumber, 2×4, 14" lengths (2)** for arch jig
- **Plywood, ¼" thick, 4"×4" (2)** for arch-jig risers
- **Flue liner, clay, 8½"×8½"×24"**
- **Refractory clay, 50lb bag**
- **Sand, 10lb bag**
- **Water**

TOOLS

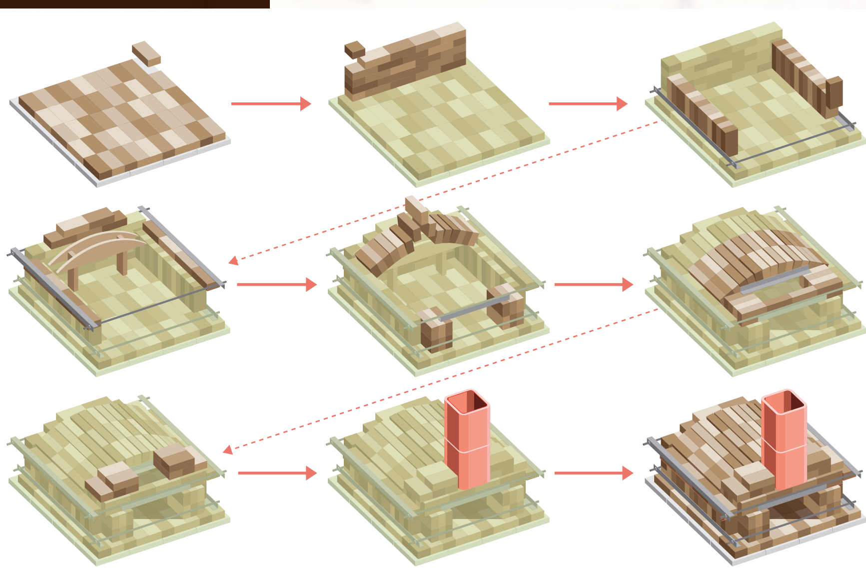
- **Drill and ⅜" bit**
- **Hammer and nails**
- **Chisel**
- **Circular saw with masonry bit (optional)**
- **Tape measure**
- **Jigsaw**

MIKE SENESE is the executive editor of *Make:* magazine. He spends his spare time tinkering with remote control aircraft and attempting to cook the perfect pizza. Find him on Twitter as @msenese.



ONE-DAY WOOD-FIRED PIZZA OVEN

SIMPLY STACK BRICKS TO MAKE THIS TEMPORARY, ARCHED-ROOF *FORNO A LEGNA*



Mike Senese, Rob Nance

FOR THE PIZZA AFICIONADO, A WOOD-FIRED BRICK OVEN IS THE PINNACLE. Nothing else cooks a pie the same way, with the 800°F–1,000°F temperatures needed to get that thin, crisp layer of smoky char covering a moist, airy crust. Unfortunately, these types of ovens are usually large, expensive, and complicated to build, leaving most of us to keep making dry, boring pizzas baked for 15 long minutes in our kitchen oven set at a disappointing 375°F.

Here's a brick oven design that overcomes those hang-ups. It's as simple as stacking blocks, and with a couple of helping hands, you can put this together, cook amazing pizzas, and tear it apart in an afternoon. Brick sizes vary, so modify the layout as

needed. I first built one during a weekend course led by Michael O'Malley at Machine Project in Los Angeles, and have since helped inspire others to make their own.

1. PICK A LOCATION

The weight of the bricks is considerable, so make sure you start with a strong workbench on a firm, level surface. We used a metal welding table — look for used ones on Craigslist — but you can also create a sturdy 4' by 4' platform of cinder block topped with 2 half-sheets of ¾" plywood.

2. LAY THE PAVERS AND FIREBRICK FLOOR

Make a 4' by 4' insulating base with the cement pavers on top of your platform. Centered on top of that, make a surface of firebrick, laid flat, roughly 10 bricks wide and 5 bricks deep. Keep the bricks tight together — this is the floor of the oven.

CAUTION: Don't use standard red bricks, as they may shatter explosively when heated to high temperatures. Use Firebrick.

3. STACK THE WALLS

Begin with the back wall, 4½ bricks wide by 5 bricks tall, laid flat. You'll need to split some bricks in half; do so by scoring a line and hitting with a chisel and hammer, or use a masonry blade on a circular saw. Save the chips. Offset each layer by half a brick, so the seams sit in the middle of the bricks below. Center 5 more on top, in two levels.

To build the sides, first drill two ⅜" holes in each 48" angle iron, 1" from both ends, in one leg of the angle. Lay 2 angle irons front-to-back on the platform, facing inward so that bricks can sit in the inside corner. Slot threaded rods through the drilled holes and tighten a nut onto each end.

Build the side walls by standing 13 bricks on end inside each angle iron, starting from the back wall. If already mixed, run a line of clay mix (Step 6) on the inside bottom edges. Cap each side with 3 bricks laid flat, then place the remaining 48" angle irons on top, facing down. Add threaded rods and nuts.

4. MAKE THE ARCH

To make the roof, build an arch-shaped jig of plywood screwed to two 2×4 legs. The arch length should be just shorter than the distance between the side walls — mine is about 32¼". The height should be about 5¼" tall, with a radius of about 27". Cut 2 matching pieces with a jigsaw, then affix to the 2×4s so that the legs extend about 9¼" below the plywood — you want this jig to stand a bit taller than your first row of standing bricks (Figure A).

To assemble the arch, place the jig against the back wall, on top of the ¼" risers. Stand the bricks on edge, pointing forward (Figure B). Keep an even space between the bricks by filling the gaps with brick shards. Remove the jig by sliding out the risers, then shimmying the legs forward to tip it backward. Repeat 2 more times to get an arched ceiling 3 bricks deep.

5. BUILD THE ENTRANCE AND CHIMNEY

On each side of the front of the oven, stack 2 layers of 3 bricks on edge, running front to back. These will frame the oven's mouth. Bridge the top with a 24" angle iron facing up and in. Place 3½ bricks across the front of it, on edge. Add 4 more on either side extending back to the arch.

Place the last 24" angle iron against the arch to bridge the gap, facing up and out. Center the clay flue insert over the gap, with its edges resting on the bricks and the angle iron (Figure C). Cap any gaps with bricks.

6. COVER IN CLAY

Smoke and heat will escape this oven unless you seal it. Mix the refractory clay with water and sand and generously coat all outside brick seams and gaps — go heavy on the arch. It won't be pretty, but you won't mind when your belly is full of amazing wood-fired pizza. Your oven is now ready to be fired up — no curing needed (Figure D).

To disassemble, let the oven cool down at least a couple hours before dismantling. Then spray the clay off the top and sides with a hose, and simply unstack the bricks. Store in a convenient spot, or pack into a trailer for mobile deployment. Or replace the refractory clay with a hardening mortar and make this a permanent fixture in your yard. *Buon appetito!*

Learn how to light your oven and get started making incredible 1,000°F pizzas with it: makezine.com/go/one-day-pizza-oven

A

B

C

D

MORE PIZZA OVEN HACKS

900° HOME OVEN HACK

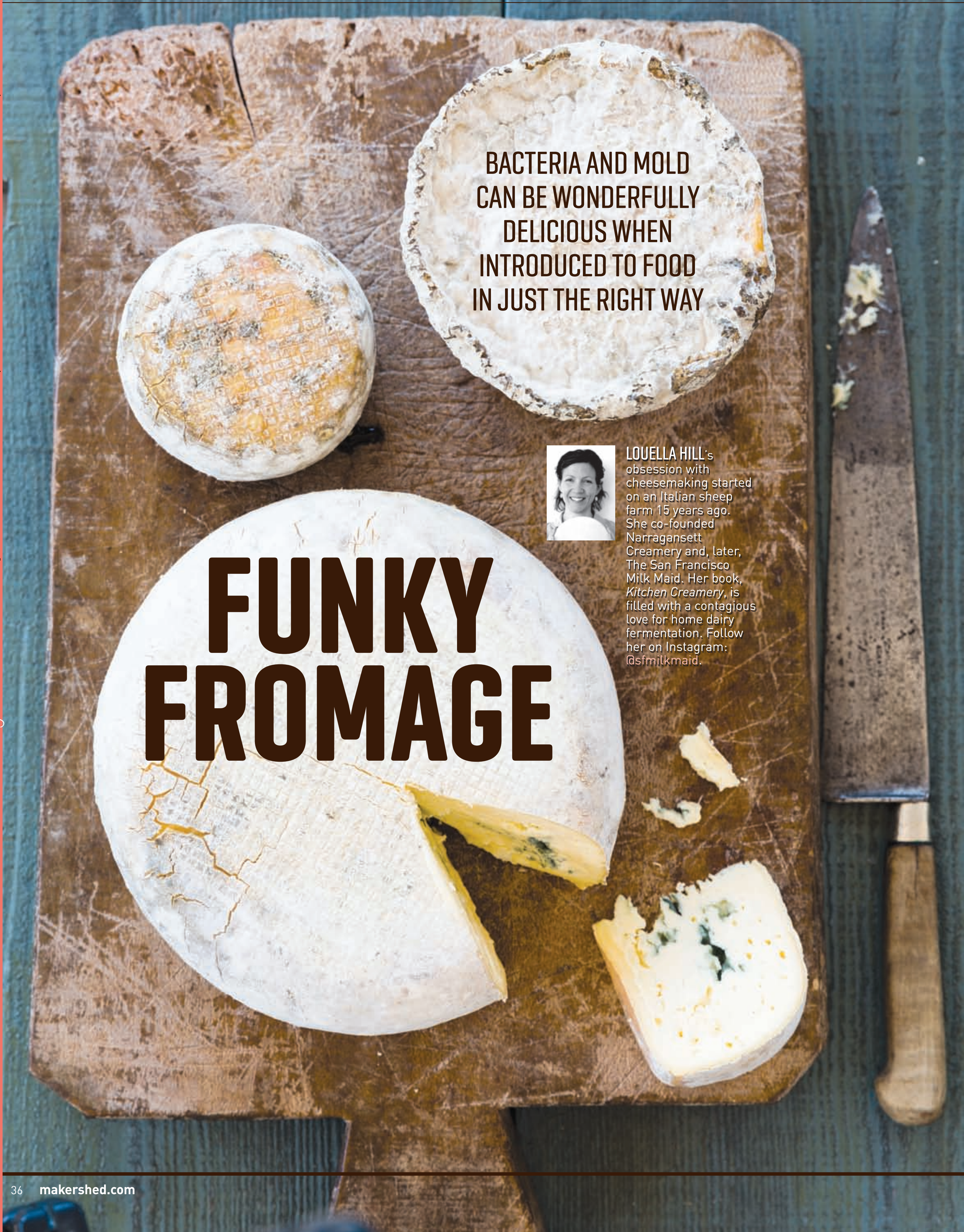
Brave pizzaiolos are cutting the metal latch that locks their ovens during self-cleaning, and timing their pizzas to the heating cycle. Jeff Varasano explains: varasanos.com/pizzarecipe.htm

LITTLE BLACK EGG

Meld a small Weber grill to an oversized turkey fryer burner, with baffles to direct the flame and heat over the top of the pizza. pizzamaking.com/forum/index.php?topic=4753.0

UUNI

This wood-fired steel box is ripe for modification. Users have added bellows and even bicycle mounts. I'm aiming for an internal rotisserie on mine. uuni.net



Written by Louella Hill **Time Required:** Cultures: 1 Hour // Mold Spores: 1 Week • **Cost:** Cultures: $5–$20 // Mold Spores: $10–$20

FUNKY FROMAGE

BACTERIA AND MOLD CAN BE WONDERFULLY DELICIOUS WHEN INTRODUCED TO FOOD IN JUST THE RIGHT WAY

LOUELLA HILL's obsession with cheesemaking started on an Italian sheep farm 15 years ago. She co-founded Narragansett Creamery and, later, The San Francisco Milk Maid. Her book, *Kitchen Creamery*, is filled with a contagious love for home dairy fermentation. Follow her on Instagram: @sfmilkmaid.

WHILE SOME PEOPLE THINK CHEESEMAKING IS COMPLICATED, and requires loads of specialized equipment, those of us already making cheese know it takes little more than good milk and a large pot. Unlike commercial mechanized processes, home cheesemaking can happen with just a few repurposed household objects and a basic understanding of biology. The tricks below will be especially useful if you've already dabbled in simpler cheese styles such as ricotta or yogurt and are ready to move on to more complex, aged ones.

ADDING CULTURES

Cheese cultures come in two basic categories. *Primary cultures* are bacteria that digest the lactose in milk, lowering the pH and helping to turn the milk into curds and whey. Store-bought cultured buttermilk is teeming with a mix of primary cultures.

Secondary cultures are the microorganisms such as bacteria, yeasts, and molds which do the "second leg" of a cheese's journey, taking it from being a simple, fresh food to something complex, aged, and specific. Often they play an important role in forming the rind (which, in my opinion, is the best part).

A common way to incorporate secondary cultures is to add freeze-dried cultures to the milk early in the process. But this entails buying a pricey packet of cultures. Luckily, there are alternatives for sending your rind in a tasty direction:

FROM A FRIEND

Select a vibrant, fresh-looking, robustly rinded cheese from your favorite store. This trick works particularly well for red-rinded cheeses (think Morbier). Be sure that the cheese you buy is high quality to avoid dealing with radiated cheese cultures, various unwanted preservatives, or expired microbes. Bring it home and inoculate a recently made wheel of cheese by rubbing the rind of the store-bought cheese against the surface of the homemade cheese. Rub thoroughly and evenly to ensure a successful cultural transfer.

BEER WASH

Beer and cheese are good old friends, so it shouldn't be a surprise that you can create an exquisite cheese rind simply by washing it with beer. Here's how to do it: At the end of a long day, open a bottle of beer. Pour a bit onto an unopened wheel of recently made homemade cheese (Figure A). Rub the beer into the rind using a scrap of cheese cloth or a dedicated toothbrush. Then enjoy the rest of the bottle yourself.

Erin Kunkel, Louella Hill

These and other cheesemaking tips and recipes and can be found in my book *Kitchen Creamery*. To read more, visit makezine.com/go/cheesemaking-tips.

GROWING MOLD SPORES

Unlike the previous trick, which transfers store-bought secondary cultures onto homemade cheese by rubbing the two together, blue cheese cultures (which are secondary cultures) must be added to the milk earlier in the process (Figure B). You can grow a batch of blue cheese mold spores quite easily on sterilized bread, and yield enough for a year's worth of Stiltons. Here's how:

1. Purchase some fresh, domestic blue cheese. Using a clean knife, cut the cheese in half to expose a fresh surface (you don't want to take mold spores from the rind or a previously exposed surface). Carefully dig out a penny-sized glob of blue mold (aiming for the blue mold and not the cheese). Set the glob on a clean piece of plastic wrap, then cover and set aside.

2. Take 2 slices of whole wheat bread (it can be stale) and break it up into small, walnut-sized chunks, excluding the crust, and place in a jar. Sprinkle 4 tablespoons of just-boiled water over the bread chunks. Form a lid from a double layer of aluminum foil and press it tightly around the rim, but not airtight. The goal is to let air in while keeping the microbes from getting in and out.

3. Stand the bread-filled, covered jar in a larger pot. Place a weight (a heavy ceramic plate works) on the top of the jar. Add water to the pot, taking care to keep the jar upright and the foil lid from getting wet, then cover it.

4. Bring to a boil and boil for 15 minutes to sterilize the bread and prevent unwanted microbes from growing on it. Turn off heat, carefully remove jar from water, and set on a clean towel. Let it cool for 1 hour.

5. Very carefully, transfer the glob of blue mold spores onto the bread, then quickly close the foil lid. Keep at room temperature in a bright room for 4–6 days by which point the contents of the jar should be completely blue.

6. If using the spores in a batch of cheese right away, take ½ cup of the blued bread out of the jar and place in another clean jar along with ½ cup of the milk you will be using to make cheese. Shake the jar to release the spores from the bread, then strain the spore-rich milk through a clean piece of tightly woven cloth and into your milk vat.

7. The leftover blued bread can be saved in the incubation jar with a secure lid in the fridge for up to 2 months. Remember to use a clean instrument when removing bread pieces from the jar and to resecure the lid promptly to limit air exposure.

FRIGID FEAST

WHEN YOU WANT THE SMOOTHEST DESSERT POSSIBLE, YOU GOTTA GO SUB-ZERO

Written by Lisa Martin

IT WASN'T THAT LONG AGO THAT PUTTING FOOD IN LIQUID NITROGEN WAS SOMETHING YOU'D ONLY SEE IN A HIGH SCHOOL SCIENCE CLASS, but these days it's fast becoming a mainstay of modernist cooking. It's odorless, it's tasteless, and it's not going to poison your food any more than our (78% nitrogen) atmosphere will poison you. Because it's so cold (–320.44°F to be exact) it boils at room temperature and evaporates out of your food as it rapidly chills it.

But why would anyone freeze food with liquid nitrogen? Every time you freeze something, it creates crystalline structures within your food, which can break up its cellular structures, affecting the texture. The faster the freeze time, the smaller and less damaging the crystals. So when professional chefs use liquid nitrogen they manipulate not only temperature, but texture as

Hep Svadja

well. Which isn't to say manipulating temperature can't let you do extraordinary things — Google "cryo-fried" for more on that. More than anything though: You do it for the hell of it.

GEAR UP

With some common-sense precautions, liquid nitrogen is perfectly safe to use for some kitchen experimentation. Here's what you need to know to get started at home.

Liquid Nitrogen

Available at your local welding supply store. Prices vary, though generally speaking the gas itself is pretty affordable. Some stores will require you to buy a minimum amount. Call around to see which store has the best deal for your specific needs. And I do mean call, since many of these places won't explicitly list this information on their websites. Also, when you move liquid nitrogen to any container, some of it will evaporate just in the process of cooling the vessel down. The rest of it will evaporate over time; how much time depends on the size of the container.

Dewar

A *dewar* is a specialty container made to both insulate and relieve pressure from the expanding gas inside. It's the safest way to move and store liquid nitrogen and you're unlikely to find someone who will sell liquid nitrogen to you if you don't have one of these. Even a small dewar will set you back a few hundred dollars, but you can buy these used or may even get lucky and find a place that will rent the dewar to you when you buy your liquid nitrogen (just expect the deposit to be almost as pricey as buying a new one).

Small Insulated Container

You'll probably want a way to move smaller amounts of liquid nitrogen from your dewar to your kitchen. Your best bet: a vacuum insulated coffee dispenser. Unlike a thermos, these are not designed to be completely sealed — sealed containers are a major no-no for any quickly evaporating liquid.

Basic Cooking Supplies

You don't need specialty items once you're actually using the liquid nitrogen. Some things you should have on hand: a stainless steel mixing bowl to pour your nitrogen into, tongs, slotted spoons, and a long-handled sieve for taking food out of the nitrogen bath. Grab a hammer or meat tenderizer too, because you're going to want to smash something that's been frozen solid.

MAKE THE ULTIMATE FAST-FREEZE SUNDAE

Using liquid nitrogen for part of your dessert is a neat trick. Using it for your entire dessert, however, is downright impressive. Here's how to make an ice cream sundae base and a bevy of garnishes using this wondrous liquid.

5-Minute Ice Creams and Sorbets

For ice cream, prepare your ingredients as you would up until the freezing step, then put these ingredients in a mixing bowl. While stirring the mixture, add an equal amount of liquid nitrogen (being careful not to overfill the bowl). For a stand mixer, use the flat beater attachment. If your ice cream isn't sufficiently chilled by the time the smoke clears, simply add more liquid nitrogen. For sorbets, just use your favorite juice instead.

DIY Dippin' Dots

Put room-temperature ice cream in a squeeze bottle and quickly squirt small droplets into the liquid nitrogen bath until you have a bunch of tiny frozen globules. Scoop them out with a sieve.

Chocolate Nests

Put warm, tempered chocolate in a piping bag and swirl the chocolate directly into the liquid nitrogen bath to create a squiggly nest of chocolate.

Perfect Fruit Pieces

Frozen solid raspberries can be broken up into their individual segments, and citrus fruits into their individual juice sacs. Freeze them, smash them to separate, and then let them thaw for juicy pops of flavor and texture.

Fresh Yet Powdered Herbs

Mint and basil work great for dessert plating. Freeze herbs until they're brittle, then grind them up. Use the powder while it's still frozen to create dusting effects on the plate. Once the powder thaws it will retain that powerful, fresh herb flavor so you won't need much.

Dragon Breath Marshmallows

Take a marshmallow and freeze it for 40–50 seconds in the liquid nitrogen, then take it out, wait about 10 seconds, and pop it into your mouth to see your breath as it comes out of your nose. This is a trick that works well with foods without moisture, so you can experiment with crackers or dry cookies too.

BE SAFE

- **Wear safety glasses.** They'll protect your eyes from stray splashes of liquid nitrogen (it's boiling, after all).
- **Cryogenic protective gloves.** Liquid nitrogen can cause frostbite if there is prolonged skin contact, but the risk of this is relatively low as long as you move the liquid fast enough. Momentary contact won't be an issue thanks to the *Leidenfrost effect* — a protective layer of evaporating gas will form between your skin and the liquid as it boils off — but this isn't long-term protection. Wearing gloves is the best practice, and can also protect you from tools that may become extremely cold. The Leidenfrost effect will not protect your eyes, so keep your safety glasses on.

Audrey Ma for Smitten Ice Cream

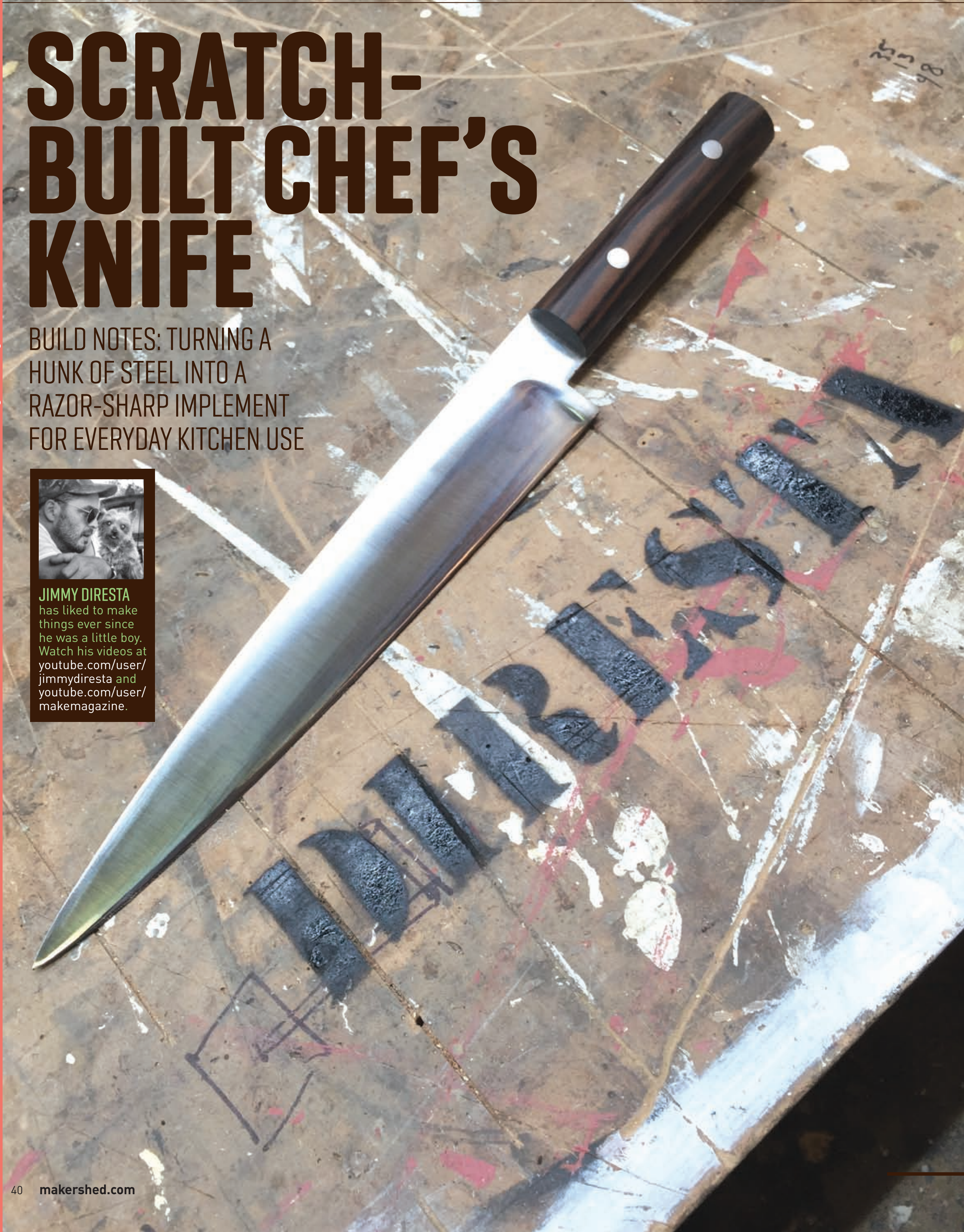
- **Ventilate.** 1L of liquid nitrogen will become 700L of nitrogen gas once it has evaporated. Enough of it in a small, enclosed space can kill you. Dead. Simply by displacing the oxygen you need. It's called *inert gas asphyxiation*. I don't want to undersell that, but the solution is simple enough: open a window, open a door.
- **Don't seal it up.** Just don't. Nothing you own can contain the pressure of liquid nitrogen turning into gas and it will explode if there's no way for the gas to safely escape the container. This is why you throw down so much money on the dewar; it's designed to not explode.
- **Don't put in your mouth:** super-chilled metal spoons; foods with a lot of moisture that have just come out of the liquid nitrogen bath; or liquid nitrogen itself.

Time Required: 6–8 hours • Cost: $20–$40

Written by Jimmy DiResta

SCRATCH-BUILT CHEF'S KNIFE

BUILD NOTES: TURNING A HUNK OF STEEL INTO A RAZOR-SHARP IMPLEMENT FOR EVERYDAY KITCHEN USE



JIMMY DIRESTA has liked to make things ever since he was a little boy. Watch his videos at youtube.com/user/jimmydiresta and youtube.com/user/makemagazine.

I LIKE A LARGE, SHARP KNIFE when I cook so I decided to design something sexy for my kitchen. I began by freestyling a shape on a piece of 01 oil-hardening tool steel. I have some cool knives whose shape I mimicked, but I gave this one an extra long handle for better control.

CUT

With a cutoff wheel on an angle grinder, I removed the negative space on the handle and the taper to get a vague shape (Figure A). I went way off the sketched line and cut more of a taper than I expected, but it gave me a long, sleek look that I was happy with.

SHAPE

I refined the shape using a 60 grit belt on my belt grinder. The combination of a top-curve down and a bottom-curve up gives it a nice centered look.

CAUTION: Wear a respirator when grinding metal to avoid breathing in the super-fine particles. They'll stay in your lungs and get rusty.

BEVEL

To keep the blade's bevel balanced on both sides, I coated the blade edge with machinist's blue layout fluid, allowing me to scratch a line for the blade's center. Next I took a chunk of wood with a 4° or 5° bevel to use as my sled. I attached the knife blank to it with a screw clamp placed just a few inches beyond the back of the blade. The clamp served as a stop against the back edge of the grinder table, creating an unground part so my knuckles wouldn't hit that very sharp back and get cut.

To get the bulk of the bevel shaped, I slid the knife blank — first one side and then the other — slowly back and forth across a 36-grit belt, letting the blade cool from time to time so as not to burn the wood (Figure B). I ground a steep, long bevel about 2" from the very sharp cutting edge to the wider back of the blade. This took a long time.

Once I got almost all the way to the other end, maybe about ¾" before the back of the blade, I unclamped the knife from the slide and switched to a 250-grit belt. Using a piece of wood to press the blade against the belt (it gets too hot to hold), I slowly worked that bevel in to the other side — at this point the blade was roughly 90% to where it needed to be.

HEAT TREAT

To harden the knife, I held it with tongs by the tang and heated it up to bright red (1,425°F–1,450°F) in a forge and then quenched it in vegetable oil, just because I was working outside and motor oil is bad for the grass. When finished, I sanded off the slag with a 250-grit belt, and then tempered it in a 400°F oven for about 1 hour.

BUILD AND ATTACH HANDLE

The handle is held in place with pegs. To make it, I centered two marks on the knife's tang, drilled small pilot holes, then enlarged them with a ⅜" bit. Then I cut two pieces of Macassar ebony to the size that I wanted, temporarily glued one onto the tang using a small amount of CA glue, and used the holes I cut in the metal to drill through one side of the handle.

Once cooled, I glued on the other side, flipped the handle over, and drilled back through the holes. I stuck wood pegs through the holes to keep the handles in place while I hand-shaped them on the band saw. I like the simplistic look of the blade, so I also wanted the handle to be a simple round shape. To work around the blade's height, I propped it up on a chunk of wood so that I could poke it straight into the band saw blade.

Using a V-block to keep the knife in place, I shaped the handle further with a Japanese rasp, did some final sanding, and then popped out the wooden pegs. I glued all the pieces back together with significantly more CA glue, coating the metal pegs and hammering them into place (Figure C). I used a jeweler's saw to cut the pegs, and then ground them, nice and smooth, down to the surface of the wood.

SHARPEN

Finally, I buffed the knife to give it a nice, razor-sharp edge from end to tip, using a buffing wheel (Figure D).

As I often say, I am the god in the world of this knife — if it becomes dull I can certainly sharpen it. It halved my dinner like a hot knife through butter. Or, more accurately, a sharp knife through a burrito.

MATERIALS

- **Oil-hardening tool steel, grade 01, ⅛"×18"** such as Presco O-1 from Precision Marshall Steel, pmsteel.com
- **Wood for handle.** I used Macassar ebony I had on hand.
- **Scrap wood**
- **Wooden pegs**
- **Vegetable oil**

TOOLS

- **Angle grinder, 4¼" with cutoff wheel**
- **Belt grinder with 36, 60, 250, 600, and 1000 grit belts**
- **Screw clamps**
- **Layout fluid** such as Dykem 80300 Steel Blue
- **Forge**
- **Oven**
- **Drill press and ⅜" bit**
- **Band saw**
- **Japanese rasp**
- **V-block**
- **Jeweler's saw**
- **Sandpaper**
- **Tongs**
- **T square**
- **Cyanoacrylate (CA) glue** aka super glue
- **Sharpie**

A


B


C


D

Jimmy DiResta

Watch Jimmy construct this knife to see all the techniques in action: makezine.com/2015/12/15/diresta-kitchen-knife

Written by Dale Dougherty

LISA QIU FETTERMAN WANTED TO MAKE AN AFFORDABLE SOUS VIDE MACHINE. BUT FIRST, SHE'D HAVE TO LEARN TO MAKE.

Hep Svadja

MAKER TO MARKET

The Nomiku (above) is a Wi-Fi-connected immersion circulator that can produce perfectly cooked meals, including steak that's edge-to-edge medium-rare (left).

Lisa demonstrates Nomiku's ability to make silky pots de crème.

"By controlling the exact cooking temperature, there is no need to worry about curdling."

In my upcoming book *Free to Make*, I recount the varied journeys undertaken by different figures in the maker movement. In chapter 3, excerpted here, we meet Lisa Qiu Fetterman, who learned to solder, moved to China, and even contemplated selling a kidney while designing and developing her sous vide device, Nomiku.

Lisa Qiu Fetterman did not think of herself as an inventor, per se, nor an entrepreneur. She did not know about makers, and she did not grow up considering herself to be one. She loved food and cooking, and that passion led her to develop a new product and eventually start a company.

Lisa Qiu came to the United States from China at the age of 7, and her family settled on Long Island, New York. She explains:

"From a really young age, I realized, 'oh, people connect through food.' I've been obsessed with food ever since. When I got into NYU, I went to Babbo, which was the closest restaurant to school, run by Mario Batali. I walked in and begged him for a job in Italian, and he gave me one on the spot. I worked in the kitchen and in the front of the house, wherever they needed me. If you get paid $8 an hour, people will basically let you do anything if you show active interest."

After graduation, she kept working in restaurants until she got a job at Hearst Corporation's digital department.

She met her future husband, Abe Fetterman, who had moved to New York City after finishing his Ph.D. in astrophysics at Princeton, at a fancy gym. "On our first date, we talked about food. He said he was really into food, and I said, 'oh, really?'" She told Abe about sous vide cooking:

"I wanted to save up money to buy a $1,000 sous vide machine, because it's the best way to cook. In every single restaurant that I worked in, we had one: a huge hulking piece of laboratory equipment that we relied on for 70% of our components. I started thinking this has to be in everybody's home because it's so easy to use. All you do is put your food in a vacuum bag and drop it in the water and walk away. That's it. It's crazy easy. Abe said, 'Let's just make one.'"

A sous vide cooking machine functions by immersing food inside a vacuum bag into water that is kept at a constant temperature — much lower than normally used for cooking — over a long period of time, three to five hours. Lisa and Abe's first homebrew version used a bowl to hold the water and an immersive tea-heating coil to control the temperature. It sort of worked.

Abe did some research and found a DIY sous vide project by Scott Heimendinger in *Make:*. "It required soldering, which we didn't know how to do," Abe recalls. "We didn't know how to do a lot of things," adds Lisa, laughing. "But we knew that it was possible to DIY something."

One of the places Abe and Lisa met regularly was a vegan restaurant, the World Café, near NYU. "You can sit upstairs for hours and they won't bother you," said Lisa. It was there they overheard a conversation. A writer for *Make:*, Matt Metts, was interviewing Mitch Altman, a well-known hacker and maker of the TV-B-Gone device that allows you to turn off any TV by remote control. Altman travels around the world teaching soldering classes and advising hackerspaces. He just happened to be in the same café as Lisa and Abe that day.

Lisa asked Abe, "What's a maker? It seems like we might be makers." Not shy, she went up to them and started asking questions. "Mitch gave me the key to his hackerspace and invited me to his soldering class in Brooklyn." It was literally an unfinished basement in someone's house. Afterward, they found an Arduino class at a Brooklyn hackerspace named NYC Resistor and decided to take it. I asked Lisa and Abe if they had known what Arduino was before that. "No," said Lisa. Abe knew how to program in C++, and he found Arduino easy to use. From what they learned, they began building their own sous vide cooker, controlling the electronics with an Arduino.

Lisa continues on to develop her device; by the end she's run two highly successful Kickstarter campaigns, established U.S. manufacturing, and launched a food revolution with Nomiku. Read more in *Free to Make*, available late 2017.

Written and photographed by Wayne Hammond **Time Required:** A Weekend • **Cost:** $40–$180

PERIODIC TABLE OF SPICES

BRING ORDER (AND FAMILY, GENUS, AND SPECIES) TO YOUR SEASONINGS

MY OLD SPICE DRAWER HAD MANY ISSUES:
— out of space
— tins not airtight
— arbitrary alphabetical organization
— no labeling for the spice-impaired cook
— selection had grown from base pantry ingredients to a "collection."

TAXONOMY

Research led me to a better organizational principle: botanical taxonomy, as in Order-Family-Genus-Species, per the International Code of Nomenclature of algae, fungi and plants, 2012 (the Melbourne code); and International Code of Nomenclature for Cultivated Plants, 2010.

Arrangement into a periodic table shape was possible but too "cute" and wasted a lot of space. (A guy did a magnetic spice rack similar to this on Instructables, but he used the leaky tins I was getting rid of, and took up 24"×36" of wall space that I don't have, for half as many spices as I have.)

I did have a doorless kitchen cabinet available, 11"d × 17"w × 30"h, after removing little-used wine shelves.

So I made my own compact "periodic" table to form the organizational backdrop for the spice rack (Figure A). This graphic is a spreadsheet in Apple's Numbers app — you can download a PDF version from the project page online at makezine.com/go/periodic-table-of-spices and modify it for your favorite spices.

MATERIALS

- **Aluminum sheet, ⅛"** for the shelves. You could also use stainless steel or plywood.
- **Jars, 4oz (80)** I used 4oz candle jars $1.35 each from Specialty Bottle. They have a great shape and an airtight seal. You could also use your existing jars or tins.
- **Styrene poster board** Your local print shop probably has it.
- **Shelf pegs**
- **LED light fixture, battery powered (optional)**

TOOLS

- **Printer**
- **Punch**
- **Sandpaper**
- **Drill**
- **Sharpie marker**
- **Water jet cutter (optional)**

WAYNE HAMMOND is a maker, husband, father, printer, brewer, and geographer.

DESIGN

I printed the table on 30-mil styrene and punched holes for shelf supports (Figure B).

Then I designed U-shaped shelves (Figure C) to support ten 4oz jars each, with 3 shelf support contact points. I researched acrylic, glass, stainless steel, and aluminum, and then prototyped in steel and aluminum.

The final shelves were produced in ⅛" aluminum at a local metal shop with a water jet cutter. I sanded the edges and faces for a scuffed stainless "commercial kitchen" look (Figure D).

INSTALLATION

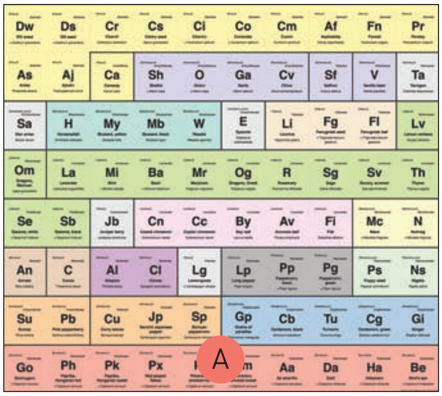
I drilled the empty cabinet with holes for shelf pegs, and added a battery-powered LED light fixture above, which doubled as a night light. Then I wrapped the periodic table of spices around the back and sides of the cabinet in a U shape.

Next, I installed shelf pegs and shelves, and colored in the front edges of the aluminum shelves with a black Sharpie to match the borders on the periodic table (Figure E).

The final step was to place the spice jars, each labeled with its 2-letter symbol.

Bam. It's science.

See more photos and share your geeky spice rack ideas at makezine.com/go/periodic-table-of-spices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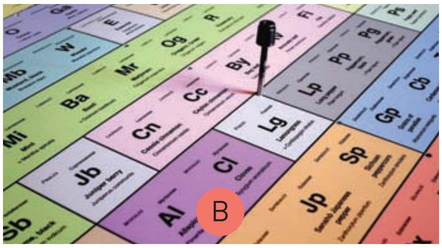
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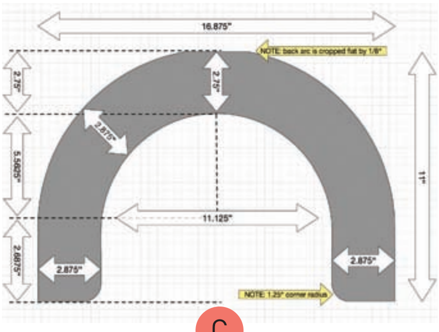

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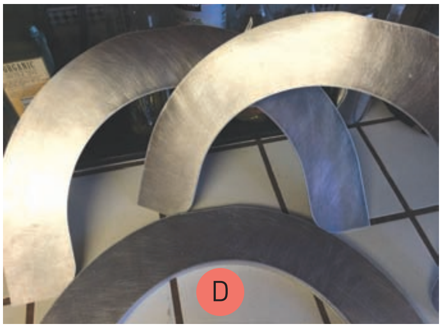
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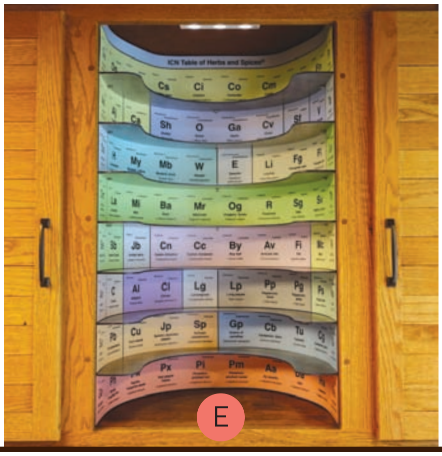
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Written by John Edgar Park **Time Required:** A Weekend • **Cost:** $250–$2,750

TALL COLD ONE

BUILD A BEHEMOTH COLD BREW COFFEE DRIP TOWER FOR THE SMOOTHEST CUP

MATERIALS

- **Glass beverage dispenser, 2 liter, with removable spigot** such as Amazon #B0118KP2XU
- **Elbow fitting and nut** connects dispenser to solenoid valve
- **Teflon pipe tape**
- **Beverage solenoid valve, 12V DC, normally closed** Alcon ⅜ NPT female, McMaster-Carr #5489T673
- **Push-to-connect fitting, plastic, ⅜" NPT male thread to ¼" press-fit** aka John Guest fitting
- **Food-safe tubing, ¼" diameter**
- **Food-safe stopcock valve** to fit ¼" tubing
- **Tabletop siphon beaker, Yama 5 cup upper glass replacement** espressoparts.com #YAMTCA5DT
- **Cloth filter and screen assembly** espressoparts.com #YAMCFSCR
- **Graham condenser (optional)** just for looks, Amazon #B005QDPR22
- **Boiling flask, flat bottom, 2 liter** Amazon #B00ET6H4DM
- **Stopper, #10 (optional)** if you're using the Graham condenser
- **Acrylic sheet, ⅛" thick, 24"×24"**
- **Machine screws, M4 ×18mm, with nuts (12)**
- **Brackets and screws** for mounting shelves to the wall or to a board
- **Arduino Uno microcontroller**
- **Prototyping shield for Arduino** such as Adafruit #2077
- **Enclosure, about 4"×3"×1.6"** I used allelectronics.com #MB-173.
- **Power supplies, regulated, 12V DC 1A (2)** for Arduino and solenoid
- **Potentiometers, 1kΩ, with knobs (2)** Look for cool knobs to fit yours!
- **Transistor, N-channel FET, TO220 package**
- **Diode, 1N4001 type**
- **Resistor, 10kΩ**
- **Screw terminals (2)**
- **Wire, stranded**
- **Spade terminal crimp connectors, ¼" (2) and crimper**
- **Double-stick foam tape**

TOOLS

- **Soldering iron and solder**
- **Computer with Arduino software** free from arduino.cc/downloads
- **Laser cutter (optional)** Or have a shop cut the acrylic, or cut them from plywood, or design your own.

JOHN EDGAR PARK likes to make things and tell people about it. He builds projects for Adafruit Industries, Boing Boing, and *Make:*. He has ninja warrior goals. You can find him at jpixl.net and Twitter @johnedgarpark

COLD BREW COFFEE'S RICH, DELICIOUS FLAVOR AND LOW ACIDITY MEAN IT TASTES GREAT OVER ICE, where hot-brewed coffee just tastes diluted and acidic. My small commercial drip tower works very well, but I decided to build a much larger brewing tower from scratch, and to make it considerably more precise while I was at it — drip rate is everything when it comes to cold brew. I chose a food-safe solenoid valve and built a controller for it — just a simple transistor circuit mounted on a prototyping shield, two potentiometers, and a bit of code running on an Arduino Uno. Two knobs adjust the frequency of the valve opening and closing, and the length of time it remains open per drip. For manual fine-tuning, I discovered a Hario valve (from coffee parts suppliers) press-fits very nicely inside ¼" tubing — but you can use any food-safe stopcock valve that fits.

ASSEMBLY

Remove the existing spigot from the beverage dispenser. Wrap the replacement elbow's threads with teflon tape, then insert into the dispenser, using any washers and gaskets necessary to create a watertight seal. Thread on the nut and tighten. Wrap the exposed elbow threads with teflon tape, then screw on the solenoid valve. Screw the John Guest push-to-connect fitting into the solenoid valve. Insert a small length of ¼" tubing, then fit the stopcock valve in place.

CONTROLLER

Follow the circuit diagram on the project page at makezine.com/go/cold-brew-drip-coffee to solder the transistor, diode, resistor, potentiometers, and power supply to the proto shield. I used screw terminals to connect the power supply and solenoid wires to the board. Plug the power supply into the wall AC power, and connect the solenoid; I used spade terminals here.

Plug the proto shield into the Arduino Uno, then grab the code file *coldCoffeeDripBrew.ino* from the project page, and upload it to the Arduino over USB. Disconnect from USB, then plug the second power

supply into the Arduino's power jack. The solenoid valve will begin to open and close, and you can test different timing adjustments with the 2 potentiometers.

Ream out 2 holes in the enclosure for the potentiometers, then mount them and add knobs. Also add holes, if needed, for power and solenoid wires. Place the Arduino and proto shield into the enclosure (Figure A).

MOUNTING

Download the files from the project page and cut the acrylic holders using a laser cutter, band saw, or scroll saw. Attach the angle brackets with the M4 screws and nuts.

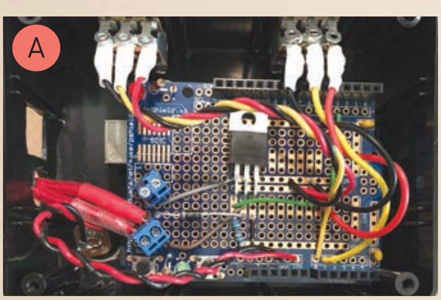
Mount the lowest shelf first, then stack your boiling flask, stopper, Graham condenser, and grounds beaker on top (this will take 2 people) in order to mark ideal placement for the middle shelf. Use the same technique to mount the top shelf.

Run the wiring up through the holes in the shelves, then connect the wires into the controller. Close the lid and affix the controller to the underside of the top shelf using double-stick foam tape.

Insert the filter screen into the bottom of the grounds beaker, then place all the glass components on their shelves. Plug in the solenoid valve, and you're ready to brew!

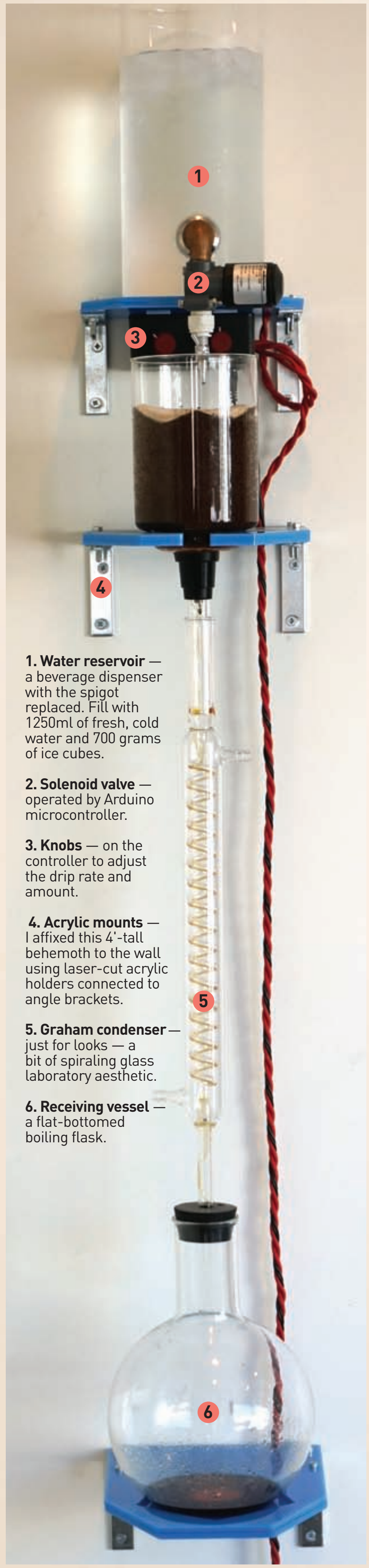
BREWING

Power up the Arduino and solenoid. The water will mingle with the grounds and begin to extract those wonderful volatile solids that turn it into the magical elixir of cold-brewed coffee. Watch as it streams through the coil of the condenser into the flask waiting expectantly below! Depending on your grind and your drip rate, it'll take up to 18 hours, but it's well worth the wait. When it's done, pour it on ice and enjoy your delicious, high-tech, cold brew coffee.



Hep Svadja, John Edgar Park

See the full build, get the code and cutting files, and share your coffee hacks at makezine.com/go/cold-brew-drip-coffee



1. Water reservoir — a beverage dispenser with the spigot replaced. Fill with 1250ml of fresh, cold water and 700 grams of ice cubes.

2. Solenoid valve — operated by Arduino microcontroller.

3. Knobs — on the controller to adjust the drip rate and amount.

4. Acrylic mounts — I affixed this 4'-tall behemoth to the wall using laser-cut acrylic holders connected to angle brackets.

5. Graham condenser — just for looks — a bit of spiraling glass laboratory aesthetic.

6. Receiving vessel — a flat-bottomed boiling flask.

NOT A LATTE

John Edgar Park

Cappuccino and its brethren are delightful to consume, but what if you'd like to add that beautiful creamy mouthfeel to coffee without the frothed milk? Science comes to the rescue in the form of a polysaccharide secreted by *Xanthomonas campestris* bacteria during sugar fermentation — better known as xanthan gum.

Xanthan gum has long been used as a thickening agent, homogenizer, and emulsifier in commercially produced foods, but now it's available in supermarkets thanks to its use as a gluten substitute in gluten-free baking. A tiny amount — as low as 0.1% by weight — is adequate to increase the viscosity of most liquids. When whipped, a xanthan-thickened liquid will trap and suspend many, many tiny air bubbles.

MODERNIST FAUX LATTE Serves 2

EQUIPMENT

- **Coffee brewer**
- **Measuring cups/spoons or gram scale**
- **Blender**

INGREDIENTS

- **12 fluid ounces | 350ml | 330g water**
- **½ C | 33g freshly ground coffee**
- **¼ tsp | 0.4g xanthan gum**

1. BREW COFFEE

Brew your coffee as you usually do.

2. ADD XANTHAN INSTEAD OF MILK

Pour the coffee into your blender and add the xanthan gum.

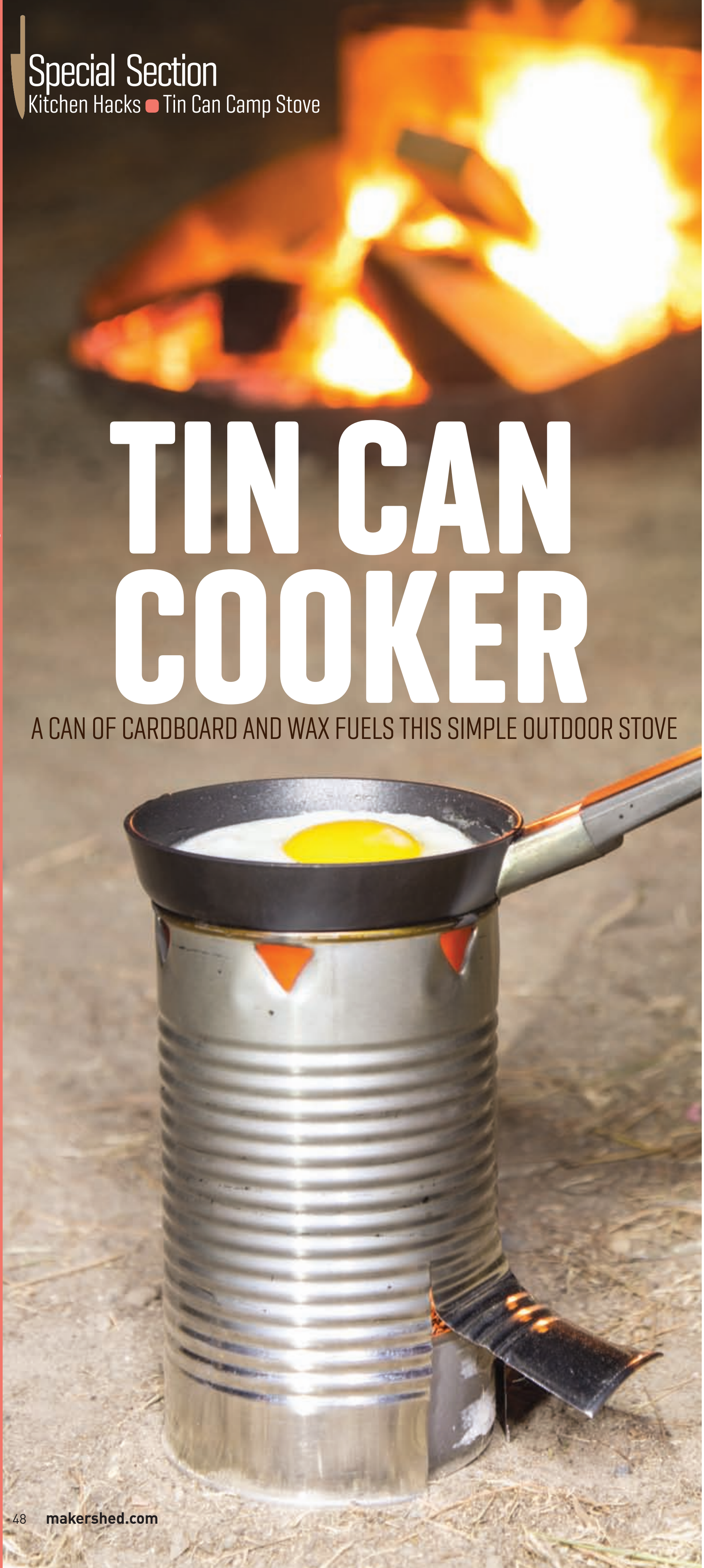
3. BLEND

Blend for about 30 seconds to whip in the air bubbles.

4. SERVE

Drink and enjoy your velvety, dairy-free modernist coffee.

Written by Kathy Ceceri **Time Required:** 2 Hours • **Cost:** $0–$5



TIN CAN COOKER

A CAN OF CARDBOARD AND WAX FUELS THIS SIMPLE OUTDOOR STOVE

MATERIALS

- » **Several small tin cans** such as tuna cans or candy tins. Remove the tops completely and discard.
- » **Large tin can** #10 institutional size is best. All cans should be washed clean. Also remove the label and any glue. Avoid using cans with plastic coatings.
- » **Corrugated cardboard** cut into strips slightly wider than the small cans are tall
- » **Unscented white candles or paraffin wax blocks**

TOOLS

- » **Double boiler to melt wax** or a medium saucepan and slightly larger saucepan
- » **Stove** (preferably electric) **or hot plate**
- » **Can opener, manual or automatic** for removing top of can
- » **Can opener, "church key" type** for punching triangle-shaped holes in the can
- » **Heavy work gloves**
- » **Metal tongs**
- » **Hot pads or oven mitts, nonflammable**
- » **Brick or metal pot lid**
- » **Matches or lighter**
- » **Tin snips (optional)**
- » **Pliers (optional)**

KATHY CECERI (craftsforlearning.com) is the author of *Paper Inventions*, *Making Simple Robots*, and other books for beginning makers using low-tech/no-tech projects and materials.

SAFETY TIPS FOR TIN CAN COOKERY

Tin Can Cookers use an open flame. They can be dangerous, so be sure to follow these safety rules!

- Adult supervision is needed to make and use a Tin Can Cooker.
- Wear heavy gloves when handling cut-metal edges.
- Always keep an eye on melting wax and on the lit cooker. Do not leave them unattended.
- Do not melt wax in the microwave or directly on the stove. Always use a double boiler (or make one from two saucepans).
- Always use hot pads or oven mitts to handle hot pots. Use metal tongs to adjust the cooking can or the wax burner.
- Make sure to use your Tin Can Cooker on a level, fireproof surface, such as a flat paving stone. Watch out for hot liquid wax in the burner — avoid spilling it.
- Do not pour water on burning wax. Use a brick or a metal lid to cover the wax can and smother the flames.
- Tin can cookers can blacken cooking utensils with soot from the burning wax, so don't use them with your best pots and pans. Pick up a camping skillet and spatula or small, sturdy garage sale pots and pans and save them just for outdoor cooking.

Hep Svadja, Kathy Ceceri

THE TIN CAN COOKER IS A HOMEMADE OUTDOOR STOVE THAT REALLY WORKS. Generations of Scouts have learned to make and use "Buddy Burners" for camping and emergencies. Instead of wood or liquid fuel, the Tin Can Cooker burns a small can of wax and cardboard. A larger can fits over it and holds your cooking pot. Each wax can should burn an hour or more. Make several so you always have one on hand.

1. Curl up strips of cardboard and fit them loosely inside each of your small cans. Leave enough space for wax. Or you can cut short strips and arrange them to form a star that divides the can into pie-shaped slices. The cardboard will act as a wick to get the wax burning across the top of the can. Set the prepared cans on a protected surface, such as a cookie sheet covered in newspaper or aluminum foil. Place it close to where you'll be melting the wax.

2. Break up wax or candles to fit into the top pan of the double boiler. Fill the bottom pan about halfway with water. Fit the top pan into it so it sits above the water. If you don't have a double boiler, set a medium-sized saucepan so it sits over a larger saucepan of boiling water. Turn the stove on medium to heat the water to a steady boil. Let the wax melt until it is completely liquid.

3. Carefully pour the melted wax into the prepared cans. Leave the top edge of the cardboard sticking up above the level of the wax. If your wax starts to harden as you're pouring it, just reheat it to melt it again. Let cool until hardened.

4. Take the large can and remove the entire top with a can opener.

5. Hold the large can with the open end pointing away from you. Take the church key can opener and make 3 or 4 openings at the closed end, around one side, about 1" apart.

6. Turn the large can so the opening is toward you. You have two options for letting air in at the bottom to feed the flames:

- **If you don't have tin snips:** Use the church key can opener to punch holes all around the open end of the can, about 3" apart. Take a pair of pliers and fold up the sharp points of metal created by each hole and squeeze them flat.
- **If you do have tin snips:** Create a flap that acts like a fireplace damper to control the airflow. The more oxygen, the higher the flames. Put on heavy work gloves to protect your hands from sharp metal edges. Use the tin snips to cut 2 slits into the side, about 3" inches long and 3" apart. Then grab the edge of the can between the slits and bend it outward to make the flap.

7. To use your stove, place the wax can on a flat, nonflammable surface, like a stone paver. Light the cardboard strips, like lighting the wick of a candle. You want the flame to cover the entire top of the can.

When the wax can is lit, adjust the flap on the large can and place it over the smaller can so the holes on the top are facing away from you. (This keeps smoke from blowing in your face.) Now you can cook on top!

Safety note: Use nonflammable oven mitts and a pair of pliers if you need to adjust the flap while the stove is in use. The entire tin can stove gets hot, so never touch it with bare hands while it is lit!

Your Tin Can Cooker is perfect for traditional outdoor fare like grilled cheese and egg-in-a-hole. Find those recipes and more in my book *Edible Inventions: Cooking Hacks and Yummy Recipes You Can Build, Mix, Bake, and Grow.*

This article is adapted from *Edible Inventions*, available at the Maker Shed (makershed.com) and fine bookstores.

Written by AnnMarie Thomas

PLAY WITH YOUR FOOD

NEW TECHNOLOGY AND OLD TECHNIQUES COMBINE AT ALINEA RESTAURANT

A FEW YEARS AGO, A FRIEND INVITED ME TO DINNER AT AN UNUSUAL CHICAGO RESTAURANT — one that closed and reopened every four months in a different form: new food, new theme, new décor, new service ware. I was intrigued, and agreed to visit during the restaurant's vegan incarnation. As I was writing *Making Makers: Kids, Tools, and Innovation* at the time, I reached out to the restaurant's co-owner, Nick Kokonas, and asked for an interview, in the hopes that he would have a good maker childhood story to share. I wasn't disappointed. In addition to a great story for the book, Nick also took me on a tour of his other restaurant, Alinea. That evening, at Next: Vegan (other iterations of the restaurant have included Next: Paris 1906, Next: Childhood, and Next: Sicily), I found myself eating food that was both delicious and playful. They made plates from a tree that the city had to cut down, built an edible centerpiece, and designed dishes specifically for the food we were eating. As a designer and engineer, I was enchanted. So much so, that every few weeks for the next six months, I emailed Kokonas and begged to collaborate on a project.

I ended up spending a year working with the team at Alinea. The best part was getting to observe the work of the designers, chefs, servers, and others who work there. Where I had expected to see a typical kitchen, at Alinea I found a space that blended old techniques and new technology, artistry and craft. During a typical evening, 20 or so coat-clad chefs worked in silence breaking down fish, preparing sous vide bags, wrapping pork belly in seaweed, precisely cutting discs of black truffle, and filling edible balloons with flavored helium, all the while maintaining a pristine kitchen, down to the carpeted black rug.

Kokonas explained that his team's process "is to ask what sort of experience or emotion we want to evoke for a guest. Then we figure out how to do that using every tool we can imagine. Then we do it once. Then we engineer how to repeat that 100 times per night. That's what separates us. We never say it's impossible."

So many of the attributes that make the maker movement appealing to me were visible in that kitchen:

- **Persistence:** Making the same intricate dish dozens of times in a given evening, while keeping each iteration compelling.
- **Resourcefulness:** When a component of one dessert became too sticky over the course of the night, the chefs improvised a new version on the spot.
- **Sharing:** Rather than keep Alinea's recipes a secret, Chef Grant Achatz published them in a book.
- **Playfulness:** Did I mention the floating edible balloons?

While Alinea (and Next:) push the definitions of what the restaurant experience can be, we shouldn't overlook the myriad opportunities we have to make with food every day. Our kitchens become chemistry labs and machine shops over the course of preparing a simple, or complex, meal.

Despite my work with Alinea coming to an end, my fascination with the artistry that I saw there remained, and I've sought out new ways to take my lab's work in playful electronics into the kitchen. While "Don't play with your food" is a phrase many of us heard repeatedly during our childhoods, makers such as Chef Achatz and his team are wonderful reminders that perhaps that is exactly what we should be doing.

Christian Seel

ANNMARIE THOMAS runs the Playful Learning Lab at the University of St. Thomas, and is the co-creator of Squishy Circuits.

Hep Svadja

BETTER BITTERS

FOR THE TASTIEST DRINKS, MAKE YOUR OWN FLAVORED BITTERS

Time Required: 1–2 Weeks • Cost: $20–$30

Written by Diane Gilleland

BITTERS ADD A LITTLE DEPTH AND MYSTERY TO THE FLAVOR OF COCKTAILS AND NONALCOHOLIC DRINKS. You can buy one or two brands in most supermarkets, but why not make your own? It's so easy, and you can experiment with all kinds of flavors.

You can follow this bitters recipe, find a recipe online, or create something of your own. It's important to have at least one bittering agent in the mix, like gentian or quassia. Aside from that, you can have fun mixing various flavors. It's a great way to make your party beverages truly special!

1. MEASURE

For an 8oz jar, you'll need about 2oz of herbs in total. Put the jar on the scale and reset it to zero. To start, add ½oz of bittering agent and ¼oz of each of the spices. You can add a bit more in Step 4.

Next, chop up 2oz of dried fruit, so more of its surface area will come in contact with the alcohol. Add it to the jar.

2. STEEP

Pour vodka until the jar is filled to about 2" below the rim. Cover it tightly, and set it in a cool, dark place. Let the mixture steep for 1–2 weeks, gently shaking the jar daily.

3. TEST

Now it's time to taste your bitters and see how the flavor is developing. But don't taste them straight! The flavor is much too concentrated. Try putting a few drops in a half glass of sparkling water.

If you like the flavor, move on to Step 5. If you're not quite happy, try Step 4.

4. ADJUST

If your bitters need a little flavor adjustment, you can add more of any of the ingredients you like and steep for another 1–2 weeks. Keep tasting and adjusting until you like the taste.

5. BOTTLE

Strain out all the solid ingredients with a wire strainer. Press the solids to squeeze out as much liquid as possible. Pour the bitters into a dropper bottle and label. Store in a cool, dark place.

MATERIALS

MAKES TWO 8-OUNCE BATCHES OF BITTERS

- **750ml high-proof vodka or neutral grain spirits** such as Everclear grain alcohol
- **1oz bittering agent** such as gentian root or quassia wood, available from humboldtherbals.com
- **1oz each of fennel seeds, coriander seeds, caraway seeds, and whole cloves** I buy spices from penzeys.com.
- **4oz unsweetened dried cherries or other fruit**

TOOLS

- **Scale**
- **Jars, 8oz, with tight-fitting lids, sterilized (2)**
- **Eyedropper**
- **Wire mesh strainer**
- **Glass dropper bottles, 8oz (2)** available from sks-bottle.com

DIANE GILLELAND produced the CraftyPod blog/podcast, co-authored *Quilting Happiness*, and wrote *Kinzashi in Bloom* and her newest, *All Points Patchwork*.

MO' BITTERS: For John Edgar Park's delicious Aromatic Bitters No. 1 recipe, visit makezine.com/go/bitters-recipe

Time Required: 1–2 Hours • **Cost:** $5–$10

Written by Anthony Lam

LASER-CUT SUSHI

ETCH BEAUTIFUL DESIGNS IN NORI SEAWEED WITH ANY LASER CUTTER

I FIRST SAW LASER-CUT SUSHI WHILE READING DESIGNBOOM AND IT REALLY STUCK IN MY MIND. BEAUTIFUL!

So I figured out how to re-create the process. Since the laser cutter does all the work, I mostly just had to think about what design I'd like to generate in Adobe Illustrator. It did take a few tries to get the pattern centered properly, and to get the laser cutting right without burning the seaweed.

1. CREATING YOUR DESIGN

Your pattern could be anything, but it should be sized to fit your nori, and designed with repetition in mind, so you can copy/paste in your drawing program. I took inspiration from simple geometry and the Japanese sakura (cherry blossom) design.

I didn't need to cut my nori sheets to size, before or after the process, but I left about a ¼" margin so I could hold the nori down with some weights during cutting.

2. LASER-CUTTING SEAWEED

Set your laser cutter's power to a low setting. The cutter I used has settings from –100% to 100% power, so to be safe I set it at –50% to avoid any potential fires or charring of the nori.

I set the speed at "standard," because if it were too slow it would possibly start burning. Test your laser cutter to find the right mix of speed and power.

3. ROLLING SUSHI

Experiment with different margins and patterns. Mine are decorative but not very strong; they're suitable for maki rolls or inside-out rolls. But a pattern that leaves more of the nori intact could be strong enough to wrap and hold hand rolls. Happy rolling!

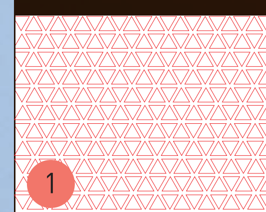
MATERIALS

» **Nori edible seaweed sheets for wrapping sushi** Find it in your local Asian market or well-stocked grocery store. The type I used had measurements of 8"×7½". I don't believe they're all the same, but many brands are relatively close.

TOOLS

» **Laser cutter** Any type will do. Visit a local makerspace if you don't have one at home.

ANTHONY LAM is a former engineering intern for *Make:*. An industrial designer by trade, he is easily excited by anything regarding technology, DIY projects, or video games.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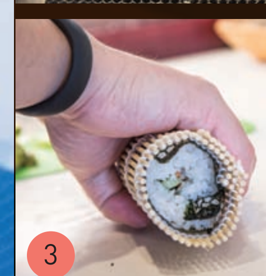
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Hep Svadja, Anthony Lam

Share your laser sushi patterns at makezine.com/go/laser-cut-sushi

SAUCE THAT'S HOT (OR NOT)

A CONDIMENT SO SIMPLE YOU'LL NEVER BUY STORE-BOUGHT AGAIN!

Time Required: 2–4 Weeks • **Cost:** $0–$20

Written by Dale Dougherty

MATERIALS

- Peppers (10lb for 24oz of sauce, depending on variety)
- Salt, pickling or kosher salt with no iodine or preservatives
- Vinegar, spices, carrots, tomatoes, or other veggies and flavorings (optional)

TOOLS

- Food processor, blender, or juicer
- Container, such as Mason jar or crock
- Cheesecloth
- Strainer

A

B

C

Dale Dougherty

FOR ALL OF ITS COMPLEXITY, MAKING HOT SAUCE IS ACTUALLY AS SIMPLE AS COMBINING TWO INGREDIENTS: ripened hot peppers and salt. Just crush the peppers, add some salt, and then wait for fermentation to start and finish. While the process is easy enough, there's lots of room for variation — especially if you grow your own varieties of peppers. Mixing different peppers in a hot sauce can blend heat with distinctive flavors. I like using red Fresno chiles, and the much hotter orange habanero peppers, which I sometimes blend together.

PREPPING PEPPERS

Harvest your peppers (Figure A), then wash them and remove the stems. You can use a food processor or blender to chop them up into a mash. Alternatively, a vegetable juicer is a good way to extract the juice from ripe peppers (Figure B). After juicing you'll want to mix the juice and pulp back together. Next, pour the mixture into a glass jar or crock that has some headroom.

BEWARE: If you use plastic or silicone tools, those materials will retain some of the peppery heat!

Instead of table salt, look for pickling salt or kosher salt that has no iodine or preservatives. Add enough salt — not too much and not too little. Cover the jar with cheesecloth, which will keep out pests while allowing air to circulate. You can also use a Mason jar with an airlock fitted into the lid.

The salt allows *Lactobacillales*, or lactic acid bacteria (LAB), to establish themselves. In a process called *lactic acid fermentation*, the bacteria consume the sugars in the juice and produce lactic acid. This lowers the pH of the ferment, which protects it from harmful types of bacteria, and adds a distinctly acidic and delicious flavor.

WAITING GAME

Now you must wait several weeks while you watch the ferment progress. Ferments are living things and they take their own sweet time, but 2–4 weeks is usually enough. If you see mold, just scrape it off the top.

Once fermentation is done, strain it to remove the pulp, pressing it to extract as much liquid as possible (Figure C). You can juice the strained pulp and add the resulting liquid back in.

At this point, you can age the hot sauce, but it's optional. I bought a one-gallon barrel, which is charred on the inside. I add the sauce, seal the barrel with a bung, and let it sit untouched for several months before bottling.

Once bottled, the hot sauce will separate with the solids settling on the bottom. Commercial sauces use xanthan gum or other ingredients to keep the sauce from separating. I take separation as a sign that the sauce is homemade, and requires shaking before use.

GOING FURTHER

You can add vinegar to the sauce, if you like. I don't. Vinegar is found in most commercial sauces. It adds flavor, but mostly helps as a preservative.

For more variation, you can add tomatoes, carrots, and other vegetables, which will temper the heat. You can also add spices. I like the full-on taste of the peppers themselves. Your hot sauce can be used as a topping on anything from meat to eggs to tacos, and can give soul to sauces and marinades, as well as beans and soups. In making your own hot sauce, focus not just on the hot part but also on creating a satisfying, strongly flavored sauce.

Written by Mike Laine **Time Required:** 24 Hours • **Cost:** $10–$20

CRYSTAL CLEAR ICE BALLS

COOL YOUR NEXT COCKTAIL WITH LARGE, BEAUTIFUL SPHERES OF ICE MADE WITH THIS SIMPLE TECHNIQUE

HERE'S AN EASY METHOD TO MAKE CLEAR ICE BALLS for soft drinks, cocktails, or a whiskey/rocks glass. One ball will keep a drink cool for at least 60 minutes, with minimal dilution compared to ice cubes of equal volume. Plus, it looks incredible in the glass.

The secret is directional freezing — cooling the water in such a way that any air bubbles are pushed out of the ball mold before it fully forms into ice. Normally, ice freezes from the outside in, forcing unseen air bubbles inward until they collect and cloud up in the center. Adding an insulated container, however, provides a reservoir of water that freezes slower than that in the non-insulated mold. This lets the freezing begin at the top of the mold and move downward, pushing air bubbles out into the reservoir instead of trapping them. The result? Crystal clear ice!

BE A BALLER

1. Fill insulated container to the top with bottled spring water. Tap water works too, but in my trials spring water produced the clearest ice.

2. Fill ice ball mold with spring water too (Figure A) and seal with finger.

3. Invert the ball mold (Figure B) and fit it snugly onto the filled container (Figure C).

4. Freeze for 24 hours and remove clear ice ball.

Store your ice balls in a zip-lock baggy until cocktail hour.

MAKE A SLOW-FREEZE JACKET

If your freezer is set to 0°F, your ice balls may still form too quickly and show some clouding. You can fix this by making an external insulation sleeve from sill foam (Figure D).

1. Measure and wrap 3 separate layers of foam around the container and ball mold, cutting the pieces at 45° for seamless wrapping.

2. Tape each layer in place, or use spray adhesive (with Goop adhesive on the seams) to make it permanent.

3. Add a cap of sill foam with a hole cut at an angle to expose the very top of the ball mold.

4. Fill mold with water, place on container, then slide the sleeve over the top and place in freezer.

See before-and-after photos and share your tips and tricks at **makezine.com/go/clear-ice-baller**

MATERIALS

- **Insulated food container, 10oz** The Thermos Funtainer works well.
- **Silicone ball mold, 2½" sphere, BPA-free**
- **Styrofoam Sill Seal Foam Gasket, 12"×36" (optional)** or similar closed-cell polyethylene insulation
- **Spray adhesive (optional)**
- **Goop adhesive (optional)**

TOOLS

- **Craft knife**
- **Scissors**
- **Tape**

MIKE LAINE retired in 2010 after 36 years in education. He enjoys traveling with his wife, building websites to help educate the world, and sipping the occasional Scotch with perfectly clear ice balls.

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D

Hep Svadja

SMART BEER FRIDGE

HACK A WII BALANCE BOARD TO TELL YOU HOW MANY BEERS ARE LEFT

Written by Jamie Bailey

Time Required: An Afternoon • Cost: $100–$500

TIRED OF WAITING FOR THE REFRIGERATOR OF THE "FUTURE"? The one that auto-magically tells you what's in it, and what to get when you go to the store? Dust off that old Wii Balance Board, grab a Raspberry Pi, and build the future yourself. Your smart beer fridge will tell you exactly how many bottles it has in it, how many beers you drank, and even when you drank them. Here's how it works.

1. HACK THE WII BALANCE BOARD

If we use a scale to weigh the refrigerator and its contents, then simple math will tell us how many bottles are present. The Wii Balance Board is the perfect solution. It fits perfectly under a compact fridge, measures up to 330lbs, and uses Bluetooth for communications. We just need a Raspberry Pi computer with a Bluetooth dongle to turn it into a scale. You can download the Python code from the project page at makezine.com/go/rasp-pi-beer-fridge.

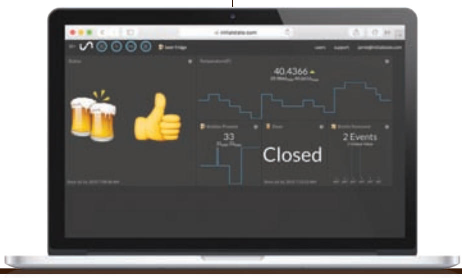
Two quick Balance Board hacks are needed: swap the batteries for an AC adapter, and tape a pencil to the bottom so you can use it to press the Sync button (without lifting the fridge!).

2. ADD A DOOR SENSOR

Tape the magnetic switch to the fridge door and connect it to GPIO pin 17 on the Pi.

3. CONNECT TO THE CLOUD

The Pi will stream all your refrigerator data to a cloud service, which turns it into a nice dashboard you can access from your laptop or mobile device. I used my account at Initial State (my company); you could also rework this project to use services like Temboo, Xively, and Google Cloud.



4. CUSTOMIZE YOUR USER SETTINGS

Open the Python script *beerfridge_make.py* and edit the User Settings to reflect the empty weight of your fridge, the weight per bottle (or can) of your favorite beverage, and the access key(s) for your cloud service.

5. RUN IT!

Run the final script:

```
sudo python beerfridge_make.py
```

Now every time you close your refrigerator door, the number of bottles present is calculated by weighing the fridge and its contents.

Go to your Initial State account and select the data "bucket" named Beer Fridge, then click Tiles to view your dashboard. Here you can see how many bottles are present and how many have been removed.

Switch to the Waves visualization to see the history of your data. I can see I drank two beers on May 25 at 7:57 and 9:28 p.m.; I can also see that while I was out of town on May 28, my underage nephew opened my beer fridge at 1 a.m., only to realize those new gizmos might just be snooping on his beer thievery habits. He thought better of taking a beer and closed the door. Ha!

GO FURTHER

Add a streaming temperature sensor, or a Raspberry Pi camera to snap a picture every time someone opens your refrigerator — in case you need to catch a beer thief!

Hep Svadja, Jamie Bailey

MATERIALS

- **Compact refrigerator** I used Frigidaire #FFBC46L2QS.
- **Wii Balance Board**
- **Wii Fit rechargeable battery pack with AC adapter**
- **Raspberry Pi single-board computer** Pi 2 Model B or newer, from the Maker Shed, makershed.com
- **Bluetooth adapter USB dongle** Amazon #B00JN5Y5E0
- **Magnetic contact switch** Adafruit #375
- **Breadboard with jumper wires**
- **Resistor, 10kΩ**
- **Felt pads, ⅜" (3)**
- **Pencil and tape**

TOOLS

- **Computer**

JAMIE BAILEY is a systems engineer with 14 years experience in product development, integrated circuit design, and software development. He is the founder and CEO of Initial State, an Internet of Things data startup company.

Get the complete how-to at makezine.com/go/rasp-pi-beer-fridge

Time Required: 2 Hours • **Cost:** $10–$20

Written by Ben Krasnow

FIZZIFY YOUR FRUIT

CARBONATE YOUR HEALTHY SNACKS WITH EFFERVESCENT TABLETS

WHEN YOU DRINK SODA, BUBBLES OF CARBON DIOXIDE (CO_2) CAUSE THE TINGLING SENSATION ON YOUR TONGUE. In addition to the physical sensation, the CO_2 combines with your saliva to produce carbonic acid, which is an important flavor component of carbonated beverages. If you've ever taken a swig of flat soda or beer, you'll know that the carbonation is really important.

For a healthy treat, you can add the sparkling qualities of CO_2 to fresh fruit in your own kitchen. You can achieve this with solid CO_2 (dry ice), but it has to be measured very carefully due to the pressurized nature of this project. Using effervescent tablets like Alka-Seltzer is a great alternative since they have a long shelf life and produce a known quantity of CO_2.

1. ADD TABLETS

Add 4 effervescent tablets to the container (Figure A). This will produce a pressure of 20psi at room temperature in the 1-quart container. Don't add more than 4 tablets, or the excess pressure could pop the lid off. If your container is smaller than 1 quart, scale the number of tablets accordingly.

2. CUT AND ADD CUP

Cut off the top of the disposable plastic cup so that it is just a few inches tall. Then cut down one side and halfway across the bottom (Figure B). Push the collapsed cup into the container, with the bottom facing up (Figure C).

3. CUT AND PLACE FRUIT

Cut up some fruit and place on top of the cup (Figure D). Keep the fruit from falling or it will absorb some of the aspirin and the flavor will suffer.

4. ADD WATER AND LID

Add ¾ cup water (Figure E), and quickly screw on the lid. Tighten firmly, but don't overdo it.

5. CHILL AND ENJOY

Chill the container in the fridge for a few hours, or preferably overnight. Slowly open the container, and enjoy your fizzy fruit right away! You can put your fizzy fruit through these steps again for extra fizz.

CAUTION:
This is a high-pressure project. Use plastic instead of glass, and keep the lid pointed away from yourself and others.

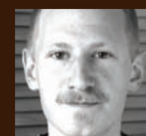
OPTIONAL: You can add a pressure gauge to read the PSI. Drill a hole in the lid with an R-sized drill bit and clean it with a sharp knife. Using a hand drill or pliers, screw the pipe tap about ¾ of the way into the hole to cut threads into the plastic, then remove. Finally, screw the pressure gauge into the tapped hole, being very careful to align the threads properly.

MATERIALS

- **Plastic bottle, 1-quart, wide mouth** such as Nalgene 32oz Tritan
- **Effervescent tablets** such as Alka-Seltzer
- **Fresh fruit** apples, grapes, pears, etc.
- **Disposable plastic cup**
- **¾ cup water**

TOOLS

- **Pipe thread tap, ⅛" (optional)**
- **Drill bit, size R (optional)**
- **Pressure gauge (optional)** McMaster-Carr #3847K71



BEN KRASNOW works at Google[x] creating advanced prototypes, and previously developed virtual reality hardware at Valve. Follow his personal projects at Applied Science: youtube.com/bkraz333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E

Hep Svadja, Ben Krasnow

1+2+3 EDIBLE MILK JUG SURPRISE

Written by Anthony Lam

CAST A CHOCOLATE BOTTLE THAT LOOKS JUST LIKE THE REAL THING

EVER HAVE KINDER SURPRISE EGGS WHEN YOU WERE GROWING UP? I did, and they made eating chocolate awesome! This project is a similar surprise, but instead of little toys, we'll fill it with M&M's. And for our mold we'll use a milk jug, to create a white chocolate bottle that looks just like the real thing. This project is not only a fun cooking session, it's a good introduction to mold-making and casting.

1. MELT IT

Put the chocolate in your heatproof bowl. (In a pinch, you can use a Mason jar.) Melt it slowly in the microwave (heat 1 minute, stir, then 15-second intervals) or on the stove (pour 2" of water into a pot, simmer, then set the bowl on top), stirring occasionally, until it becomes liquid. Take care not to get any water in your chocolate, as this can change the texture.

2. POUR IT

Don your oven mitts to pick up the bowl and pour some melted chocolate into the milk jug. Immediately, turn the container all around so that the chocolate covers the inside completely. Repeat this process a couple of times to make sure the walls aren't too thin, so they won't break when you pull the chocolate out of the jug.

When you've covered the whole surface well, place the container in the fridge and let it cool for a good 10–15 minutes.

3. RELEASE IT

When the chocolate is chilled, use an X-Acto knife to carefully cut the container away without damaging the chocolate. (I tried pre-cutting and taping my jug so this would be easier, but it didn't work much better than just cutting the jug away.)

Gently reapply the label to your new chocolate bottle and fit the cap back on.

Fill your look-alike bottle with treats (or tiny toys), cap it, and surprise someone. You can pour the treats out, or just break the bottle open — and eat it!

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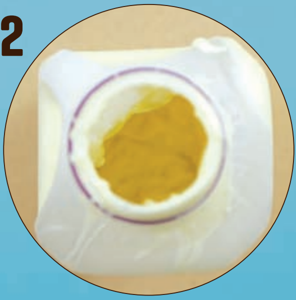

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TIP: You can do the same trick with a Coke bottle and bittersweet chocolate!

ANTHONY LAM is a former engineering intern for *Make:*. An industrial designer by trade, he is easily excited by anything regarding technology, DIY projects, or video games.

Hep Svadja, Anthony Lam

Time Required: 2–3 Hours

Cost: $20–$30

You will need:

- **Small milk jug, rinsed and dried** Save the cap and the label.
- **White chocolate chips or baking bars**
- **M&M's or other treats** to fill the finished bottle
- **Microwave oven, or stove and saucepan**
- **Heatproof bowl** a little bigger than your pot. Or use a double boiler.
- **Spoon**
- **Oven mitts**
- **X-Acto knife**
- **Tape (optional)**

Skill Builder

TIPS AND TRICKS TO HELP EXPERTS AND AMATEURS ALIKE

GREASY DOES IT

IS YOUR ROBOT GRINDING TO A HALT? Have a door that makes an annoying *SQUEEEAK* every time you open it? Don't reach for the WD-40 yet! In general, the most common application of a lubricant is to reduce friction between surfaces, but not all lubricants are equal. In this handy guide, we'll go over a few of the most common lubricants, how they work, and when to use them.

A layman's guide to using common lubricants the right way WRITTEN BY HARRY TUTTLE

OILS

Oils are thin liquids made of long polymer chains, with additives for various extra properties. Common additives include antioxidants to keep the oil from oxidizing, corrosion inhibitors to prevent parts from corroding, and detergents to keep deposits from forming. These long chains are hard to squeeze out from between surfaces, making oils useful as a slippery barrier between them. Oils come in different "weights" (such as 5W or 10W), which correspond to viscosity. The lower the number, the thinner the oil, and the more easily it will flow.

USES: Hinges, bearings, tool maintenance, sharpening blades

TYPES: Motor, 3-in-1, sewing machine, bar and chain

USE WHEN:

- You want to lubricate something without the resistance inherent in using grease
- You need lubrication to wick into a small space, without having to take anything apart

DO NOT USE WHEN:

- The surfaces being lubricated are exposed to dust or dirt, which can eventually gum up and cause more friction
- You need to keep things around the surfaces clean, because oils are low in viscosity and thus tend to drip and run
- The surfaces are exposed to water or anything that can wash the oil away. It won't last long! (While oil can help make things water resistant, it can also absorb water over time. The more water that absorbs into the oil, the lower its adhesion will be, causing it to wash off of the very parts that need lubrication.)

Hep Svadja

GREASES

Greases are made by using oil (typically mineral oil) and mixing it with thickeners (such as lithium-based soaps). They may also contain additional lubricating particles, such as graphite, molybdenum disulfide, or polytetrafluoroethylene (PTFE, aka teflon). Greases combine the lubricating properties of oils with added stickiness, allowing the lubricant to adhere to the surfaces better. Greases can even act as a barrier, protecting the surfaces from contaminants that can corrode or damage them. Like oils, greases come in a range of consistencies, from ketchup-thin to thick like cheddar cheese. One downside to grease is that because it's so thick and sticky, it can cause resistance in small or fast-moving mechanisms.

USES:
Gears, bearings, chains, linkages

TYPES:
White lithium, marine, silicone

USE WHEN:

- You need lubrication to stay put and stick to surfaces for a long time
- You want to seal out contaminants such as water or dust
- You use a machine so infrequently that you may forget to oil it

DO NOT USE WHEN:

- You have fine or fast-moving mechanisms where thick grease would create too much resistance
- You don't want a mess. When parts move, they can fling grease all around, so it may not be the best option for keeping things clean

PENETRATING LUBRICANTS

Any shade-tree mechanic would agree that these types of lubricants deserve their own special section. Penetrating lubricants are the saviors of many stuck-bolt combatants, loosening years of rust and debris in minutes. Contrary to the other substances covered here, penetrating oils are *not* designed for long-lasting lubrication. Instead, they are low-viscosity oils with additives that are specifically designed for one purpose: to infiltrate the tiny cracks between surfaces (such as screw threads), add lubrication, and break up rust.

There are a lot of different penetrating oils out there, but did you know that you can make your own low-cost penetrating oil that outperforms almost all of them? In an experiment conducted by Drexel University engineering students, they found that a mixture of vegetable oil and acetone works as well (or better) than WD-40 at loosening stuck bolts.

It's easy to make! Just mix up a solution that's 90% vegetable oil and 10% acetone, and squirt it wherever necessary. Be careful when mixing, as acetone is flammable, and will melt many plastic containers. If possible, use a glass or metal container to mix it, or buy an oil can to make things even easier. Also, be sure to shake the mixture before each use, as acetone and vegetable oil tend to separate over time.

WHY SHOULDN'T I USE WD-40 ON EVERYTHING?

WD-40 actually stands for "Water Displacement formula 40," and while it can help loosen rusty bolts, the film of oil left behind isn't nearly enough for good, long-lasting lubrication. You might find that the troublesome squeak subsides for a little while, but soon enough you'll have to go spray it away again. Using the right lubricant the first time will ensure that the problem is solved long enough for you to forget all about it. Save the WD-40 for what it does best: light lubrication, cleaning, and freeing stuck-together Lego bricks.

USES:
3D printer rails, threaded rods, locks, hinges

TYPES:
Graphite powder or spray, molybdenum disulfide spray, (dry) silicone spray, PTFE spray

DRY LUBRICANTS

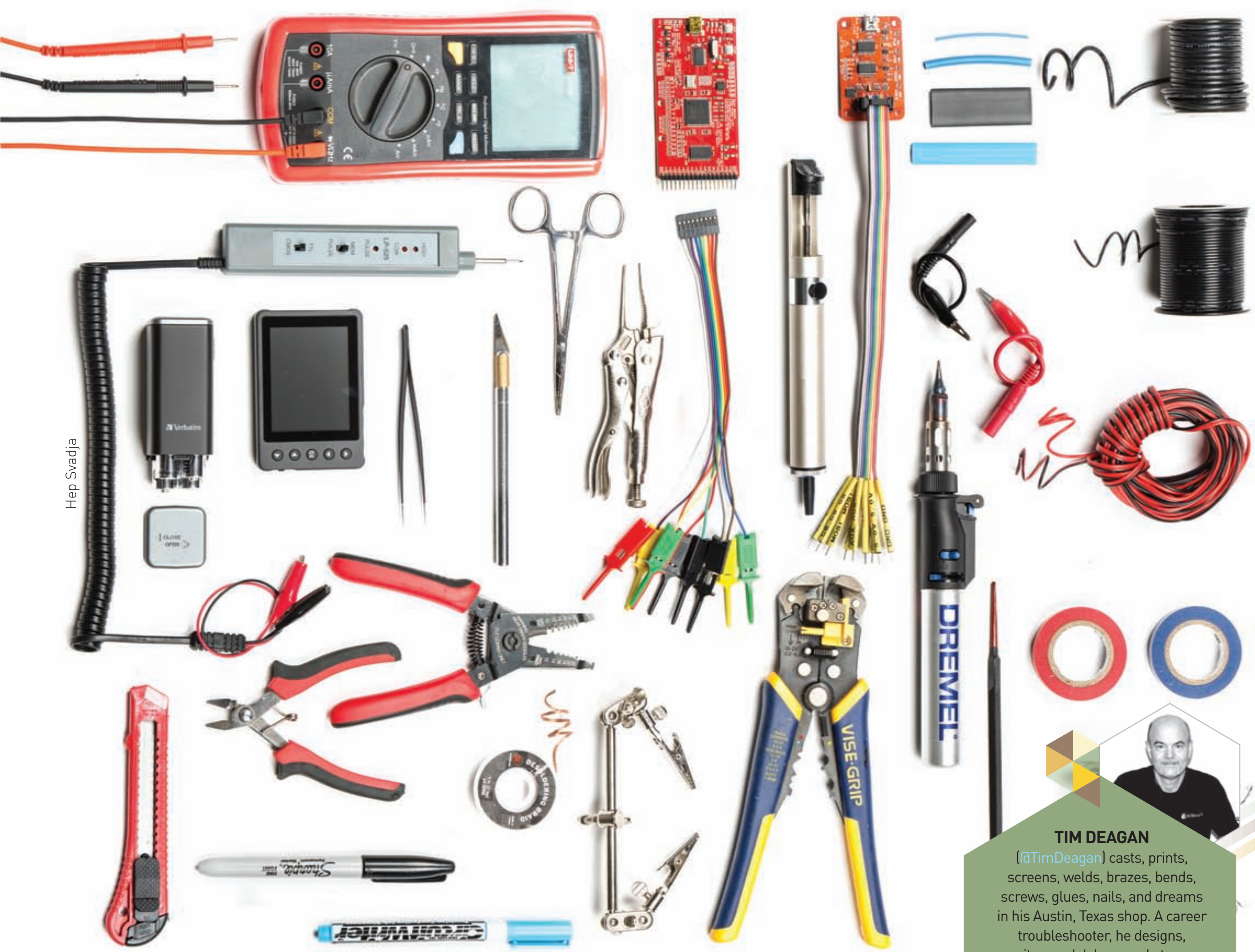
Dry lubricants are made up of lubricating particles such as graphite, molybdenum disulfide, silicone, or PTFE. At the molecular level, these particles are super slippery, so they reduce the friction between surfaces in contact with one another. It's common to find these lubricants in spray form, where they are mixed with water, alcohol, or some other solvent that will evaporate away after application, leaving behind a thin film.

USE WHEN:

- You have tiny parts that shouldn't be gunked up by grease or oil that will attract dust
- You need to keep surrounding surfaces clean
- Your surfaces are exposed to extremely high heat or pressure, which would typically oxidize oils

DO NOT USE WHEN:

- Your surfaces are exposed to solvents or other liquids that can wash them away



Hep Svadja

TIM DEAGAN
(@TimDeagan) casts, prints, screens, welds, brazes, bends, screws, glues, nails, and dreams in his Austin, Texas shop. A career troubleshooter, he designs, writes, and debugs code to pay the bills. He has written for *Make:* magazine and *Nuts & Volts*, *Lotus Notes Advisor* and *Database Advisor*.

Tim Deagan

FIX-IT FIELD KIT

What to pack to make quick electronics repairs on the go

WRITTEN BY TIM DEAGAN

IF YOU TAKE YOUR ELECTRONIC PROJECTS OUT INTO THE WILD, YOU'LL PRETTY QUICKLY WANT TO HAVE A REPAIR KIT FOR THE INEVITABLE BREAKDOWNS. My personal kit covers almost any kind of electrical or microcontroller project, and while it won't win any prizes for neatness, it packs a lot of useful stuff into a travel-friendly toolbox.

The layout isn't critical, but internal separation is useful, if only to speed retrieval of smaller items. Water resistance is also a big win — many times weather conspires with breakdowns and I find myself having to pull my box out of the rain or mud.

Here's an overview of what I carry and why, to give you a better idea of how to prepare your own repair kit. Happy fixing!

Hep Svadja

A WIRE in various gauges is a necessity. I carry 16 and 24 gauge in both stranded and solid core, and some heavier gauge in case I'm wiring a heavy load.

B HEAT-SHRINK in every size up to ½".

C ELECTRICAL TAPE is great for marking. A few colors do wonders when labeling or distinguishing wires.

D DUAL-STRAND RED/BLACK WIRE I go through a lot for running power.

E SOLDER is a must, somewhere in the .032" (20 gauge) range.

F WIRE WRAP comes in handy when jumpering or soldering to surface-mount components.

G AUTOMATIC WIRE STRIPPER I carry one in my kit at all times.

H BUTANE-POWERED SOLDERING IRONS are something I now cannot live without. They generally come with a torch tip that's great for heat shrink. Extra fuel is a must — a small butane bottle will keep you soldering for days.

I DESOLDERING BRAID I'll always carry it, but many folks prefer a **J SOLDER-SUCKER**, which can be easier to use.

K HELPING HAND SPRING CLAMPS can make an impossible job possible. They'll usually fold up tight to take up less room.

L BUS PIRATE This universal interface talks through a serial connection to 1-wire, I2C, JTAG, MIDI, SPI, PC Keyboard, LCDs, and more. It's an incredible protocol Swiss army knife.

M DSO NANO V3 OSCILLOSCOPE is a 32-bit digital scope and signal generator running at 1 MS/s with a 200kHz analog input.

N BATTERY-POWERED USB OUTLET

O OPEN BENCH LOGIC SNIFFER is a tiny 32-channel logic analyzer that lets you trigger on and watch up to 32 digital channels.

P LOGIC PROBES are useful portable tools for troubleshooting micro-controller circuits. They detect a high, low, or pulsing value on a pin or contact. Knowing the state of your pins is key to understanding what your Arduino or GPIO is doing. A multimeter works, but it's a clumsy cousin to the elegance of a logic probe.

Q CIRCUIT WRITER allows me to draw a conductive trace for a simple fix.

R PERMANENT MARKERS are useful for labeling.

S FLUSH CUTTERS A good pair is critical. They're great for cutting wire, but essential for cutting the tails of leads sticking through the bottom of a PCB.

T **CRIMP TERMINALS AND A DECENT CRIMPING TOOL** I carry a range for when I want a more permanent connection.

U **MULTIMETER AND TEST LEADS**

V **TWEEZERS** capable of gripping surface-mount tinies are also a must-have.

W **ALLIGATOR AND/OR PIN CLIPS** to attach the probes, so you can still use both hands. Don't rely on probes alone.

X **TRIANGULAR FILE** can shape metal and clean contacts in a way that nothing else will.

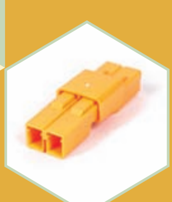
Y **BOX CUTTER** for heavier cutting, carving, and stripping.

Z **SMALL VISE-GRIP PLIERS** and a surgeon's **AA** **HEMOSTAT** to grab, hold, and squeeze things.

BB **X-ACTO KNIFE** for fine work.

CONNECT IT QUICK

QUICK SPLICE CONNECTORS Made by Scotchlok, these let you tap into a line you can't cut.

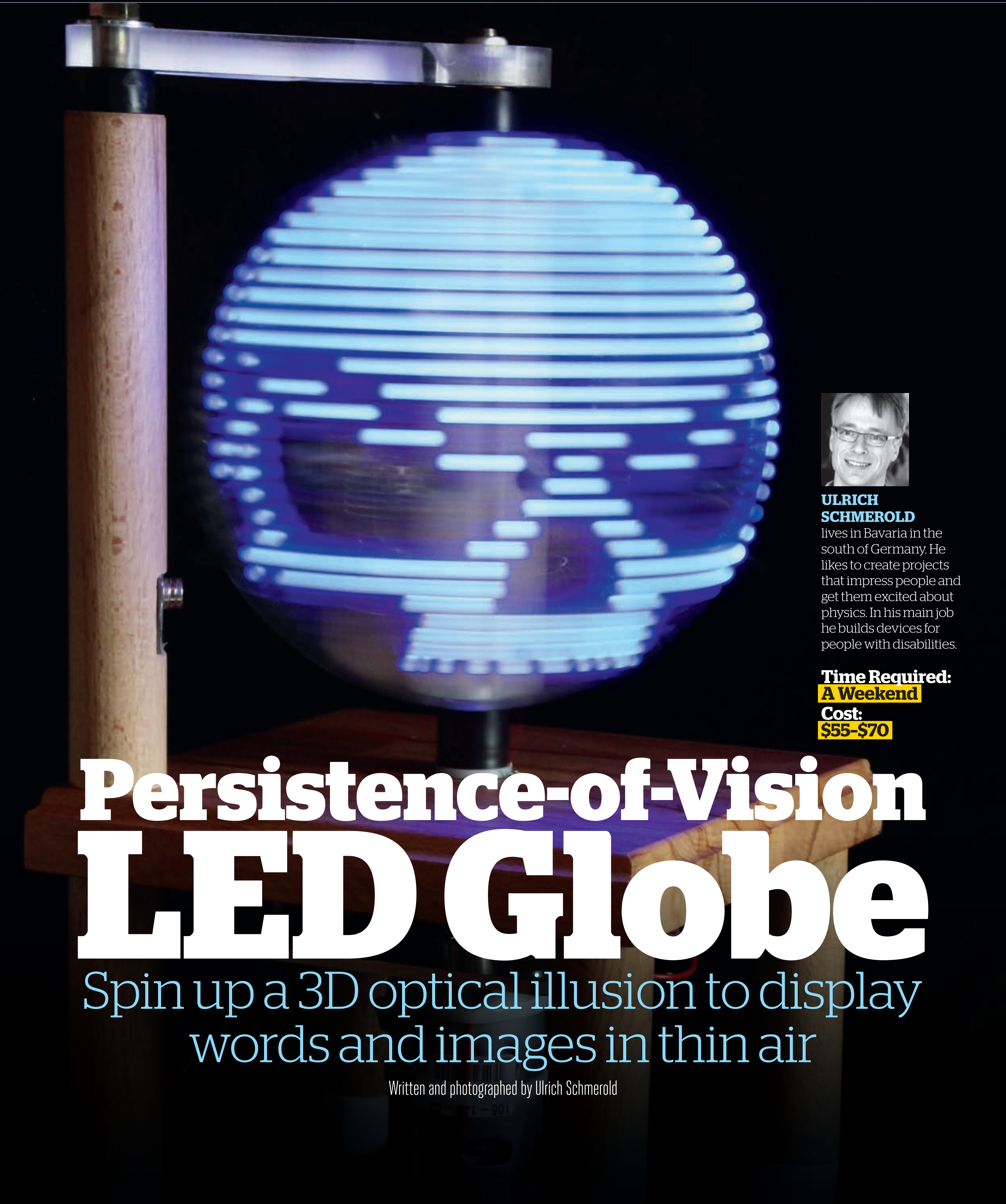


IDEAL LUMINAIRE DISCONNECT POWERPLUGS I really like these push-in plugs for 12–18 gauge wires. They're designed for residential fluorescent lighting ballasts, but work great when you need an easy way to plug and unplug something inside a case. Like all push-in connectors, they prefer solid core wire, but you can tin the tips of stranded wire and make them work.

ANDERSON POWER POLES I love these for creating strong, durable power connections. They come in all sizes (up to versions that can handle 350A!) but the smallest size shell will take the contacts for 15, 30, or 45 amps, so I carry those and a range of contacts.

TRADITIONAL WIRE NUTS come in handy in a lot of situations, so I carry a bunch of different sizes.

WAGO LEVER NUTS I've fallen hard for these. They let you easily connect and disconnect multiple wires.



Persistence-of-Vision LED Globe

Spin up a 3D optical illusion to display words and images in thin air

Written and photographed by Ulrich Schmerold

ULRICH SCHMEROLD lives in Bavaria in the south of Germany. He likes to create projects that impress people and get them excited about physics. In his main job he builds devices for people with disabilities.

Time Required: A Weekend

Cost: $55–$70

Materials

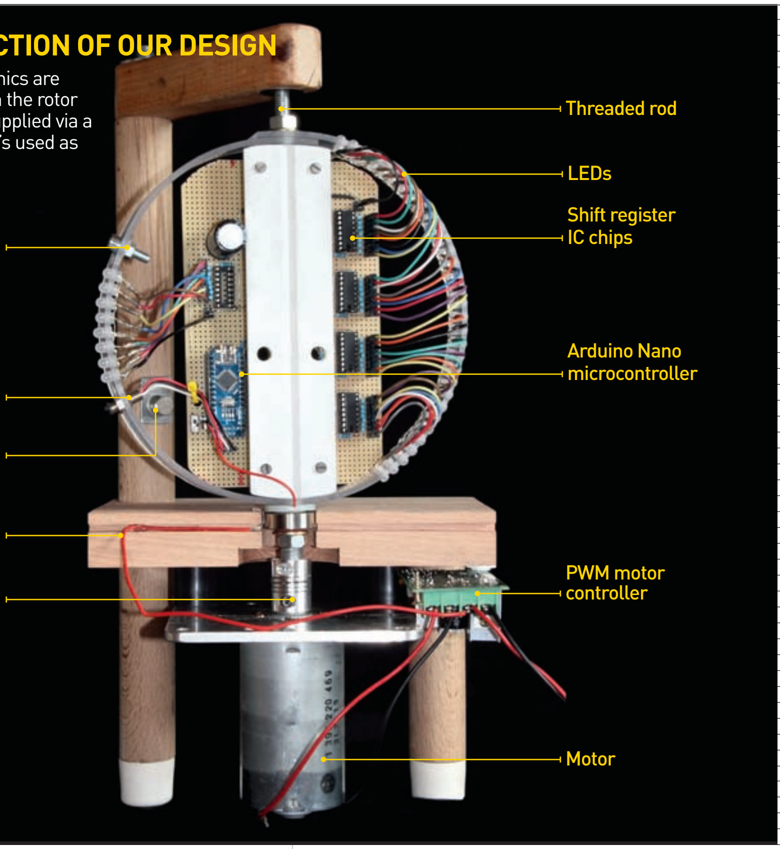
- » **Polycarbonate plastic or aluminum strip, 20mm wide** for making the rotor. We used 3mm-thick polycarbonate.
- » **LEDs, blue (40)**
- » **Resistors, 100Ω (40)**
- » **Arduino Nano microcontroller board**
- » **Shift register IC chips, 74HC595 (5)** Adafruit Industries #450, adafruit.com
- » **Capacitor, electrolytic, 2200μF 16V**
- » **Diode, 1N4004**
- » **Perf board with solder pads** clipped to 160mm×100mm
- » **Jumper wires, female-female, 20cm (30)** We used Dupont-style ribbon cables; you can split off the quantity you need.
- » **Heat-shrink tubing**
- » **Headers, male, breakaway (40)** for LED jumpers
- » **Headers, female, 1×15 (2) (optional)** for Arduino
- » **Copper wire, 20 gauge or so**
- » **Screw terminals (2)** for power wires
- » **Hall effect sensor, unipolar, non-latching** like from a fan motor; Honeywell #SS441A or Infineon #TLE4905L E6433
- » **Neodymium magnet**
- » **Your choice of hardware** for attaching circuit board to threaded-rod axis. We used a flanged aluminum tube from Alfer (bit.ly/29R5OtI) that's hard to find. You can try 8mm pipe straps and epoxy, or improvise a different solution.
- » **Large DC motor, high RPM, 12V, 5A, about 30W** You want at least 1,080rpm (18 frames per second) to create smooth animation. We used Pollin #310529; in the USA you can try Amazon #B00NLBFOIS, with a 5mm shaft, or look for similar on eBay.
- » **PWM motor controller, 12V 5A**
- » **Threaded rod, M8** with 4 nuts and washers
- » **Ball bearings: 608ZZ (5) and 6000ZZ (1)** Four of the 608s are for balance testing only.
- » **Flexible shaft coupling, 8mm × 5mm** or whatever fits your motor shaft. McMaster-Carr (mcmaster.com) is a good source.
- » **Nylon wall anchor** for 8mm screw. We used Fischer S10.
- » **Insulating M8 washer** or regular washer and a ⅜" gasket or faucet washer
- » **Banana jack, 4mm**
- » **Glue**
- » **Vibration damper (optional)** We used a doorstop; you could try silicone pads.
- » **M3 screws and nuts** for balance weights
- » **Wood, various** for making a globe stand

Tools

- » **Drill with bits** Use a drill press if you can, and get a 4.9mm bit to fit 5mm LEDs.
- » **Woodworking and metalworking tools**
- » **Soldering iron**
- » **Heat gun or hair dryer**
- » **Oven, clay flowerpot, and metal clamps** if you're bending polycarbonate
- » **Wooden disc and vise** if you're bending aluminum
- » **Computer with Arduino IDE software** free download from arduino.cc/downloads

CROSS SECTION OF OUR DESIGN

The LED electronics are fully contained in the rotor ring; Power is supplied via a ball bearing that's used as a slip ring.



MAYBE YOU'VE SEEN A PERSISTENCE-OF-VISION (POV) ILLUSION BEFORE: an array of bright LEDs on the spokes of a spinning bicycle wheel that magically paints colorful animations, light effects, and messages in the night. These visual effects are always good for a "Wow!" — but we'll go them one better and build a 3-dimensional illusion: the POV Globe.

The term *persistence of vision* refers to a phenomenon of human vision: a light stimulus lingers as an aftereffect on the retina for about 1⁄10 of a second. When light stimuli are sequenced in rapid succession, they merge into one continuous image. Scientists still argue how much of this phenomenon is shared between the eye and the brain, but the effect is real — in fact it's the basis for film and television.

In most POV displays, a linear (1-dimensional) array of LED lights rotates around a single point, like a bike wheel. By measuring their rotation rate and controlling their flashes with millisecond precision, we can create the illusion of a 2-dimensional image lingering in thin air.

In our POV Globe, we're adding a new dimension. We rotate a curved array of LEDs around a rotational axis, like a planet. When the flashing LEDs draw images in the air — say, the continents of the Earth — the result is a 3-dimensional, spherical illusion: a globe! Of course, our globe can make other images — like the Death Star from *Star Wars*, a skull, or the *Make:* logo — appear magically in the room. It all depends on the perfect timing of the LEDs.

This project has 4 main parts: the electronics, which control at least 24–40 LEDs using an Arduino Nano microcontroller and 74HC595 shift registers; the POV Calculator software that breaks down an image into a bit-pattern that your globe can display; the Arduino sketch that breaks this pattern into segments and sends it to the shift registers; and, finally, the mechanics that rotate the LEDs. It's a moderately difficult project, but with a little experience on the soldering iron and some woodworking and metalworking skills, it can be accomplished in a weekend.

The microcontroller's job is to issue a predetermined pattern of binary pixels to the large number of LEDs. This data must be sent synchronously with the ring's rotation, triggered by a magnetic field sensor (a Hall effect probe). But the Arduino has relatively few output pins, so we resort to a trick: We use simple shift register chips,

The mechanics: bent and drilled polycarbonate rotor, ball bearings, M8 threaded rod, aluminum flanged tube, flexible shaft coupling, and fasteners.

which collect the serially transmitted data (8 bits per chip) and on command make the data parallel (available all at once) at their output pins. This strategy takes advantage of the Arduino's high-speed serial (SPI) pins, requires much less programming effort, and greatly simplifies the wiring.

This build is just a suggestion. Once your first globe is working, you're sure to come up with ideas for extensions or modifications. We couldn't stop at just one!

THE ROTOR RING

To make the rotor ring, you can use aluminum bar stock from the hardware store, but it may tend to buckle when bending. As a nice-looking alternative, we also tried polycarbonate plastic (trade name Lexan or Makrolon), 20mm wide and 3mm thick — it was flexible enough and problem-free to work with (Figure A).

Avoid acrylic (plexiglass); it tends to splinter or stick when drilled, and the globe's centrifugal forces could cause it to crack and fail.

Before bending, holes are drilled for the LEDs, the Hall sensor, the central axis, and the balancing weights. If you use a 4.9mm drill bit, you can press-fit 5mm LEDs tightly into the ring without glue.

The more evenly the holes for the LEDs are placed, the better the globe image will be. Since our drill press runs true (and center-punching plastic sucks) we made a small drilling template from aluminum scrap, with 7 holes spaced 6mm apart (Figure B). After drilling 7 holes, we advanced it and drilled again, aligning it by putting an LED in the last hole drilled (Figure C). Thus we succeeded in very accurate (and stress-free) drilling.

As a guide for bending our polycarbonate strip, we used a clay flowerpot approximately the diameter of our rotor ring. We wrapped the plastic strip onto this and fixed it with metal clips, then baked it in a kitchen oven for 10 minutes at 340°F (170°C). The result was a very evenly shaped rotor ring (Figure D).

For our aluminum version, we sawed a wooden disc and curved the aluminum strips around it (Figure E). The diameter of the disc should be at least 20%–30% smaller than the desired rotor diameter, since the aluminum strips spring back somewhat after bending.

THE LEDS

For easier assembly and repair, we didn't solder the LEDs to the circuit board, but connected them with female jumper wires. These come with a connector on each end; since we need just one connector per lead, we cut them to make 2 leads from each jumper (Figure F). The cable ends are stripped a few millimeters and a piece of heat-shrink tubing is slipped over each one.

On each LED, the positive lead (anode, the longer leg) is bent outward at a 90° angle. The negative lead (cathode, shorter leg) is cut to 5mm–7mm in length and bent into a small eyelet. Then the positive lead is trimmed to 10mm–15mm long and the stripped cable end is wound around it, soldered in place, and insulated with the heat-shrink (Figure G).

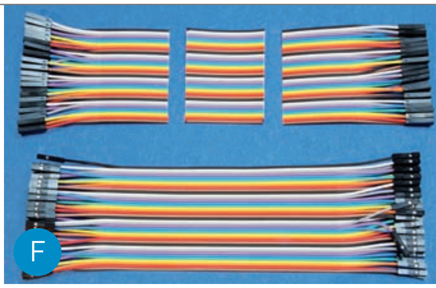
IMPORTANT: Because these connections could easily be broken by the globe's high centrifugal forces and air resistance, we're leaving the LED leads fairly long. Together with the heat-shrink, this offers some stress relief. After soldering and shrinking, test each LED to ensure that all is in order.

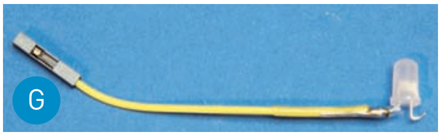
Now the LEDs are pressed with a screwdriver into the prepared rotor ring. If you drilled a hole larger than 4.9mm you'll need a little glue. Lastly, the cathode legs are soldered together with copper wire (Figure H) and connected to the ground (GND) of the circuit board.

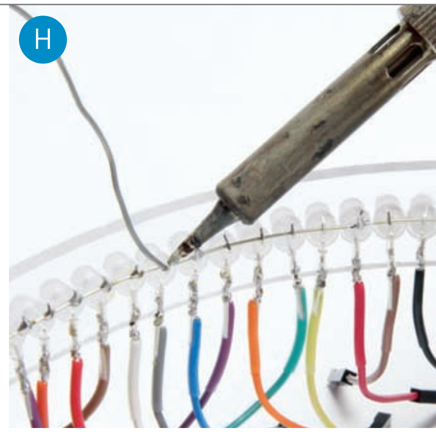
"IGNITION TIMING"

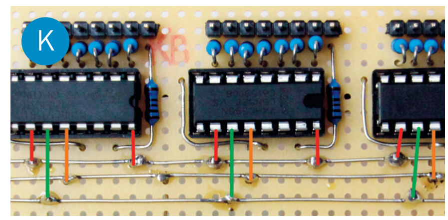
When the globe is spinning, the bit-pattern that's output to the LEDs must always begin at precisely the right instant. The purpose of the Hall sensor mounted on the ring is to fly past a stationary magnet with each revolution. This triggers a hardware interrupt on Arduino pin D2, providing the "ignition timing" for starting each output. The output frequency is also calculated from the rotational speed so that the pattern can be sent at a matching speed.

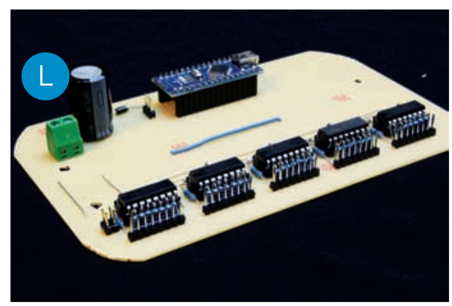
Since the direction of the magnetic field doesn't change, only a unipolar Hall sensor will work (Figure I). The sleeve of a 4mm banana jack makes a perfect holder for the fragile sensor (Figure J); using its panel mounting nuts, you can adjust the distance to the magnet during final assembly. The sensor we protect with a drop of glue.











The shift register connections follow a simple scheme, which facilitates the wiring.

Our globe is controlled by an Arduino Nano. Since it has only 13 output pins and we've got 40 LEDs, we'll use its SPI pins D10, D11, and D13 to control our 74HC595 shift registers. This makes it possible to drive a lot of LEDs on only 3 pins.

Each set of 8 LEDs in our globe is driven by one 74HC595 chip. (Ideally, your total number of LEDs should be divisible by 8.) The brighter the LEDs for a given power, the better. Blue and white LEDs generally achieve the highest brightness.

The blue LEDs that we used take 3V–3.4V at 20mA current. With our 5V supply voltage, they'll each need a current-limiting resistor of 100Ω. The datasheet for the 74HC595 tells us it can withstand a maximum 70mA total current. If all 8 LEDs are turned on, theoretically 160mA would flow through a shift register, but we measure only about 70mA, and everything works alright.

For a super-bright LED version, we recommend you control the LEDs through additional drivers. An open collector Darlington driver like the ULN2803 would work; use a common anode on the supply voltage instead of a grounded cathode.

POWER SUPPLY

Power is supplied to the shift registers and LEDs via the voltage regulator on the Arduino. Since this can provide a maximum 500mA, we're limited to 7 shift registers and 56 LEDs. For more LEDs, you can add a separate 5V regulator (see the project page online for details); this also applies with the aforementioned power drivers.

Since power is not always transmitted smoothly through our globe's ball-bearing "slip ring," we buffer the voltage in a 2200µF electrolytic capacitor. This then transmits power to the voltage regulator pin (Vin) of the Arduino and operates the built-in voltage regulator in the opposite direction. We protect the Arduino with a diode, but still — it's an impermissible operating status that may well "Void Your Warranty."

WIRE IT UP

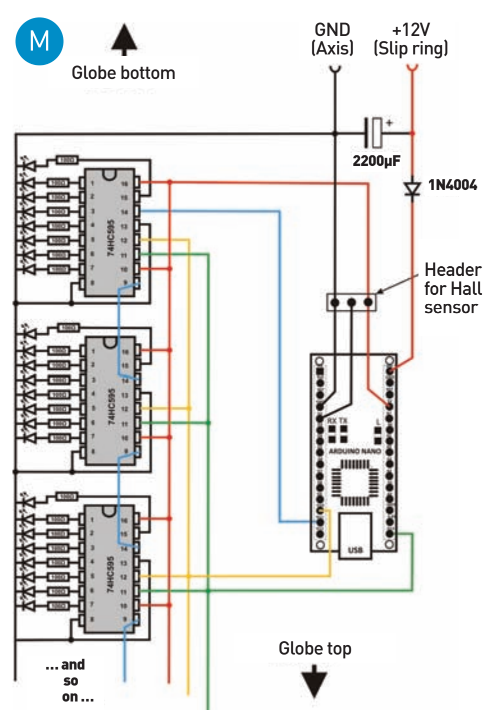
This circuit is easy to wire on plain perf board (Figures K and L). You can relocate the mounting holes and the components for even better balance — more on that later.

We clipped the corners of our perf board to fit in our rotor ring, then we distributed the IC sockets for the shift registers evenly on the right side. Leave at least 3 or 4 holes between each socket; you'll need the space for soldering components.

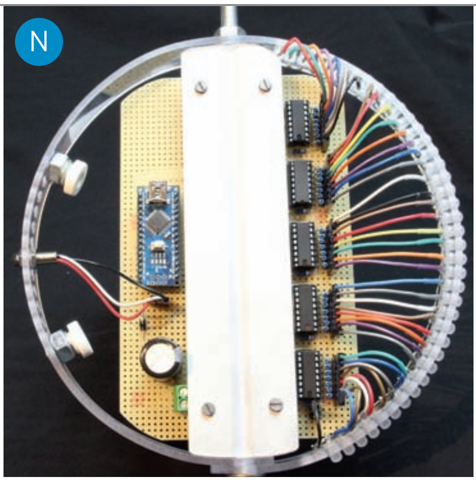
Carefully position the 74HC595s so that their outputs QB–QH (pins 1–7) face the board edge, which allows you to have a shorter connection to the male headers for the LED cables. Between the chip outputs and headers, we soldered 100Ω resistors standing upright, to save space. For output QA (pin 15) on the other side of the chip, there's room to solder its resistor flat.

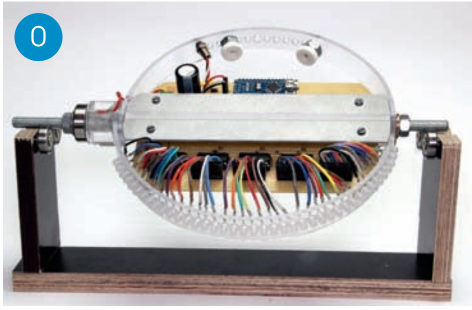
The shift registers require common lines for ground (GND pin 8 and G or OE pin 13), supply voltage (VCC pin 16 and SCLR pin 10, the red line in Figure M), SPI clock signal (SCK pin 11, green) and register clock or latch release (RCK pin 12, yellow). These signals are passed along as a kind of tapped bus to all shift registers.

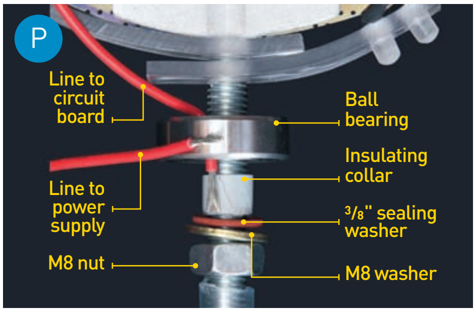
The serial data from the Arduino reaches the serial input of the first shift register (SER pin 14, blue) and then the data cascades from IC to IC — from the Q'H output (pin 9) of one to the SER input of the next one. In theory you could chain dozens of these chips together, but you only need 5 or 6 to control 40 or 48 LEDs.



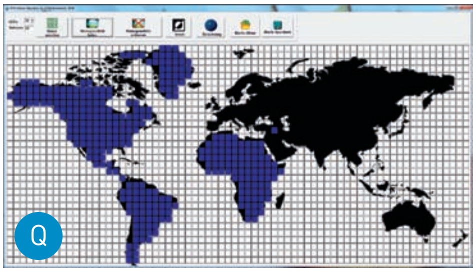
The circuit diagram for controlling the LEDs.







DIY "slip ring" details: The ball bearing itself is used as a conductive slip ring to supply power to the circuit board. Clamping the wire strands is sufficient for reliable contact to the bearing, when it's pushed down over the insulating collar. The axis rod serves as grounding.



On the left side of the circuit board, the Arduino and the remaining components are soldered. We mounted the Arduino on female headers so we can easily exchange it if we accidentally destroy one.

BALANCING THE ROTOR

To support the circuit board, we found an 8.5mm aluminum tube with two flanges at the hardware store (Alfer #26228), but it's only sold on the industrial market. You'll have to wrangle something similar on your own to attach the board to the M8 threaded rod that serves as an axis.

For rotor balancing, we screwed 4 ball bearings onto a small wooden frame, suspended the rotor on these, and adjusted the weight ratios until the rotor could stop in any position ("indifferent" equilibrium). We had already drilled holes opposite the LEDs to affix nuts and washers (and the Hall sensor) as a counterweight (Figures N and O).

This static balancing, however, does not replace dynamic balancing during operation; that can only be done experimentally with the finished globe. Patience is needed so that placement of weights on the speeding globe does not cause it to wobble like a failed washing machine.

SUPPLYING FLYING POWER

Now we have to get power to our rotating circuit board. Since we could not find a suitable slip ring, we made an unconventional solution — using a ball bearing as a slip ring instead (Figure P). Grounding is no problem; we use the motor housing and the threaded-rod axis for that. The supply voltage, however, comes through the ball bearing itself, which must be isolated from the axis for this purpose.

To make our insulating spacer ring, we cut the neck off a nylon wall anchor and pushed it between the bearing's inner ring and the threaded rod. A 3/8" faucet washer from the plumbing aisle insulates the bearing from the M8 nut.

As a drive for our rotor we used a beefy DC motor (Pollin #310529). The speed is regulated by a PWM motor controller for DC motors; we found one for just under $7 on eBay. Since perfect alignment of the rotor axis and motor shaft is very difficult to achieve, we use a flexible shaft coupling.

We installed doorstoppers on the stand's feet as a vibration damper.

For the first tests we mounted the shaft at the upper end too, so we could run the globe even though the rotor wasn't perfectly balanced. In our final version, we have omitted the "tree" (and the upper bearing) entirely.

TIP: Threaded rods under tension tend to become distorted, so don't tighten the nuts too tightly. Alternatively, you could substitute ordinary 8mm steel rod, threaded only at the ends.

POV CALCULATOR

To display, for example, continents on the globe, we need to turn our image into a bit-pattern that can be readily integrated into an Arduino sketch. I wrote the software POV Globe Calculator (PC only) to make this easy. You can download it from the project page at makezine.com/go/pov-led-globe.

After starting the software, you'll set the resolution of your globe: vertical (number of LEDs) and horizontal (how many vertical segments you want to draw). Then click on New Grid in the top left corner. Load a background image if you wish, then left-click on the pixels of your grid to draw them in (blue) or right-click to delete them again (Figure Q). Clicking Invert will reverse them all.

When you're done, click the Calculate button to automatically generate the code for your LED array. Just copy it into your Arduino sketch, or store it for later revision.

FAST SERIAL OUTPUT

As we've mentioned, to produce a flickering display that's stable in mid-air requires perfect timing of the LEDs. In our first experiments we used the Arduino's `ShiftOut` command to supply the shift register with data, but it was visibly faulty at higher speeds. Upon inspection we learned that `ShiftOut` is realized with the slow-walking `digitalWrite` command. There had to be a more positive and elegant method.

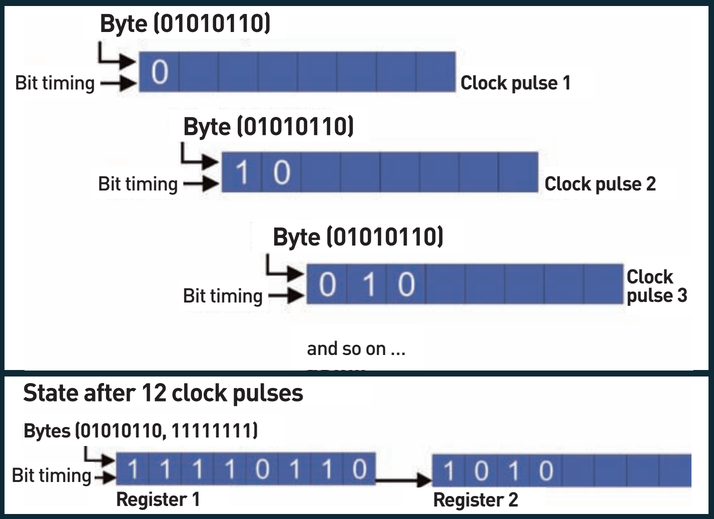
To go really fast (when it comes to synchronous serial data transmission) you want to use SPI — the Serial Peripheral Interface protocol. SPI can communicate at speeds up to one-half your processor speed. The Arduino Nano's ATmega328p runs at 16MHz, which means our SPI speeds can

SHIFT REGISTERS — PASS IT ON

A shift register is a clocked logic circuit that stores and supplies a push of binary data. It consists of a series of flip-flops. With each clock pulse on the clock pin (SRCLK), one bit (state HIGH or LOW) is sent to the serial data pin (SER) and stored in the register at the first flip-flop location. On the next clock pulse, that bit is passed to the next space in the register and the first space is reassigned a new bit — like a bucket brigade. Thus, the data is always shifted by one digit at each clock pulse.

In a latching register like the 74HC595, the data is first loaded into an internal buffer, then copied all at once to the output register when the latch signal is received — a HIGH pulse on the register clock pin (RCLK). This way, we can transmit the next batch of data without disturbing the existing state of the outputs (and our LEDs).

When the shift register fills up spaces QA–QH, it overflows to the Q'H output (pin 9), which continues to pass new values along to the next shift register in the daisy chain, even while the latch isn't being triggered.



be up to 8MHz. Each byte (8 LEDs) requires only 1 microsecond, so all 40 LEDs are supplied in 5 microseconds. Blazing!

Note that the SPI ports on the Arduino are pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK); we're not using pin 12.

ARDUINO TASKS

You can download the Arduino sketch from the project page and follow along with the comments to see what the code is doing. In the declaration part of the sketch, we input the basic data for our globe. The image we're drawing is stored in a 2-dimensional array. The first dimension is the number of shift registers, the second is the number of columns to draw (referred to in the program as segments). This entire block can be generated by our POV-Calculator and then just copied into the sketch.

To start, the SPI pins are defined as outputs. Since we need a defined state for the Hall sensor, we use **`INPUT_PULLUP`** to activate the Arduino's internal pull-up resistor on pin 2. Next, the SPI interface and the interrupts are configured.

Now we need to know the time it takes for the LED strip to make one revolution, in order to calculate the interval between outputs of the individual columns of pixels. That is, for each LED in the strip, how long do we leave it on or off, to draw our image?

For time measurement, we use the Arduino's 16-bit Timer 1. On the first hardware interrupt (**`INT0`**) from the Hall sensor on pin D2, the interrupt handler **`TIMER1_INT0_vect`** sets Timer 1 to zero.

On the next interrupt, we read the timer again; this value now represents the time (in processor clock cycles) required for the LED strip to make one complete revolution. We now divide this value by the number of segments we want to display. The result is then assigned to the 8-bit Timer 0 as the correct interval for redrawing the LEDs.

With each release of this timer (overflow interrupt **`TIMER0_COMPA_vect`**) the update flag will be set to true. This signals the loop routine that a new set of bytes is to be sent to the shift register. At the beginning of the SPI data transfers, the latch pins (RCLK) of all shift registers are set to LOW. This signals the registers that new data is coming. **`SPI_shiftOut`** now sends one byte after the other to the register. At the end of transmission, the latch pins are again pulled HIGH, causing the collected data to appear in one fell swoop at the outputs.

To ensure a smoother image, we don't re-calculate the interval for Timer 0 for every tiny speed deviation; only for those above a certain threshold. This minimizes image "twitch" when the interval is reset. The hysteresis values 1 and 2 in line 100 are experimental and may be customized accordingly.

We have also programmed an ASCII character table for displaying text, and additional routines for animation, which you'll find in the code downloads. So you can, for example, rotate your image presentation at variable speeds.

We're excited to see what you'll do with your own POV Globe — show us your build on the project page online!

Download the code, get more photos, diagrams, and tips, and share your build at makezine.com/go/pov-led-globe.

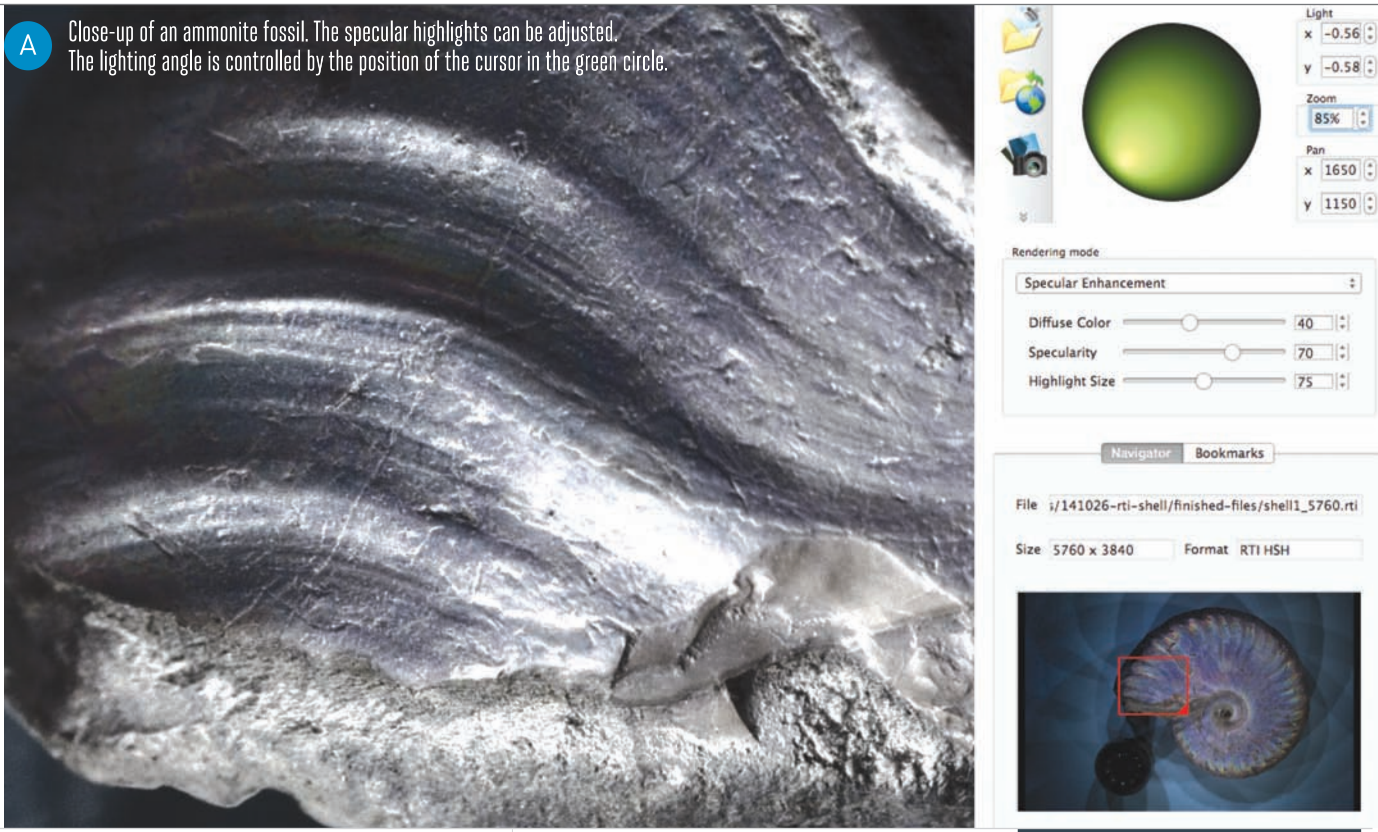
Time Required: 12-14 Hours (A Weekend)
Cost: $60-$70

Macro Magic

Shoot super detailed, 3D-enhanced photos with this homemade RTI camera rig

Written by Ted Kinsman

An ammonite fossil imaged in the *surface normal vector* mode. The normal vector represents a line that is 90° to the surface. The software calculates a surface angle for each point on the sample, then assigns colors to these points based on their angle.



A Close-up of an ammonite fossil. The specular highlights can be adjusted. The lighting angle is controlled by the position of the cursor in the green circle.

SOMETIMES IT'S DIFFICULT FOR A SINGLE PHOTOGRAPH TO ADEQUATELY RECORD AND REPRESENT ALL OF AN OBJECT'S IMPORTANT DETAIL. By using *RTI (reflectance transformation imaging)* photography, researchers are better able to capture and enhance an object's individual topography, texture, and color. Unlike one single photograph, an RTI photographic system uses numerous lighting angles to produce dozens of sequential images of the same object or artifact that can reveal hidden detail.

RTI is a computational photographic method that collects between 40–100 images with light sources at different fixed locations. Imaging software can deduce the location of the light sources, and the resulting images are used to create a mathematical 3D map of the surface. How does it work? By analyzing the reflectance of each pixel from each lighting angle, the software calculates *surface normal vectors* — basically the vector that's perpendicular to the surface at each specific pixel. This 3D data not only allows you to magically adjust the lighting during viewing later, it also lets you exaggerate surface features to show their exquisite detail.

RTI-enhanced images prove invaluable to scientists and conservators for research, conservation, and fine art authentication purposes. RTI can be extremely useful in archaeology for imaging and analyzing pottery fragments, small tools, and stone artifacts, for example. RTI systems are also used in forensic science to photographically record and analyze bullet or projectile striations.

Botanical and zoological fossils are ideal for RTI imaging, because they often have intricate shapes, repeating patterns, and interesting surface textures. Ammonite fossils, for example — which were free-swimming mollusks living in our oceans about the same time as the dinosaurs — have ribbed, spiral-form shells that produce wonderful RTI images (Figure A).

Beyond these applications, the possibilities are limitless! Here's how you can construct your own simple reflectance transformation imaging (RTI) setup and start shooting.

CONSTRUCTING THE RTI SYSTEM

The process described here outlines a simple device that automatically collects 48 reference images that you can feed into RTI software. The software for building and viewing RTI photography has been developed by a number of researchers and is available from Cultural Heritage Imaging at culturalheritageimaging.org/Technologies/RTI.

The requirement of the light sources for the

Ted Kinsman

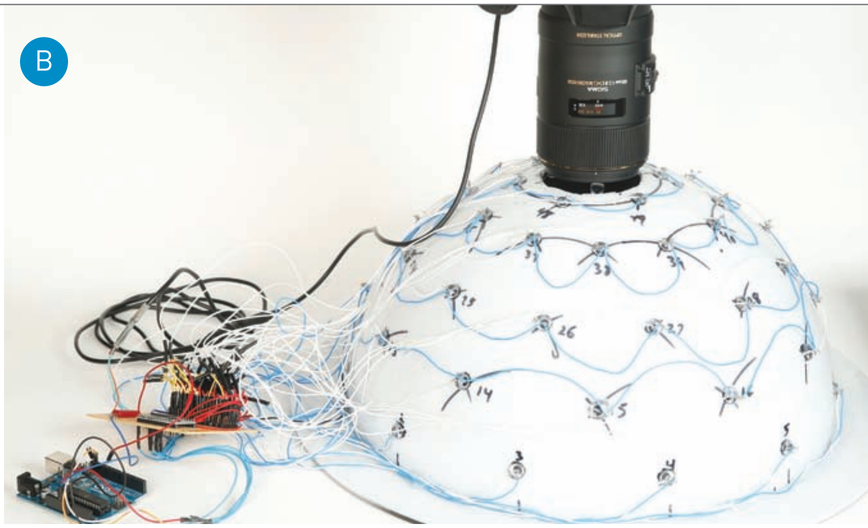
TED KINSMAN
is one of the few active high-speed photographers able to photograph at times less than 1/1,000,000th of a second. He is currently an assistant professor in the Photographic Sciences department at Rochester Institute of Technology (RIT).

Materials

- » **Dome** You can use a simple lighting dome or 3D print the available STL file.
- » **LEDs (48)** 10mm for a simple lighting dome, or 5mm if you're using my 3D printed dome
- » **LED light array driver, 16×8 matrix** HT16K33 breakout, Adafruit #1427 adafruit.com
- » **Arduino Uno microcontroller**
- » **Reed switch**
- » **Spray paint, black (optional)**
- » **DSLR camera with macro lens**

Tools

- » **Dremel with cut-off wheel** to cut hole for camera
- » **Drill**
- » **Soldering iron and solder**
- » **Computer with RTI software and Arduino IDE** free from culturalheritageimaging.org/Technologies/RTI and arduino.cc/downloads



You can download and print this dome, which is compatible with 5mm LEDs, from the project page online.

RTI image set is that they be about 50 in number and placed evenly on a half sphere. I used a simple lighting dome (Figure B). In order to remove unwanted room light, I spray-painted the inside black and then drilled several rows of holes evenly spaced from the horizontal (Figure C). I recommend you start with 4 rows of 12 individual lights, for a total of 48 lights. Numbering each hole makes the wiring easier.

At the top of the dome I cut a large round hole for the camera using a Dremel, which easily removed the unwanted plastic and made a smooth cut. The Arduino's 5V pin supplies power for the large 10mm white LEDs, which draw 80mA. To switch each LED on and off, I used an Adafruit LED array, which thankfully limits the number of control wires needed to drive the 48 individual LEDs.

The program's function is relatively simple. Initially, an individual LED is turned on, the camera shutter is triggered, and then the light turns off. The program sequentially repeats the cycle for all the remaining lights. The prototype is designed for a 105mm macro lens and a Canon 5D Mark III DSLR camera body. In order to image at a low ISO and an adequate depth of field, the lights are programmed to stay on for 5 seconds. In this way, you can collect a full set of images in about 4 minutes.

The exposure and the LED-on time can be optimized for the subject and increased if desired. If a large number of RTI image sets are being collected, the LED-on time should be reduced to just slightly longer than the exposure time. To insure repeatability and exposure efficiency, it's important that the LED illumination continues for the complete duration of the shutter exposure.

3D-PRINTED DOME OPTION

Building the dome presented a number of problems. To simplify the process, I designed a 3D dome that you can print at home. The bed size of most 3D printers is limited, so this dome is designed for macro work. The holes are about the size of a 5mm LED, but they'll change diameter as the RTI dome is scaled for a particular printer. Consider them pilot holes that can be easily drilled to the desired diameter.

This dome also includes an excess of holes, so that future systems can use additional sets of LEDs, each operating at a different wavelength (Figure D). My thanks to Andy Kinsman for his help with the 3D design.

THE SCHEMATIC

The wiring schematic (Figure E) is simple, but the execution is quite time-consuming. It took about 12 hours to cut and solder all the contacts — this was slower than usual due to the teflon-coated wire, which was difficult to strip. In the future I'll use a wire wrap tool, which is preferred for prototyping circuits.

Since the Arduino doesn't have 48 outputs to control the lights, the microprocessor talks to an LED array driver board, which in this case is the Adafruit 16×8 LED Matrix Driver Backpack (HT16K33 Breakout). The communication protocol for this board is I2C, so it uses only 2 pins on the Arduino (SDA and SCL). This board is designed to work specifically with the Arduino Uno microprocessor and an array of LED lights. (You can use up to 8 selectable I2C addresses for a total of 8 matrices, each one controlling 16×8 LEDs for a total of 1,024 LEDs!)

After stringing long lines from each LED back to the array controller, I soon discovered there is a faster technique: Connect all the LEDs in each row together on their ground side before returning to the array driver. This simplifies the wiring, but complicates how to visualize the circuit. This common-ground wiring setup can be seen as the blue wires on the prototype dome (Figure F).

Pin 12 on the Arduino triggers the camera. When this pin goes HIGH, a reed switch trips my camera. The reed switch is a safety measure I used to protect my camera trigger from any dangerous voltages generated by the Arduino. The reed switch is also easy to wire and is very inexpensive. I have not included a schematic of a trigger system for the camera, since most cameras are different.

CREATING THE RTI FILE

The resulting image set is converted to JPGs and run through the RTI builder software. Then just use the RTI viewer program to see the resulting file. All the software is freely available, and easy-to-follow directions are accessible as a PDF on the Cultural Heritage Imaging website.

I hope you find this RTI system an easy and elegant technique for collecting images for the RTI process and exploring a new world of high-detail, 3D photography.

What have you photographed with your RTI system? Grab the 3D file and Arduino code, and share your photos on the project page at makezine.com/go/RTI-system.

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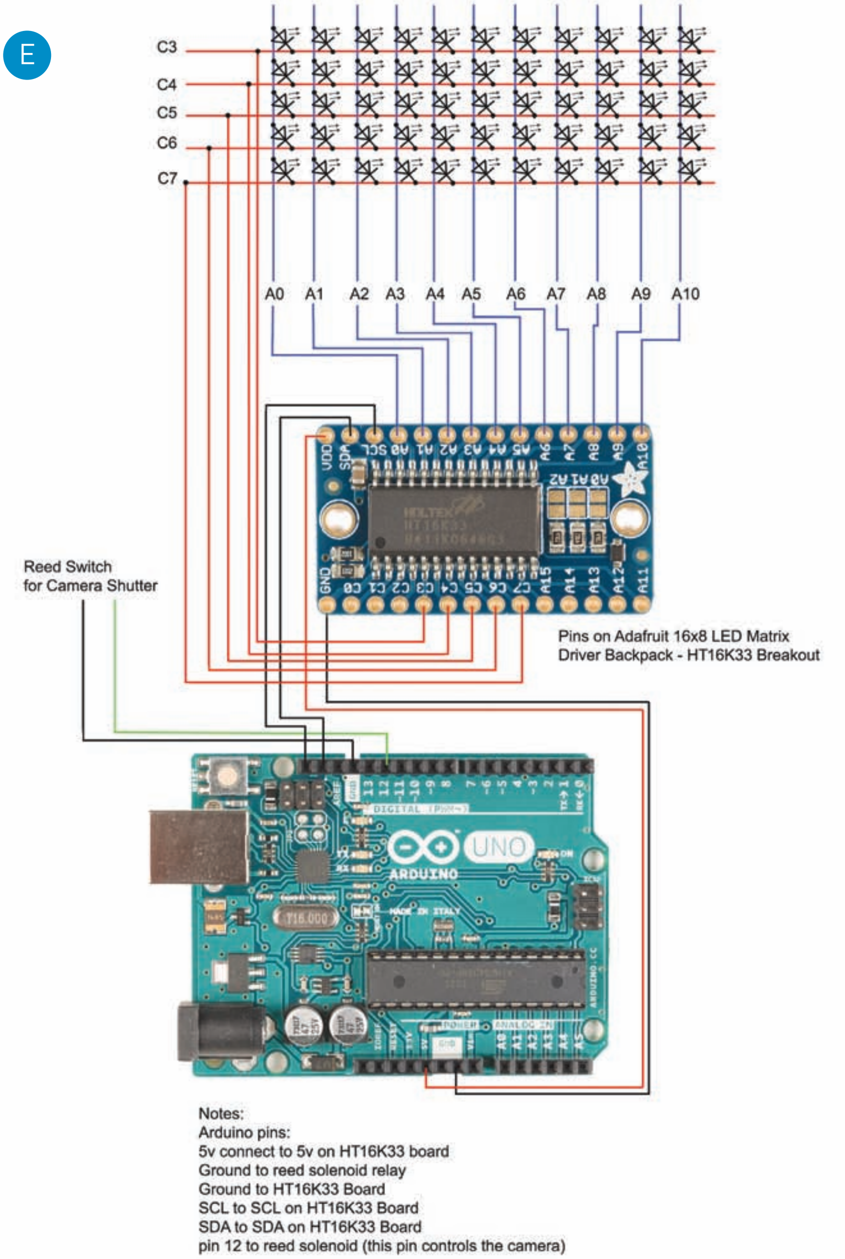

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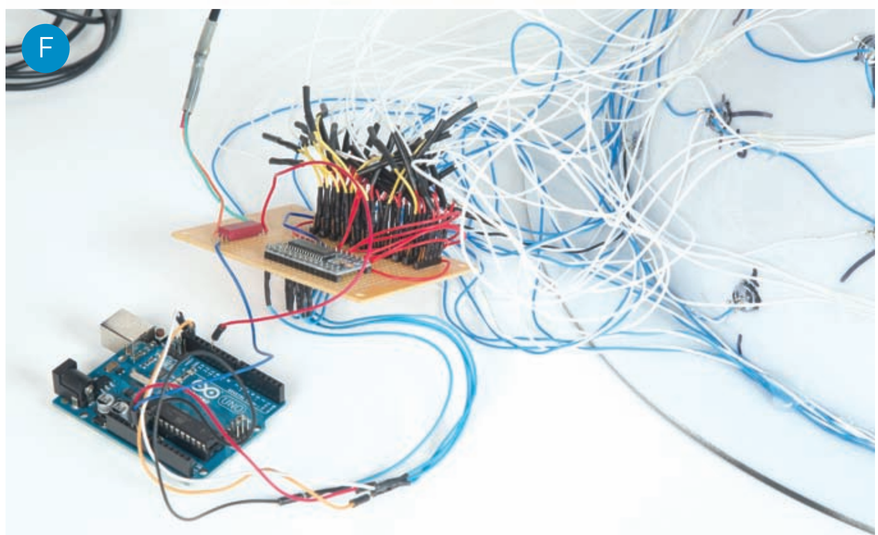
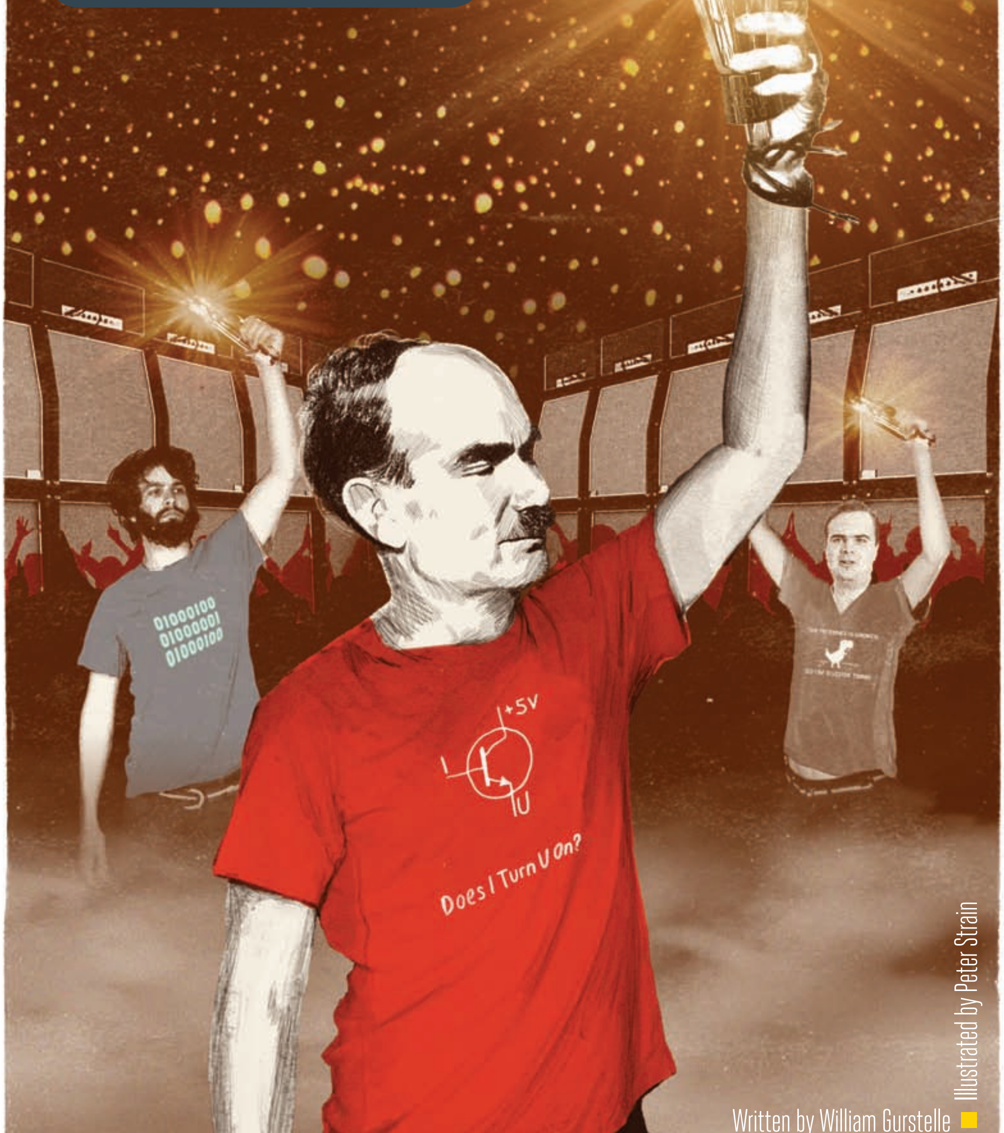


Lee de Forest and the Amplifier



WILLIAM GURSTELLE is a contributing editor of *Make:*. Find his new book on DIY artillery, *Ready the Cannons*, at readythecannons.com.

Written by William Gurstelle

Illustrated by Peter Strain

The invention of electronic amplification gave us radio, TV, computers, and the Marshall stack

SINCE HE WAS THE SON OF AN ALABAMA MINISTER, EVERYONE EXPECTED THAT YOUNG LEE DE FOREST WOULD FOLLOW IN HIS DAD'S FOOTSTEPS, living a spiritual life and preaching to his congregations. But it turned out that de Forest was fascinated by science, not theology. He possessed the important gifts an inventor needs — not only was he good with tools, but he had a passion for making new things. In 1899 he got his Ph.D. from Yale and started work with the Western Electric Company in Chicago. He did well, but before long, he left in order to work independently on projects of his own choosing.

De Forest's greatest achievement came in 1906 when he developed the first amplifying vacuum tube. This tube could do something new and extremely important: it could increase the power of radio signals. There was a big problem with early radio: the signals received by radio sets were so weak that they could only be heard through headphones. If radio were ever to become really popular, the sound had to be made loud enough to be heard by several people at once, which meant it needed a loudspeaker (see my previous column, makezine.com/go/moving-coil-loudspeaker) driven by powerful electrical signals.

TURN IT UP

De Forest's invention, which he called the Audion, was an electronic device that could transform a small electrical signal coming in one side of the device to a much larger one when it exited the other side.

The Audion tube was a *triode*, with three connections: the anode, the cathode, and the control grid. Current passing through the filament (cathode) heats it up, which causes it to emit a stream of electrons. The electrons, being negatively charged, are attracted to the positive plate (anode) at the top of the Audion. De Forest's world-changing idea was to place a grid of wires between the filament and the positive plate. The grid becomes more or less negatively charged as more or less voltage is applied to it. As the signal to the grid varies, it controls the number of electrons flowing between the filament and the anode. This is how a tube amplifier increases the size of the signal — it uses a small signal to control a much larger voltage.

Time Required: **30–60 Minutes**
Cost: **$10–$15**

Materials

- **Transistors, NPN, BC547 type (2)** Buy online at places such as SparkFun, Amazon, or Newark.
- **Resistors: 100kΩ (1) and 220Ω (1)**
- **LED, 2V–3V**
- **Battery holder, 4xAA, with leads**
- **Batteries, AA (4)**
- **Solderless breadboard**
- **Jumper wires**
- **Buzzer, 6V (optional)**

Tools

- **Soldering iron (optional)**

TUBES TO TRANSISTORS

Once engineers figured out how useful amplifiers could be, they were incorporated into radios, telephone systems, scientific instruments, and much more. The vacuum tube business exploded. During the next 50 years, millions of tubes were manufactured. But tubes had a lot of shortcomings — most significantly they were big, expensive, and hot.

So, in 1945, Bell Labs put together a team of scientists to find a better alternative to the vacuum tube. The team came up with another sort of amplifier called the transistor. Like a vacuum tube, this silicon-based or solid-state amplifier also has three parts. Current applied to the middle part controls a much larger current or voltage between the top and bottom parts. Modern amplifiers are made with integrated circuits which contain the equivalent of thousands or even millions or transistors or vacuum tubes, in a single electronic component.

BUILD AN AMPLIFIER-BASED TOUCH SWITCH

In this edition of Remaking History we'll use electronic amplification, the concept pioneered by Lee de Forest, to make a touch switch. We'll use a pair of simple solid-state transistors (although in principle, de Forest's vacuum tube Audions could be made to work as well) to amplify a tiny bit of electrical current moving through your finger.

Your body has a fair amount of electrical resistance, which is why you can't just grab two pieces of wire with your hands and complete a low-voltage (6 volts DC) circuit to make a LED light up. That's not to say that no current flows at all, it's just that your skin presents so much resistance (about 100,000 ohms depending on how clean and dry it is) that the amount of amperage coursing through you is exceedingly small. But if that small amount of electrical flow can be detected and then increased, say through the use of an electronic amplifier, than you can use your finger alone as a switch that completes a circuit to light LEDs or sound a buzzer.

To assemble your touch switch, refer to the circuit diagram (Figure A). If you're using a solderless breadboard, then it's a very easy setup, just follow the photos here. Otherwise you can connect the components directly together, and then solder them.

1. Examine the LED and identify the positive lead, which typically is the longer one.

2. Holding the transistor with the flat side toward you and the legs down, identify the collector (left leg), the base (center leg), and the emitter (the right leg.)

3. Wire the transistors together so the emitter of the first stage transistor is connected to the base of the second stage transistor. Connect the emitter of the second stage transistor to a negative power rail on the breadboard. Add a short jumper from the base of the first transistor to an unused row on the breadboard (Figure B).

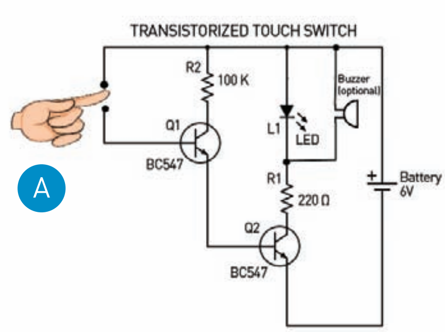
4. Place a 100kΩ resistor between the first transistor collector and a positive power rail. Connect the positive lead of the LED to the positive rail. Insert a 220Ω resistor between the negative LED lead and the collector of the second transistor (Figure C).

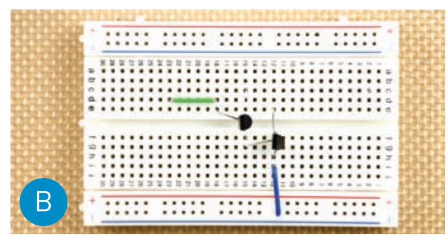
5. Now you'll use 2 jumper wires placed vertically on the breadboard to create your touch switch. Place one of the vertical wires on the positive rail. Connect the other vertical wire to the little jumper from the first transistor base. Connect a buzzer in parallel with the LED if you want to. Finally, connect your 6V battery pack to the positive and negative power rails (Figure D).

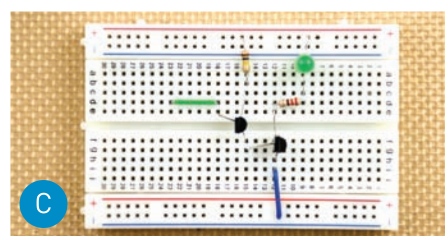
NOW GET AMPED

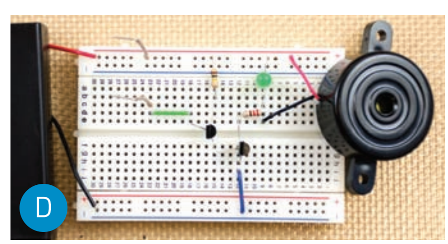
In this circuit, the amplifiers are wired in series to provide a gain, or amplification, several hundred times the original current. When you press on the bare wire connected to the 6V rail simultaneously with the base of the transistor connected to the 100K resistor, only a tiny amount of current flows from the battery, through your finger, to the transistor base (Figure E). But that small current is amplified first by one transistor, then by the second, increasing it enough to light the LED and sound the buzzer. Congrats, you've made your own amplifying touch switch!

What else can you do with a simple transistor-amplified touch switch? Share your project ideas at makezine.com/go/remaking-amplification.





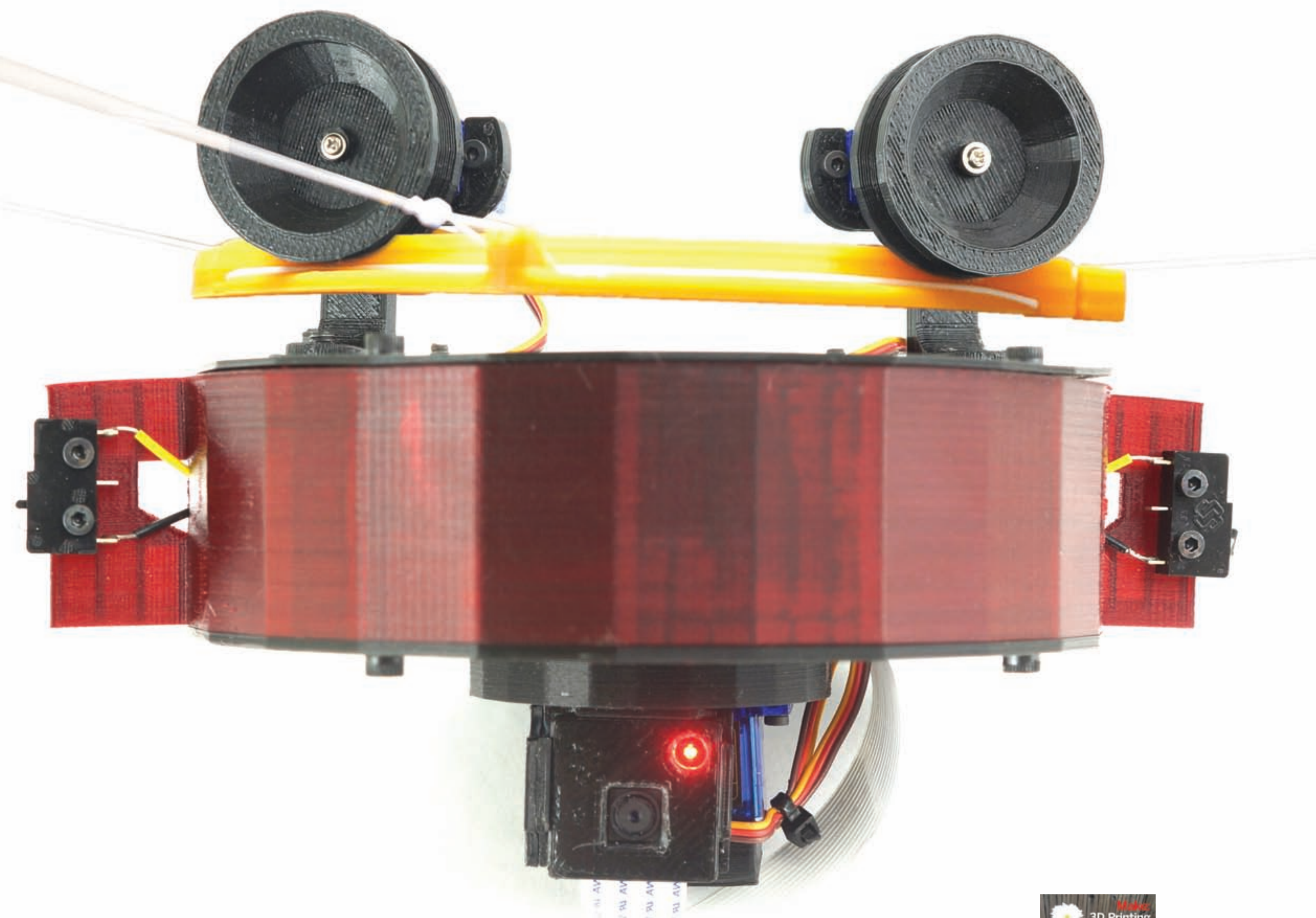




Anthony Lam, Hep Svadja

3D-Printed Raspberry Pi SKYCAM

It rides a monorail of string, streams video, and is remote-controlled from my phone. Written by Brook Drumm



Brook Drumm

HUGE THANKS: Brian Roe designed the 90° and 45° 3D-printed skyway corners, while my friend and code wizard Mick Balaban and Printrbot engineer Nick Ernst got me sorted on the software tutorials.

This project is excerpted from ***Make: 3D Printing Projects***, available at the Maker Shed (makershed.com) and fine bookstores.

BUILDING A ROBOT FROM SCRATCH HAS BEEN A DREAM OF MINE SINCE I WAS VERY YOUNG. In fact, I have a few robot kits sitting in boxes in my garage right now — but I just couldn't get excited about a line-following robot or a simple tank. I just like doing things differently and attacking problems from a fresh perspective.

My Skycam is a little robot that travels on a rope or string, can turn corners, and even has a little camera with pan and tilt. The whole thing can be controlled from your phone or any browser — and it even streams live video.

This project was born out of the desire to make a robot that I can control from my phone. I had recently been playing with the Raspberry Pi and Google Coder, a neat bit of software that teaches the basics of web development. Using Coder, I was able to control an LED from my phone, so I knew controlling other hardware was possible. I enlisted friends to help me over the hardware and electronics hurdles, so I don't deserve full credit, but that's the beauty of the maker movement — a rich community of people ready to help!

My dream has come true. I built a robot. Not just any robot, but one that rides a monorail of string in the sky, streams video, and is remote-controlled from my phone. I love being a maker.

BUILD YOUR STREAMING SKYCAM

1. ASSEMBLE THE TOP PLATE

1a. Press the 2 bearings into their pockets in the top plate, *Skycam-top.stl* (Figure A).

1b. Attach switches

Attach the 2 power switches to the top plate with four M3×8mm screws and nuts (Figure B). One switch is used to power the Raspberry Pi, the other is used to power the servos. (I used 2 different switches so I could tell them apart, but the difference is purely aesthetic.)

1c. Mount the servos

Insert the 2 continuous rotation servos into

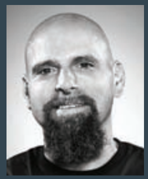
Materials

- **3D-printed Skycam parts** Download the STL files from the *Make: 3D Printing Projects* page at github.com/Make3DPrinting Projects/Skycam and print them, or send them out to a service. Print 2 wheels and one of all the other files.
- **Getting Started with Raspberry Pi 3.0 Kit** from the Maker Shed (makershed.com), includes the following parts (or buy them separately):
  - **Raspberry Pi 3 single-board computer** I used an older model and a Wi-Fi dongle, but the new Pi 3 has built-in Wi-Fi.
  - **Power supply, micro-USB 5V 1A** for programming only
  - **HDMI cable** for programming only
  - **microSD card, 8GB or greater** The kit has a 16GB card.
  - **Pi enclosure (optional)**
- **Raspberry Pi Camera module** V1 or V2
- **Flex cable for Pi Camera, 12"** Adafruit #1648, adafruit.com
- **Ball bearings, radial, 624 size (2)** Amazon #B008IFXA2E or equivalent
- **Slide switches, SPDT (2)** Amazon #B009752DE0
- **Servomotors, micro size (2)** Hextronic #HXT900, hobbyking.com
- **Servomotors, continuous rotation, micro size (2)** such as Fitec #FS90R, Adafruit #2442
- **Battery packs: 4xAA (1) and 6xAA (1)** Amazon #B000LFVFT4 and B000LFVFU8. For the 6xAA, you can substitute batteries that give 8.4V–12V DC, such as a 2- or 3-cell LiPo, or two 18650 Li-Ions.
- **Perf board**
- **Voltage regulator IC chip, 5V** Digi-Key #MC7805CT-BPMS-ND, digikey.com
- **Capacitor, 100μF electrolytic** Digi-Key #493-1548-ND
- **Micro lever switches, 3-pin, normally open (2) (optional)** for endstops; Digi-Key #CKN10157-ND
- **Resistors, 1kΩ (4) (optional)** Digi-Key #CF14JT1K00CT-ND
- **Male headers, 40-pin** Digi-Key #S1011EC-40-ND; you'll cut this into 2- and 3-pin headers
- **Machine screws: M4×12mm (2), M3×8mm (18), M3×10mm (4), and M2.5×10mm (4)** McMaster-Carr #91290A148, 91290A113, 91290A115, and 91290A103, mcmaster.com
- **Hex nuts, M3 (4)** McMaster #90592A009 or 90592A085
- **Washers, M4 (4)** McMaster #91166A230
- **Rubber bands (2)**
- **Jumper wires, female/female (6)** Adafruit #266
- **Paracord, wire cable, or high-test fishing line** for your skyway

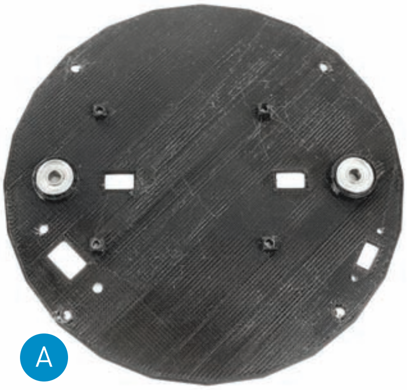
Tools

- **3D printer and filament**
- **Computer with microSD card slot**
- **Allen wrench, 2.5mm**
- **Needlenose pliers**
- **Wire cutters**
- **X-Acto knife**
- **Soldering iron and solder**
- **Micro USB cable**
- **CAT5 (Ethernet) cable**
- **Super glue**
- **Electrical tape**
- **Zip ties (optional)**

Time Required: 5-8 Hours
Cost: $140-$160



BROOK DRUMM
founder and CEO of Printrbot, Inc., is an American maker who set out to start a side business in his garage. After a wildly successful Kickstarter in 2011, he was catapulted to the white-hot intersection of crowdfunding, 3D printing, and the exploding maker culture.



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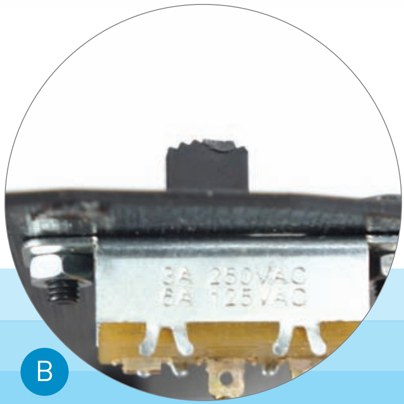

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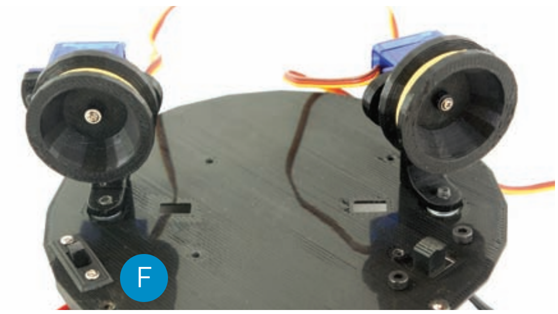
C


D


E


F

G

the left and right wheel mounts (*Skycam-left-wheel-mount.stl* and *Skycam-right-wheel-mount.stl*).

Ensure that the servo drive gear is lined up with the center of the 3D-printed vertical post, as shown in Figure C. To operate properly, the center of the wheel needs to pivot directly above the 624 bearing when the servo post is mounted.

Screw each servo to its wheel mount using two M3×10mm screws.

TIP: If you'd like to learn how to convert regular mini servos into continuous rotation servos, I've written up the process at printrbot.com/2015/02/21.

Insert one M4×12mm screw through each bearing from below, so the threads come out the top, next to the switches. Add two M4 washers to each screw (Figure D); these will allow the wheel mounts to rotate freely on the screws.

Thread the ends of the screws into the left and right wheel mounts (Figure E). Tighten the screws until the connection to the wheel mount is rigid. The wheel mount should still rotate freely on the screw post inside the bearing.

1d. Add the wheels

Press the wheels (*Skycam-wheel.stl*) onto the servo drive posts. Secure each wheel with the small self-tapping screw that came with the servos.

Wrap a small rubber band into the valley of the wheel hub (Figure F). This will help the wheel grip against the paracord or other cable that's used for your skyway.

Route your servo wires down through the square holes in the top plate, leaving enough slack to allow the wheels to rotate 45° in either direction.

2. SET UP THE RASPBERRY PI SOFTWARE

It turns out that the Raspberry Pi is a great platform for building robots! You can even create your own custom user interface and stream video live to your browser.

To get these features up and running, you'll need some free software: the **Google Coder** platform, the **Pi-Blaster** library that communicates with the servos, and **MJPG-Streamer** to stream video from the Pi's camera.

Now's the time to plug in your Pi's Wi-Fi dongle if you're using one.

2a. Install Google Coder for Raspberry Pi

Point your computer's browser to googlecreativelab.github.io/coder and select the Wired button (Figure G). Then follow the 3 steps onscreen to install Coder on your SD card and connect to your Pi.

During the third step, your browser will warn you: "Your connection is not private." Click on Advanced, and then "Proceed to coder.local."

Coder will prompt you to provide your password. Once you're logged in to your Pi and are on the Coder home screen, click the gear icon and select Wi-Fi Setup, then follow the onscreen instructions.

Disconnect the Ethernet cable from the Pi. You're now running on the Wi-Fi network! Reboot your Pi.

Log back in to your Pi by navigating to http://coder.local in Chrome. Ensure that your wireless connection is working correctly. Nice job! You're halfway there.

Explore the Coder environment. You'll be able to inspect and even edit the code right there in your browser window!

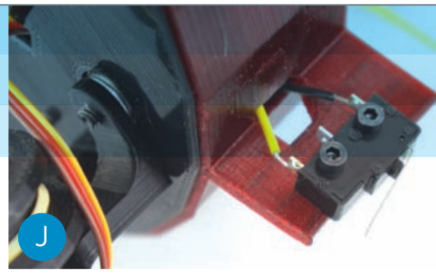
2b. Install Pi-Blaster on Raspberry Pi

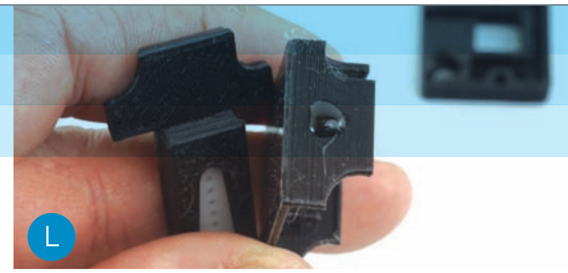
First, you need to identify the IP address of your Pi. Any network scanning software will work; I used LanScan from the Apple Store, but Windows has lots of options as well. Scan your network for the name "Edimax Technology Co. Ltd." This is your Pi; take note of its IP address. Mine was 192.168.1.115, but yours could be different.

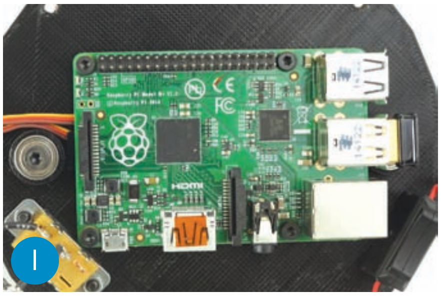
On your computer, open the terminal to access the command line and type the following line, inserting your own Pi's IP address: `ssh 192.168.1.115 -l pi`

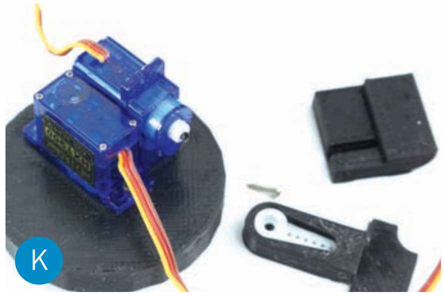
You'll be asked if you want to continue (you do). Type: **yes**

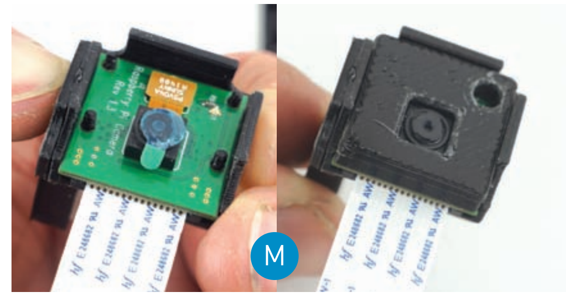
When you're prompted for a password, enter your Coder password.











Now follow the instructions on the project page at makezine.com/go/3dp-skycam to download and install the Pi-Blaster software on your Pi. Don't close your terminal session.

2c. Enable camera and install MJPG-Streamer

To enable the Camera function on your Pi, type: **`sudo raspi-config`**

The Raspberry Pi Software Configuration Tool GUI (graphical user interface) will appear. Use the cursor keys to select Enable Camera, then press Enter. The system will ask you if you're sure (you are). Select Enable and press Enter. You'll return to the main menu. Press the right arrow key to select Finish, then press Enter. Now reboot your Pi: **`sudo reboot`**

Once your Pi has rebooted, log back in to the Pi over the SSH connection as you did in Step 2b. Now follow the instructions on the project page at makezine.com/go/3dp-skycam to download and install MJPG-Streamer on your Pi.

Test that the streamer and camera are working together by opening a browser window on a separate computer, then navigating to http://*CODER-IP*:8090, replacing *CODER-IP* with your Pi's IP address; for instance, I would enter **`http://192.168.1.115:8090`**.

You should now see a page that looks like Figure H. In the second image, under the flower, if you see a snapshot of what your camera sees, then your streaming setup is working!

Move back to your terminal session, hold down the Control key, and press the X key to stop MJPG-Streamer from running.

Then follow the instructions on the project page to configure MJPG-Streamer to start automatically whenever your Pi is powered on.

Reboot your Pi (**`sudo reboot`** again) and you're ready to go.

3. ASSEMBLE THE MIDSECTION

3a. Mount the Raspberry Pi

Once your Wi-Fi streaming and servos are working, use four M3×8mm screws to mount the Raspberry Pi to the underside of the top plate (Figure I). There's 34mm of space for a small Pi enclosure (optional).

Connect the top plate assembly to the middle case (*Skycam-middle.stl*) with four M3×8mm screws.

3b. Add the endstops (optional)

The middle case has flanges for mounting 2 micro lever switches, for use as end-stops. When these hit a wall or obstacle, they'll trigger the drive servos to reverse.

Secure the endstops with four M2.5×10mm screws, with the lever switches facing out. Route the wires through the holes in the side of the middle case, under the flanges, as shown in Figure J.

4. BUILD THE CAMERA ASSEMBLY

The Skycam camera assembly hangs off the bottom plate of the robot. It uses a Raspberry Pi camera module and 2 regular micro servos to pan and tilt the camera while it streams the video to your browser.

4a. Add the pan/tilt servos

Press one servo straight into the middle of the camera pan disc (*Skycam-camera-pan.stl*), ensuring that the servo shaft is positioned in the very center of the disc. Use two M3×8mm screws to secure the servo. This one is the pan servo.

Press the bottom of the second servo — the tilt servo — into the recessed area provided on the camera pan disc, directly next to the facedown pan servo. The tilt servo's shaft and wires should be on top (Figure K). This servo is a press-fit affair, so consider taping the 2 servos together if needed for stability.

Press one of the servo horns into the recess on the tilt arm (*Skycam-camera-tilt.stl*) and secure it with a dab of super glue.

Press the tilt servo cap (*Skycam-pan-tilt-top.stl*) onto the tilt servo. This cap is nonfunctional, I just like the way it visually ties together the 2 servos into one block.

4b. Assemble the camera case

Use a dab of super glue to join the tilt arm (with the embedded servo horn) to the side of the back camera box (*Skycam-camera-back.stl*), matching up the shapes as shown in Figure L.

Mount the Raspberry Pi Camera on the tiny pins in the back camera box as shown in Figure M, then snap on the cover.

4c. Mount the camera tilt arm

Mount the camera tilt arm on the servo,


N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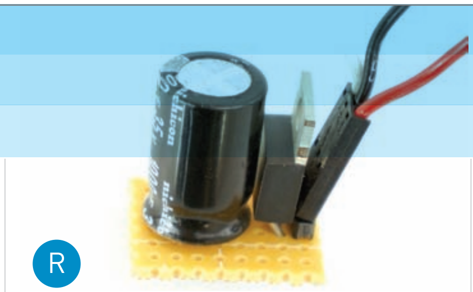
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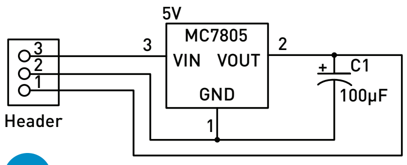

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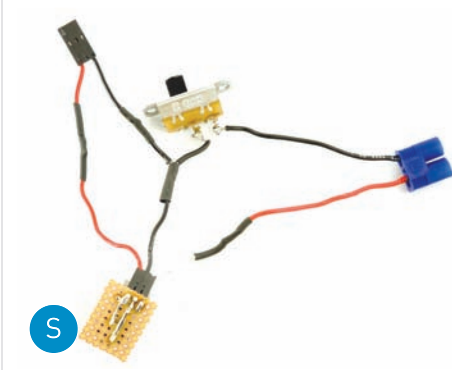
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but don't secure it with the screw just yet (Figure N). If the tilt servo and arm aren't positioned correctly, the tilt arm will hit the camera pan disc. Later when you turn on the servos, you'll be able to verify that the tilt arm is moving properly.

5. ATTACH CAMERA AND BOTTOM PLATE

5a. Glue the servo horn

Push the servo horn shown in Figure O through the back of the bottom plate (*Skycam-bottom.stl*) and secure it with a few drops of super glue.

Thread the camera cable and servo wires through the slot in the back lid, leaving plenty of slack.

5b. Mount the camera

Mount the entire camera assembly to the bottom plate using the tiny servo screw (Figure P). It's likely you'll end up repositioning the camera mount angle, but this servo doesn't have a hard stop like the tilt arm in Step 4c does. You won't do any damage if it's pointing in the wrong direction.

5c. Test-fit the bottom plate

Test-fit the middle case and bottom plate assemblies to avoid any setbacks later. The bottom plate attaches with four M3×8mm screws, but first you'll hook up the electronics and test the software to make sure it all works and everything moves properly before closing it all up.

5d. Connect the Pi Camera

Connect the camera's ribbon cable to the Pi, so you're ready to test video streaming when the project software boots up.

6. CONNECT THE ELECTRONICS

The brains of your Skycam can be repurposed for other projects. You can use what you learn here to design your own 3D-printed remote-controlled car or tank with a streaming camera!

To keep this project ultra-flexible, you'll be making your own power and signal boards. Hang in there if this is your first time hacking together one-off electronics. When it's done, you'll be able to step back and see that you've tapped into a new superpower! Both boards are made using small pieces of perforated board and use 3-pin headers for wire connections.

6a. Make the power/regulator board

The Raspberry Pi needs its own clean and smooth 5V power source, otherwise you may see less than desirable behavior. So you're going to make a power board that takes in 8.4V–12V DC from batteries, then regulates it down to the desired 5V.

To assemble the power/regulator board, solder the 100µF electrolytic capacitor, 5V regulator, and 3-pin header on a scrap of perf board, following the schematic diagram (Figure Q).

In Figure R, the white wire is the battery pack's voltage in, black is ground, and red is the 5V out of the regulator to the Raspberry Pi. You'll need to solder the board's components together underneath the perf board, as shown in Figure S.

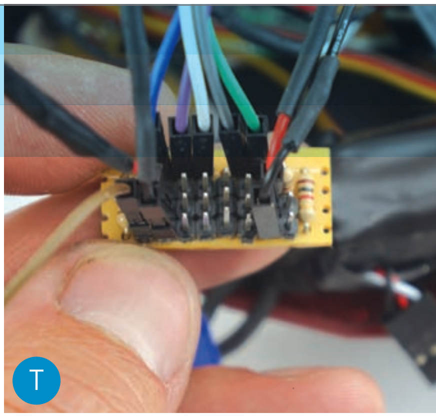
I used a blue EC3-style connector to attach the battery pack to the power/regulator board and power switch. A standard hobby servo cable was used to connect power and ground to the Raspberry Pi. This switch doesn't directly supply power to the Pi; it switches the ground line on and off to either complete the entire circuit (power on), or open the circuit (power off).

Hook up your 6xAA battery pack; then, using a multimeter, measure the output of your power/regulator board to ensure that you're getting 5V out. If you're not getting 5V, check your connections and retest before connecting this board to your Raspberry Pi.

Once it's working, cover the board in electrical tape so you don't short anything out. There's not much room inside the Skycam and it's likely that components will rub up against each other.

6b. Make the signal board

The signal board (Figure T) uses 3-pin headers to power and control the servos and connect them to the Raspberry Pi. It also connects the Skycam endstops to the Pi, so Skycam knows when it has hit a wall.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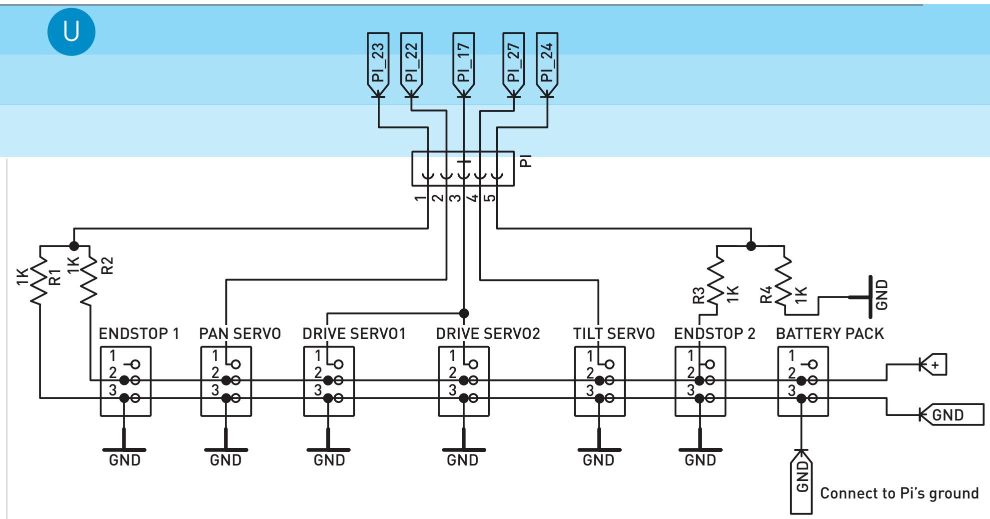


The signal board has its own, separate 4xAA battery pack, and will use the second switch you installed earlier (Step 1b) to turn power on and off.

Solder the 3-pin headers and resistors through the bottom of the perf board as shown in the schematic, Figure U. Starting from the battery pack, the positive wire (red) is connected directly to the signal board's positive input. The battery negative wire (black) goes to one of the 2 ground terminals that are not connected to the servos or endstops. You can see these 2 exposed ground connections on the right side of the schematic. After connecting to one of the grounds, hook up the other end to the switch.

Next, you'll connect another black wire from the middle terminal of your switch to the remaining GND input on the signal board. The switch opens or closes the circuit, turning the power on and off.

6c. Connect the Pi

Now connect jumper wires from the signal board to your Pi, as follows:

Connection	Raspberry Pi pin
Endstop 1	Pin 16 → GPIO23
Pan servo	Pin 15 → GPIO22
Drive servos	Pin 11 → GPIO17
Tilt servo	Pin 13 → GPIO27
Endstop 2	Pin 18 → GPIO24
Ground	Pin 14

Wrap the signal board in electrical tape to protect it from shorting. Plug everything in, and turn on the Pi and the power to the servos. It's time to test out the software controls!

7. TEST THE SOFTWARE CONTROLS

Using a browser on a computer, connect to the Pi as you've done previously. Then download my Skycam Coder project code from github.com/Make3DPrintingProjects/Skycam. Upload it to Google Coder and it will appear in the menu.

Remove your tilt arm to allow the servo to center (this is why you didn't screw it in earlier). Use the Coder interface to drive the Skycam wheel servos and pan and tilt the camera servos (Figure V). Test the tilt to find the right rotation before attaching the tilt arm and securing it with the screw. The streaming video should also be live at this point!

Assuming everything works perfectly, tuck in the wires, optionally tidy them up with zip ties, and reattach the bottom plate with four M3×8mm screws. Your Skycam is complete.

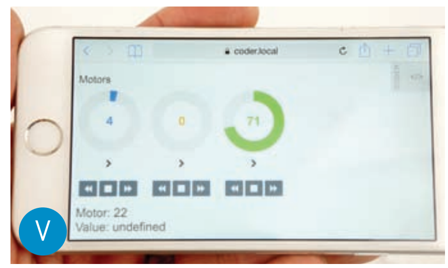
NOW DEPLOY YOUR SKYWAY

Build your skyway with thin paracord, wire cable, or high-test fishing line. You'll need to tie off to very secure places — I used interior door hinges in my house.

You can get creative with the skyway and even build in turns using 3D-printed corners (*Skycam-corners.stl*) as seen in Figure W. Using a corner requires an extra length of string attached to the back, to "pull" the corner into position. I've included a 90° turn and a 45° turn with the 3D files.

Make sure you skyway string exits the corners right at the top so that your Skycam wheels can make the transition. Also, you'll need to keep the skyway fairly level since there's not a lot of torque in the little micro servos.

Best of luck and have fun!



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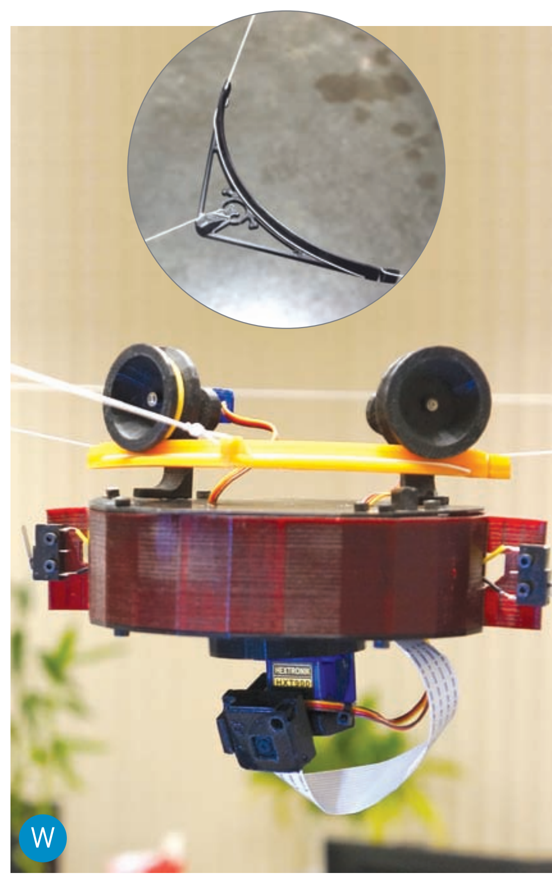
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Get more photos and tips and share your Skycam builds and videos at makezine.com/go/3dp-skycam.

Surveying Light Pollution

Written and photographed by Forrest M. Mims III

Measure sky glow — and fight for your right to the night

A

THE NIGHT SKY IS NO LONGER AS DARK AS IT WAS A FEW GENERATIONS AGO. Countless lights that illuminate our streets, parking lots, and stadiums lose some of their light to the night sky. There, it's scattered by molecules of air and particles of smog and dust known as aerosols. The result is *sky glow*, a phenomenon astronomers call *light pollution*.

The Defense Meteorological Satellite Program provides global images of city lights that clearly reveal the widespread presence of light pollution. This is spectacularly shown in the image *Earth at Night* (Figure A), which was created by Craig Mayhew and Robert Simmon (both NASA) using data provided by Marc Imhoff (NASA) and Christopher Elvidge (NOAA).

Light pollution is a major problem for professional astronomers, which is why they spend large amounts of money to build their observatories under the darkest skies they can find, including mountaintops in Hawaii and Chile. Amateur astronomers have the same problem, especially in the Eastern United States. Some have moved to Western states to better practice their night viewing.

Years ago I experienced a week of very dark skies while leading a dozen teenagers from my church on a 16-day, 1,000-mile bicycle trip from Albuquerque to Padre Island, Texas. In Eastern New Mexico, every night we had a magnificent view of the Milky Way and the meteors that occasionally flashed overhead. Distant towns revealed their presence by small domes of light.

OBSERVING LIGHT SCATTERING

Shine a laser pointer or flashlight in a dark room, and you'll see its beam highlighted by the glow produced by light scattered from molecules of air. This is known as *Rayleigh scattering*. Occasional sparkles in the beam are caused by dust, which is called *Mie scattering*. Brush a foot against the carpet and you'll see many more dust sparkles. Both Rayleigh and Mie scattering contribute to light pollution, but Mie is worse.

MEASURING LIGHT POLLUTION

Light pollution can be detected by the LED twilight photometer previously described in this column (you can build it at makezine.com/projects/twilight-photometer). I've found that orange and red LEDs work best for detecting sky glow.

Alternatively, you can build a simpler version on a solderless breadboard using the circuit in Figure B, which uses a standard silicon photodiode or miniature silicon solar cell instead of an LED. This provides increased sensitivity, which means that resistor Rf can be much smaller than the huge resistance required for the LED photometer. The resistance in ohms of Rf equals the amplification of the circuit. Thus, a circuit with a 1,000-ohm (1kΩ) feedback resistor will amplify the signal from the photodiode by 1,000. A good start value for Rf is 10 megohms (10MΩ), but you'll need to experiment since some photodiodes are more sensitive than others.

Place a tube over your photodiode so that it looks at the sky above through a cone of several degrees.

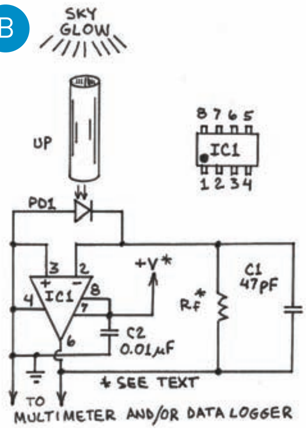
If you use a multimeter to see the output from the photometer circuit, power it with a 9V battery. If you plan to connect the circuit to a data logger, use a 5V USB supply or a 6V battery.

A LIGHT POLLUTION SURVEY

I live in a rural area near Seguin, Texas. You might think that the sky over my place

Image by Craig Mayhew and Robert Simmon, NASA GSFC.

B



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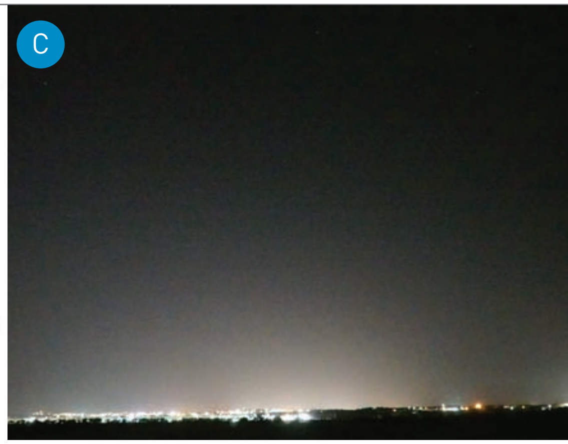

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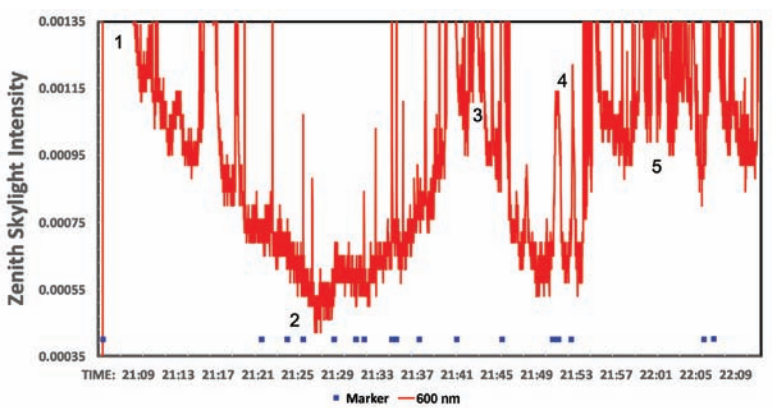


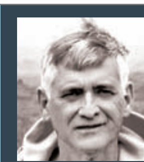
Time Required: 3–4 Hours
Cost: $15–$20

Materials

- **Capacitors, ceramic: 47pF (1) and 0.01µF (1)** designated C1 and C2, respectively
- **Operational amplifier (op-amp) IC, TLC271BIP** IC1
- **Silicon photodiode** OSRAM BPW or similar, Jameco part #1621132; PD1
- **Resistor, 10MΩ** You can experiment with this value (see text); Rf
- **Solderless breadboard**
- **Battery, 9V or 6V; or USB power supply, 5V**

Tools

- **Multimeter or data logger (optional)**



FORREST M. MIMS III (forrestmims.org), an amateur scientist and Rolex Award winner, was named by *Discover* magazine as one of the "50 Best Brains in Science." His books have sold over 7 million copies.

provides excellent viewing, but it does not. While planets and well-known stars and constellations can be observed on moonless nights, the Milky Way is usually hidden in the glow of city lights a few miles away.

For this column I decided to go on a midnight light pollution survey much like the heat island survey previously described in this column ("Tracking Heat Islands," makezine.com/projects/trackingheatislands). Instead of driving to and from San Antonio, I drove an 80-mile circuit across Seguin and then to San Marcos and back. San Antonio's light pollution is well known, and I wanted to find out more about light pollution from much smaller cities. I used a pair of 4-channel Onset UX120-006M Analog Data Loggers to record the sky glow signal at 1-second intervals. You can use a digital voltmeter to see the data but — and this is important — only if a friend is doing the driving.

I put the plastic ammo box that holds my two LED twilight photometers and their data loggers in a cardboard box in the bed of my pickup, with two bricks to keep it steady.

What happened next was a real surprise. Lights were everywhere! Of course they were always there, but this experiment made their presence seem much more obvious. Along the road there were overhead streetlights, flashing warning lights, traffic lights and, worst of all, cars tailing me with bright headlights. There were also industrial and commercial sites with brilliant floodlights and security lights. The lights of San Marcos produced a distinct bubble of light over the city (Figure C).

Assuming these lights would produce spikes in the data superimposed over a background signal from sky glow, I continued my transect, and you can see the results in Figure D. The spikes in the red trace from a 600nm orange LED are mainly from street and security lights and headlights. The underlying and more stable trace is the background sky glow scattered from the zenith sky. The blue squares indicate when I recorded brief comments about various locations. The numbers in the chart indicate:

1. Peak sky glow over Seguin
2. Darkest sky between Seguin and San Marcos
3. Peak sky glow over San Marcos
4. Sky glow spikes from two car dealerships outside San Marcos
5. Sky glow spikes while driving around San Marcos.

The sky glow over both cities in my simple survey swamped out the Milky Way, and only the brightest stars and planets could be seen. Amateur astronomers would have better viewing midway between these cities. Or they could head west for darker skies.

GOING FURTHER

» For serious study, the Sky Quality Meter is designed specifically to measure sky glow (unihedron.com/projects/darksky).

» Globe at Night (globeatnight.org) is "an international citizen-science campaign" to raise awareness of light pollution. Another excellent resource is the International Dark Skies Association (darksky.org). For a stunning dark sky global map, see darksitefinder.com/maps/world.html.

» Have an iPhone? The Dark Sky Meter app (darkskymeter.com) uses the phone's camera to measure sky glow at night.

Share your dark-sky tips and findings at makezine.com/go/light-pollution.

EMF Microphone

Listen in on the secret, weird sounds of electromagnetic fields all around you Written by Jonáš Gruska

THE "ELEKTROSLUCH" IS AN OPEN-SOURCE DEVICE FOR ELECTROMAGNETIC LISTENING (*sluch* means "ear" or "hearing" in Czech and Slovak). This simple circuit lets you discover, sonically, the world of electromagnetic fields (EMFs) that surround our every step. Just plug in your headphones and place the Elektrosluch near computers, tablets, cellphones, or any other electrical device, to listen to the unique sounds of their electromagnetic fields. Electric trolleys and trains really come to life!

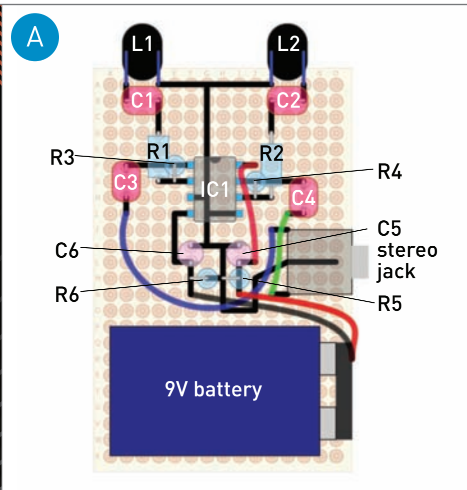
I've designed this version of Elektrosluch with the fewest parts possible, and it's open to component substitutions and future upgrades to suit your personal taste.

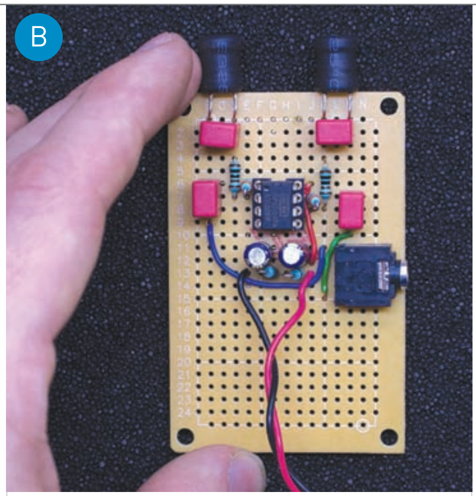
Pay close attention to the spacing of the components on the perf board, and follow the layout diagram (Figure A) and photos to see how to connect them on the bottom side of the board. Leftover leads from resistors/capacitors can be helpful in creating longer solder-bridge paths.

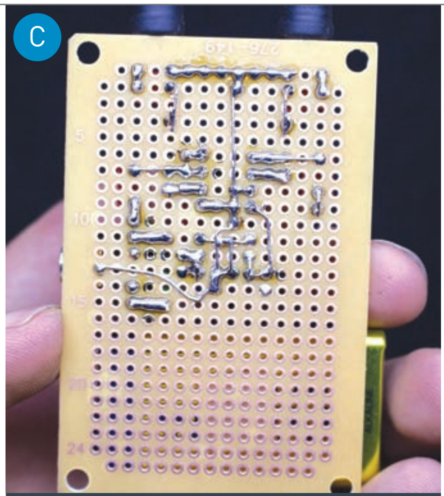
1. Solder in the inductors, L1 and L2. Make sure they're spaced far enough apart to create a perceptible stereophonic experience when listening. These little inductor coils are the essential parts of the projects — basically very long loops of thin wire around a metallic core. They act as antennas that allow us to pick up the electromagnetic fields.

2. Solder in two 2.2µF capacitors, C1 and C2. These define the bottom cut-off frequency of the circuit. The higher the value, the more bass you'll get. Since bass frequencies picked up by Elektrosluch are mostly from 50Hz or 60Hz mains power (depending on your country), some people prefer to use lower capacitor values to get rid of those.

3. Solder in the 1kΩ resistors, R1 and R2.







Hep Svadja and James Burke

Jonáš Gruska

These, together with R3 and R4 (390kΩ) define the gain of the circuit. This part of the circuit is called an inverting amplifier and results in a gain of −390. (The minus sign means the signal is inverted to the original, but in this circuit that doesn't really matter.)

4. Solder in the 390kΩ resistors, R3 and R4. As you can see in Figure B, they are soldered "standing up" to save space.

5. Solder the socket for the integrated circuit (IC). The ICs can be soldered directly, but I highly recommend using the socket: it allows you to replace the IC if you accidentally break it or want an upgrade, and lowers the risk of damaging the IC during soldering. As you see, I've made solder bridges between the socket and resistors.

6. Solder the remaining 2.2μF capacitors, C3 and C4. They're also used for bass cutoff.

7. Solder the 100μF capacitors, C5 and C6. These are part of the virtual ground circuit, which is necessary for operation of the operational amplifier (the op-amp chip).

8. Solder in the 100kΩ resistors, R5 and R6. These 2 resistors will define the virtual ground point. They act as a simple voltage divider, which in this case divides our 9V battery into three potentials: 0V, 4.5V and 9V. For our IC this will become -4.5V, 0 (virtual ground), and +4.5V.

9. Solder in the headphone jack and wires. These will connect the outputs of C3 and C4 to the stereo headphone output. Left channel is blue and right channel is green.

10. Use hookup wire to connect the positive voltage supply of the IC to the positive point in our virtual ground circuit at the bottom (C5/R5).

11. Now you can mount the op-amp IC, an OPA2134, into its socket. Feel free to experiment with other operational amplifiers. Op-amps with the same pinout include the LME49720, TL072, OPA1662, NE5532, and others.

12. Solder in the battery leads: the negative lead is connected to C6/R6, and the positive to C5/R5.

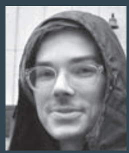
13. Double-check all connections on the bottom of the board (Figure C).

14. Plug in your battery and your headphones, and start exploring! You can create a simple battery holder by using a piece of double-sided mounting tape underneath the battery.

TAKING IT FURTHER

This device doesn't have a volume control — you can add one if you like, by placing a dual logarithmic potentiometer before the headphone jack. It also doesn't have an on/off switch — if you want one, place it in between the positive connection from the battery and the rest of the circuit.

This EMF microphone is bare-bones, but it will work great for starting your exploration of electromagnetics. Feel free to experiment with different op-amps, capacitors, and gain configurations. There's not much in this design that can go wrong!



JONÁŠ GRUSKA (jonasgru.sk) was born in Czechoslovakia and studied at Institute of Sonology in The Hague (Netherlands) and at Music Academy in Kraków (Poland). He is a developer of musical instruments and artistic software and hardware, and an explorer of chaotic rhythms, field recording, and the psychoacoustic properties of sound.

Time Required:
1–2 Hours
Cost:
$15–$30

Materials

- **Perf board** at least 15×24 holes
- **Resistors, 1% metal film: 1kΩ (2), 100kΩ (2), and 390kΩ (2)**
- **Capacitors, 2.2μF 10V (4)** polypropylene, polymer, or electrolytic
- **Capacitors, 100μF 10V (2)** low ESR electrolytic or polymer
- **Inductors, 22mH, vertical (2)**
- **Op-amp IC chip, OPA2134** Other op-amps might work too — check the pinout!
- **IC socket, 8-pin DIL type**
- **Stereo jack connector**
- **9V battery snap connector**
- **9V battery**
- **Hookup wire**

Tools

- **Soldering iron and solder** I recommend 0.5 mm, 60/40 solder.
- **Flush cutters**
- **Wire stripper (optional)**

Hear weird EMF audio, see more photos and video, and share your creations at makezine.com/go/emf-microphone.

1+2+3 DIY "Neon" Sign

Bend EL wire to create safe, affordable glowing words and graphics Written by Jenny Ching

NEON SIGNS GIVE AN AWESOME GLOW, BUT THEY'RE NOT EXACTLY A DIY PROJECT. Try neon's modern cousin: EL wire. It's low-voltage, easy to bend, and it's driven by inexpensive inverters that can do tricks like flashing or fading. Perfect for making your own "neon" sign.

1. LAY OUT YOUR DESIGN

Print your design on paper and tape it to your sign board as a guideline. (I downloaded a fun font from 1001freefonts.com.) Or, if your material is translucent, use a dry-erase marker to trace it.

Now you need to mark an X where you'll drill the holes to form the words or shapes in your design. This is tricky because EL wire can't bend 90° or turn super tight loops. The obvious holes are at the beginning and ending of each word. To figure out the rest, bend the EL wire over your word or design. Anywhere it's too difficult to bend, you'll want to drill a hole, feed it to the backside, then drill another hole to bring it to the front and start the next part of your shape.

2. DRILL HOLES

Go slowly to avoid cracking, and remove the shavings after each hole so that they don't stick to the acrylic.

3. ROUTE THE EL WIRE

Remove the paper design and feed all the EL wire through the first hole, from back to front. Secure the inverter and its leads to the back of the board with duct tape or gaffer tape.

Flip the board right-side up and trace your words by bending the EL wire. Secure it with a few drops of super glue at a time: hold it with your fingers for a few seconds, and then secure it with strips of painter's tape. Erase any guidelines as you go.

When you finish the last word, feed the remaining wire through to the back. Cut the excess, leaving about 2", and duct-tape the end to the back of the board.

Let the super glue dry overnight, then peel away all the painter's tape.

NOW LIGHT IT UP!

Plug the EL wire into the inverter, load the batteries, and switch it on. You're done!

Get more photos and tips, and share your neon sign designs at makezine.com/go/el-wire-neon-sign.

Time Required: A Weekend

Cost: $40–$60

JENNY CHING studied at Loyola Marymount University where she got her B.S. in mechanical engineering (and minor in Mandarin Chinese). She loves woodworking with her dad. jenniferching.weebly.com

Materials

- **Electroluminescent (EL) wire, about 9'** such as Adafruit #410, adafruit.com. You can use thicker wire, but 2.5mm is easiest to bend. Length depends on your sign design.
- **EL wire inverter, 2xAA size** Adafruit #317
- **Batteries, AA (2)**
- **Thin board, about 16"×16"** I used ¼" acrylic sheet.
- **Dry-erase marker**
- **Cyanoacrylate (CA) glue, aka super glue.** The gel type works best on acrylic.
- **Painter's tape, ½" or ¾" wide**
- **Duct tape or gaffer tape**

Tools

- **Drill with 3/32" bit** for 2.5mm EL wire. For thicker wire, use a bigger bit.
- **Wire cutters** or old scissors

TIP: If needed, cover any exposed EL wire on the back with duct or gaffer tape to prevent it from shining through.

Jenny Ching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makezine.com/fall-making

LINCOLN ELECTRIC

POWER MIG 210 MP

$1,199 lincolnelectric.com

I'm just a novice welder, but I enjoy it immensely. Getting started takes a bit of learning, however, with a multitude of variables to consider: material thickness, wire diameter, gas mix, and more.

The Power MIG 210 MP caught my attention with a built-in display and interface that helps tame the confusing assortment of settings, processes, and material options. Instead of manually configuring the machine for, say, MIG welding 16 gauge steel with .025 wire using 25/75 mix of CO_2 and argon gas, you simply select those options on its screen using a big dial.

It's impressively fast and easy. The machine can use almost all process types (although some require the purchase of additional pieces), and the interface makes switching pretty easy.

My tests had me laying MIG beads easily and without fuss. I've used low-budget welders that spit and stall, and nicer ones that give a very pretty output. The 210 MP performs like the better models, despite its relatively affordable price.

Experienced users have voiced the occasional gripe about the gas regulator. Fortunately, most welders like this are modular, so you can upgrade where needed. I'll also be watching the long-term reliability; anytime a device adds more technical advancements, there's more potential for things to go wrong. This one comes with a three-year warranty.

Overall, a great machine to help me take my welding well beyond the beginner level. *—Mike Senese*

Hep Svadja

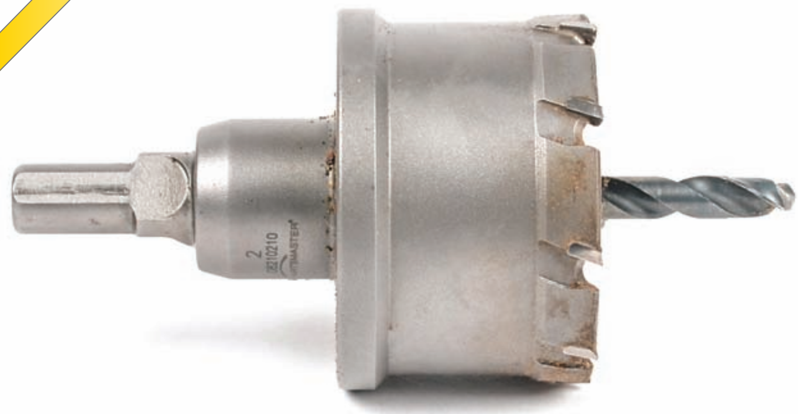
MILWAUKEE M18 TRUEVIEW LED STAND LIGHT

$249 milwaukeetool.com

It's amazing how much easier it is to work on a project past sunset when you can actually see it. I was recently building a plywood tool cubby in my driveway. As the sun set I started to squint at the project, until I grabbed the stand light. I popped the legs open with a satisfying click-clack, its battery pack (compatible with Milwaukee 18V tools) at the base providing extra stability. I telescoped the lamp to full 7' height, swiveling its head into place. Then, I turned it on to full brightness. Whoa — too bright! The medium of its three settings was fine for bathing my workspace in bright, warm light for hours.

This thing is sturdier and runs cooler than a corded halogen work light, and I'll never need to replace bulbs. My one complaint is the lack of a corded, plug-in option. I've also taken this beast to help strike the set at our elementary school auditorium, and even lofted it up onto my shoulder, bazooka-like, to use as the world's brightest flashlight.

—John Edgar Park



ZENITH INDUSTRIES ZN103117 2" CARBIDE TOOTH HOLE SAW

$66 zenithindustries.net

This drill bit is a powerhouse for those seriously tough jobs. I was working on customizing a couple of workshop carts topped with 1/8" stainless steel wrapped around 1" wood composite. I needed to drill a clean 2" hole clear through both materials, but stainless steel has a way of crushing normal metal hole saws and bits.

After many failed attempts with regular bits, cobalt bits, and titanium bits, I ordered this 2" carbide hole saw, which I chose for its affordability and quality. With a lot of torque, pressure, force, and a bit of time and sweat, I was able to cut through the parts. The bit is well constructed, with a spring-loaded lead for starting the hole and for cleanup. As with any metal cutting, remember to slow down, stay steady, and use tapping oil. Stop drilling if your drill is too hot or smoking, and run it in the air for quick cool down.

—Emily Coker

RACHIO SMART SPRINKLER CONTROLLER GEN 2

$200 for 8 zones or $250 for 16 rachio.com

I have a simple four-zone sprinkler system at home, and programming its traditional controller is always an exercise in aggravation. I got the Rachio controller to fix that, as it moves the controls to your phone and offers an intuitive interface for scheduling and controlling the system. It syncs with local weather data, so it knows to not water on rainy days, and can determine each zone's specific watering needs based on plant type, soil type, ground slope, and other factors. I love being able to turn a zone on or off from any spot in the yard, which is great for troubleshooting and making sprinkler repairs. And it integrates with Alexa (see page 92) — I feel like I'm invoking the power of Neptune every time I watch the sprinklers spray with just a voice command.

—MS

SEEEDSTUDIO BEAGLEBONE GREEN WIRELESS

$45 beagleboard.org

While never a runaway success like the Raspberry Pi, the BeagleBone line is arguably better suited for hardware prototyping than the Raspberry Pi, and it's open source — meaning you can prototype using this board and then design your own version for industrial or commercial applications.

That aspect has led to a number of BeagleBone Black copycat boards. SeeedStudio's BeagleBone Green, released last year, and the new Wireless model, are the most notable of these derivatives, making major changes to the design. They include two Grove connectors, allowing you to connect it directly to sensors and actuators using SeeedStudio's Grove ecosystem without any soldering, and, of course, the latest has a 2.4GHz wireless module supporting both Wi-Fi 802.11 b/g/n and BLE, although it doesn't have a wired Ethernet connection.

Of comparable boards, only the Raspberry Pi 3 is faster than the Green Wireless, however the BeagleBone has much better GPIO and UART support, and has onboard ADC support, which the RPi lacks. *—Alasdair Allan*

ACTOBOTICS MANTIS 6WD ROBOT CHASSIS

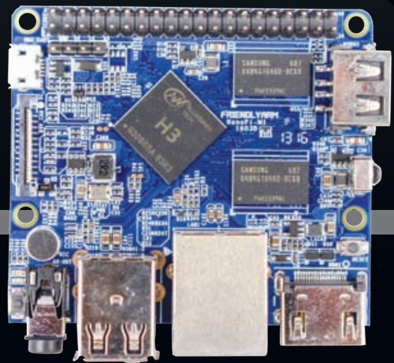
$480 for the 6WD kit
servocity.com

The Actobotics Mantis 6WD robot chassis is the most capable off-road platform I have ever seen, and it's incredibly customizable, strong, versatile, and sprier than a treaded tank-like robot. It can quickly traverse terrain too uneven for most other rovers, thanks to the independent suspension for each wheel. You can run it indoors if you have space, but the Mantis begs to be taken outside.

The Mantis is built using standard Actobotics parts, and comes with aluminum channels and beams, oil-filled aluminum-bodied shocks, and huge 5.4" knobby tires with foam inserts. You'll need to add your own motor controller, and it'll have to be beefy. Actobotics recommends a 2x30A RoboClaw. You'll also need a battery, some way to tell the motor controller what to do — such as an Arduino — and anything else you want to add, such as sensors or attachments.

The Mantis is everything I've been looking for in a robot platform. I wanted the main support structure to be a little wider, so I dug through my Actobotics parts and made the upgrade. When my needs change again, I'll dig into my Actobotics stash once more.

There's a 4WD version, and also a no-motors version of the 6WD kit, in case you want to stray from the otherwise included 313 RPM planetary gearmotors. *—Stuart Deutsch*



FRIENDLYARM NANOPI M1

$13 nanopi.org

A neat little board just two-thirds the size of the Raspberry Pi, the NanoPi M1 from FriendlyARM comes in two versions: 512MB of RAM, or 1GB for $3 more.

Powered by an Allwinner H3 processor, the board is very similar to the Orange Pi One, but with more features and perhaps better documentation. FriendlyARM was the first to react to the recent Allwinner sun8i legacy kernal security alert, providing a fix for a potentially huge security hole ahead of most other vendors.

The board comes with a 40-pin GPIO header that is pin-compatible with the RPi, and while it doesn't have the onboard Wi-Fi or Bluetooth of NextThingCo's $9 C.H.I.P., it does have an onboard IR sensor, an unusual selling point for single board computers in this class. If your project depends on IR, or you want to control audio/visual equipment that still uses IR remote controls, this board might well be the right choice. The NanoPi also has an Ethernet jack, USB ports, and an onboard microphone. This is a solid, affordable Pi replacement, especially if you don't need built-in wireless connectivity.

—AA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AMAZON ECHO AND DOT

$180 (Echo) $90 (Dot) amazon.com

When people talk about the Amazon Echo, they're usually talking about Alexa — the black, discreet gadget and its smaller sibling "Dot" are just vessels for bringing the always-listening Alexa service into our homes. Connecting to a broad web of outlets through Wi-Fi, it answers simple questions, sets reminders and timers, orders items on Amazon, and plays music, all through spoken commands.

The control is familiar to anyone who's accustomed to running voice queries on their phone — both in convenience and in occasional frustration. Getting a precise answer is a bit clunkier than on Siri or Google Now, but Alexa's responsiveness is so much faster than what I'm used to that it starts to feel conversational — largely due to the devices' microphone arrays that hear your requests even from a considerable distance.

The units shine with their external service integration. Amazon has a fairly permissive Alexa developer program, letting hardware makers build tools to control their devices via Alexa. The compatibility list grows regularly — my iDevices Outdoor Switch (Toolbox, *Make:* Vol 52) was just integrated, as is the Rachio sprinkler controller (page 89), Philips Hue lights, and a bevy of other smart devices.

Amazon is also courting the community to develop easy apps (Alexa plays nicely with IFTTT, for instance), and has even published a how-to for adding Echo functionality to a Raspberry Pi (github.com/amzn/alexa-avs-raspberry-pi). Again, it's all about getting Alexa into our homes.

Mine is mostly used as a web radio, and as a power switch for connected devices — perhaps overblown, but I'd be frustrated to lose the voice-controlled power that I've become very fond of.

—MS

POCKETCHIP

$70 getchip.com

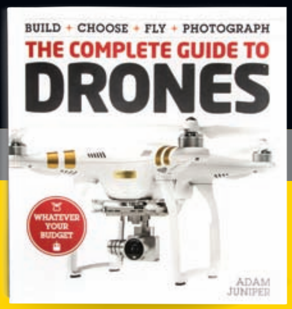
The PocketCHIP is made for those who love to play games and hack electronics. It's ready to use right out of the box and features a touchscreen, Wi-Fi, GPIO ports, QWERTY keyboard, battery pack, and C.H.I.P. computer.

The PocketCHIP comes pre-loaded with Pico-8, a community game console that gives you access to hundreds of games. What's interesting about the PocketCHIP is that you can change the included games on Pico-8 by customizing the characters, music, and even special effects. PocketCHIP also has the ability to run Linux, which is perfect for those who are a little more comfortable writing code. If you love to game, and love to code, this device is for you!

—Jenny Ching

Michael Bucuzzo

BOOKS



THE COMPLETE GUIDE TO DRONES

by Adam Juniper

$11 Ilex Press

I've been saving up to buy a drone, but with relatively little flying experience, I found it hard to understand and differentiate between certain drones that are available on the market. What makes one better than the other? Materials? Cost? Size? The amount of technology crammed into it? Other factors also weighed on my mind, like understanding how to pilot these machines.

Thankfully *The Complete Guide to Drones* by Adam Juniper is an extensively well-detailed compendium about ... well, everything I need to know about drones! I especially enjoyed the section on understanding video and image resolution — a topic I thought I already knew much about.

For the hobbyist and the pro-consumer alike, this book contains just about everything you need to embark into the R/C multicopter world. And with drones, having a reference material like this is invaluable, for as Juniper says, "Fools rush in (and a fool and his drone are soon parted)."

—Anthony Lam

MAKE IT GLOW

by Emily Coker and Kelli Townley

$20 Maker Media

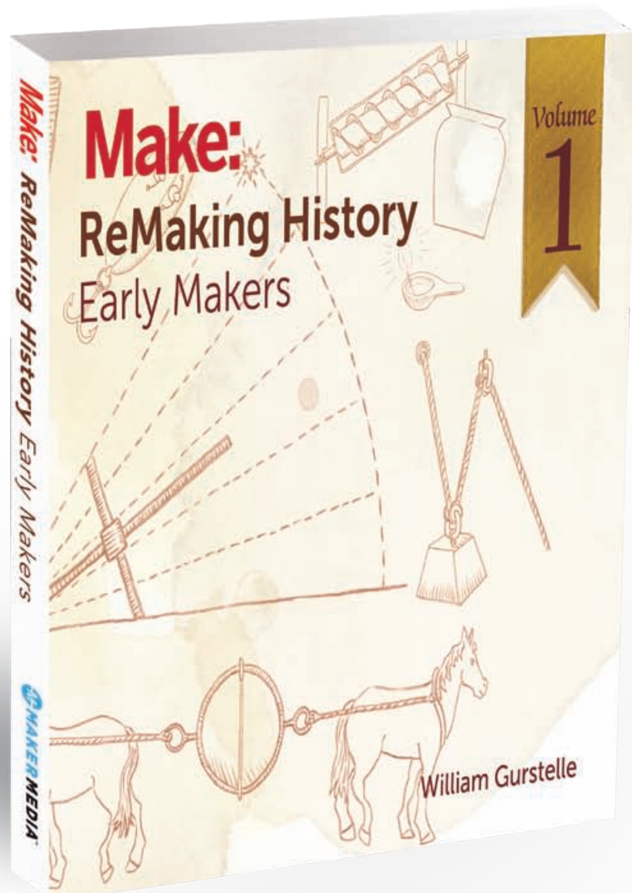
Make it Glow is a fantastic resource for a beginner hoping to incorporate lights into their projects. With three different difficulty levels, there are plenty of projects for everyone. This isn't just a lesson in electronics — the projects range from papercraft to sewing and even casting.

The focus remains on how to physically incorporate the lights into your projects. You won't find complex tutorials on how to control LED arrays, but you will find a plethora of fun and visually stunning projects. This is the perfect resource for a family hoping to make beautiful glowing things together.

—Caleb Kraft

Maker Shed **NEW**

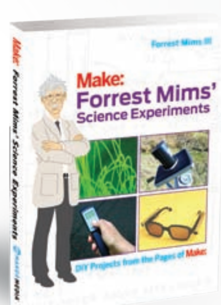
BOOKS



REMAKING HISTORY, VOLUME 1

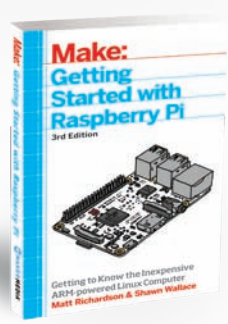
by William Gurstelle
$29.99

What does a nun have to do with fishing tackle? More than you might think. Drawn from Gurstelle's collected columns in *Make:* magazine, the ReMaking History series begins by taking a closer look at DIY science efforts beginning at the dawn of civilization and stretching forward to the 18th century. Touch the past by recreating some of its greatest inventions — not to mention getting advice from the 14th century nun who (literally) wrote the book on recreational fishing.



FORREST MIMS' SCIENCE EXPERIMENTS

by Forrest M. Mims $19.99
Learn the essential skills, methods, and procedures that you need to begin working, thinking, and recording like a professional scientist.



3RD EDITION

GETTING STARTED WITH RASPBERRY PI

by Shawn Wallace and Matt Richardson $19.99
Updated to include coverage of the Raspberry Pi Models 2 and 3, this refreshed edition takes you step by step through the many possibilities this tiny computer has to offer.

GETTING STARTED WITH CNC

by Edward Ford $24.99
Written by the founder of the game-changing Shapeoko project, this book offers beginners a general introduction to desktop CNC routing and acts as a handy reference for more experienced users. No prior CNC knowledge required.

NEW & NOTABLE BOOKS FROM MAKER MEDIA

Make: EDIBLE INVENTIONS

by Kathy Ceceri
(September; $19.99)
Kids learn to make (and hack!) all of the delicious foods they already love to eat while discovering new methods for cooking them.

Make: DRONES

by David McGriffy
(October; $29.99)
Teach your Arduino to fly with this hands-on set of drone builds and mods.

Make: PROPS AND COSTUME ARMOR

by Shawn Thorsson
(September; $29.99)
Gain the secrets of making professional-looking sci-fi and fantasy wearables.

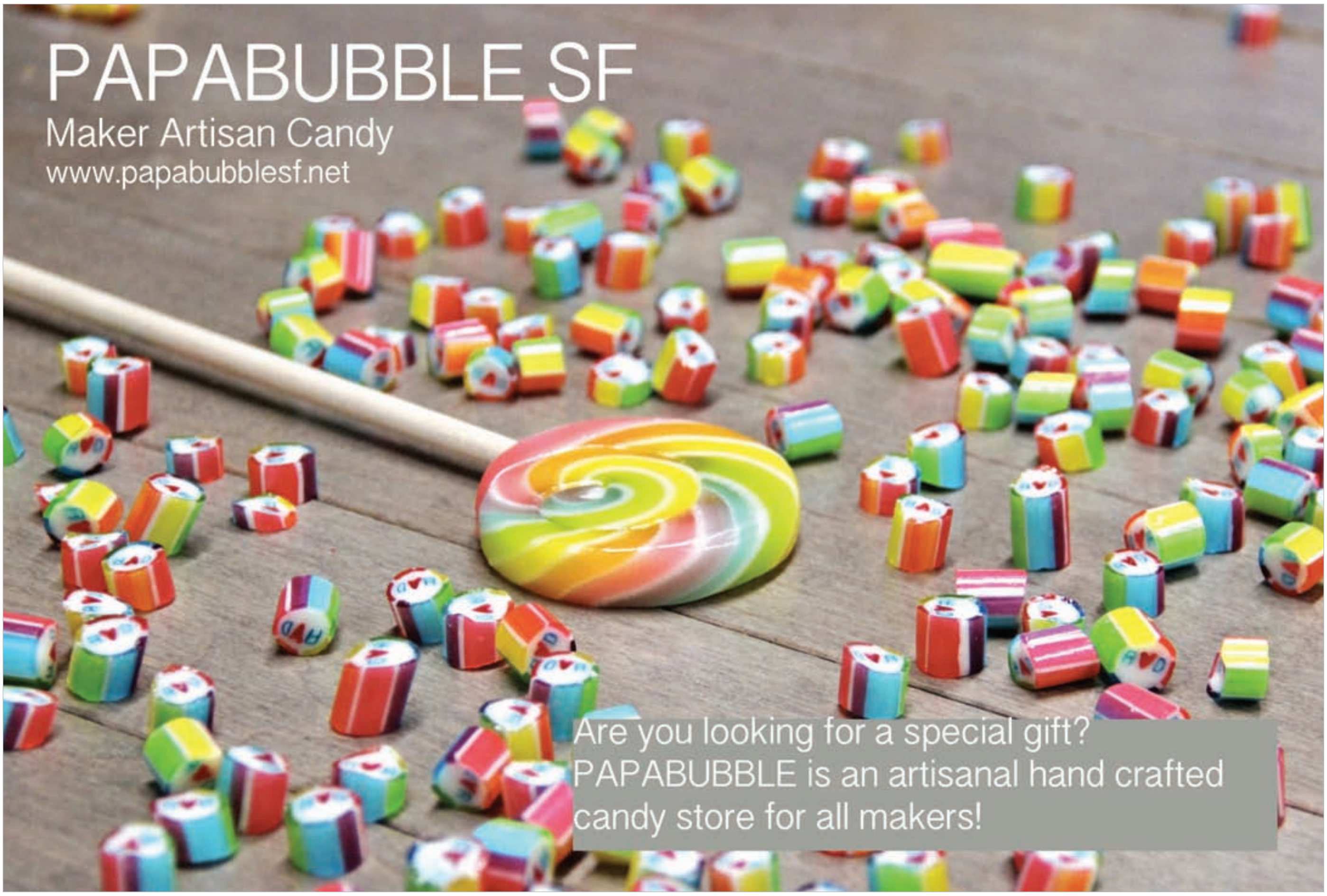
Make: DESIGN FOR CNC

by Gary Rohrbacher and Anne Filson
(September; $34.99)
Learn to design, fabricate, and assemble your own furniture.

MAKING THINGS TALK

3RD EDITION

by Tom Igoe
(October; $39.99)
Fully updated for the latest Arduino hardware and software, this book lets you combine microcontrollers, sensors, and networking hardware to make things — and make them talk to each other!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Nix + Gerber: The Last Artists in Brooklyn

Written by James Burke

I used to have so much difficulty moving through the rubble. Glass shards and rebars are no longer the anxieties I harbor, as I long ago gave up my fear of tetanus. I'm just glad the rent, just as everything else, has really plummeted in Brooklyn.

I'd reckon I see them every few months. Same building now half blown to pieces, and same workshop they had during the better days. They said before *the event* they used to make little post-apocalyptic scenes just like the ones we're now all too accustomed to wandering through. I guess they don't need to do dioramas like that anymore. Their recent works are far more optimistic.

Lori Nix and Kathleen Gerber are pleasant if not cautiously reserved. So much of nature has crawled its way back into York of old, I can only imagine what keeps them "indoors." Gotta keep your wits I 'spose.

Their latest piece is an elegant old brownstone, all pristine and carefully made. Every miniature 'zine, toothbrush, and sofa carefully rendered to pre-dust era glory. It's so pleasant to just get lost in their scenes and remember the good days. I'm sure they do too, but I'd never bothered asking.

Lori and Kathleen said they'd do something different for their next series. I can tell they're ready as that most recent diorama lies discarded on the crumbled street corner, in the trash pile that never gets collected. It just sits there in the overcast sky; it'd probably waft more if there were any sun left to refract through the post-nuclear dust.

Well, 'bout time I trek south ways. Too cold for my liking, but Lori and Kathleen seem to have plenty to kindle. If you ever see 'em, say Robert Hall says hello.

For the past 14 years Brooklyn-based artists Lori Nix and Kathleen Gerber have created intricately detailed dioramas. Before *the event* they were featured in various ad campaigns and gallery showings. nixgerberstudio.com.

Lori Nix

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