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Build the "Crittergram Capture Cam"

JULIUS SCHMIEDEL
MULTIMEDIA ARTIST

NICK NORMAL
CONTRIBUTING EDITOR, MAKE

The Arduino microcontroller is a great prototyping platform that lets you build awesome electronics projects with minimal effort. Over the years, many people have designed compatible hardware modules and software libraries that expand what the open-source Arduino ecosystem can do.

Here, we'll show you how to plug together several of these common components to create a custom trail camera that sits and waits until it detects movement to take pictures: an Arduino Uno microcontroller, the RadioShack JPEG camera module, a PIR motion sensor unit and a special Aurduino "shield" with an SD card reader.

If you look at the specifications of the camera module, you may notice it has a built-in motion detector. So why not use this instead of the PIR? The camera module detects motion by changes in the image so that, for example, a branch moved by the wind would cause it to trigger. But the PIR sensor is temperature sensitive, meaning it will only trigger if things are hotter (or cooler) than the surrounding environment. Humans, most animals, and moving cars will trigger the PIR, whereas a swaying branch and other windblown debris will not.

1

Insert the card into the slot on the SD card shield and connect the shield to the Arduino. Download and install the *sdfat* library and connect the Arduino to your computer. Open the SD Formatter sketch from the Arduino menu, upload it to your board and open Serial Monitor to start formatting the card.

2

The camera comes with a four-wire cable. Connect the female end to the camera module with red to +5V, black to GND, brown to RXD, and white to TXD. On the PIR sensor, connect a female/male jumper wire to GND (black), OUT (blue), and VCC (red).

3

Unplug the USB cable and connect the GND, OUT, and VCC jumpers from the PIR sensor to GND, pin 7, and pin 8 on the SD card shield, respectively.

Build the "Crittergram Capture Cam"

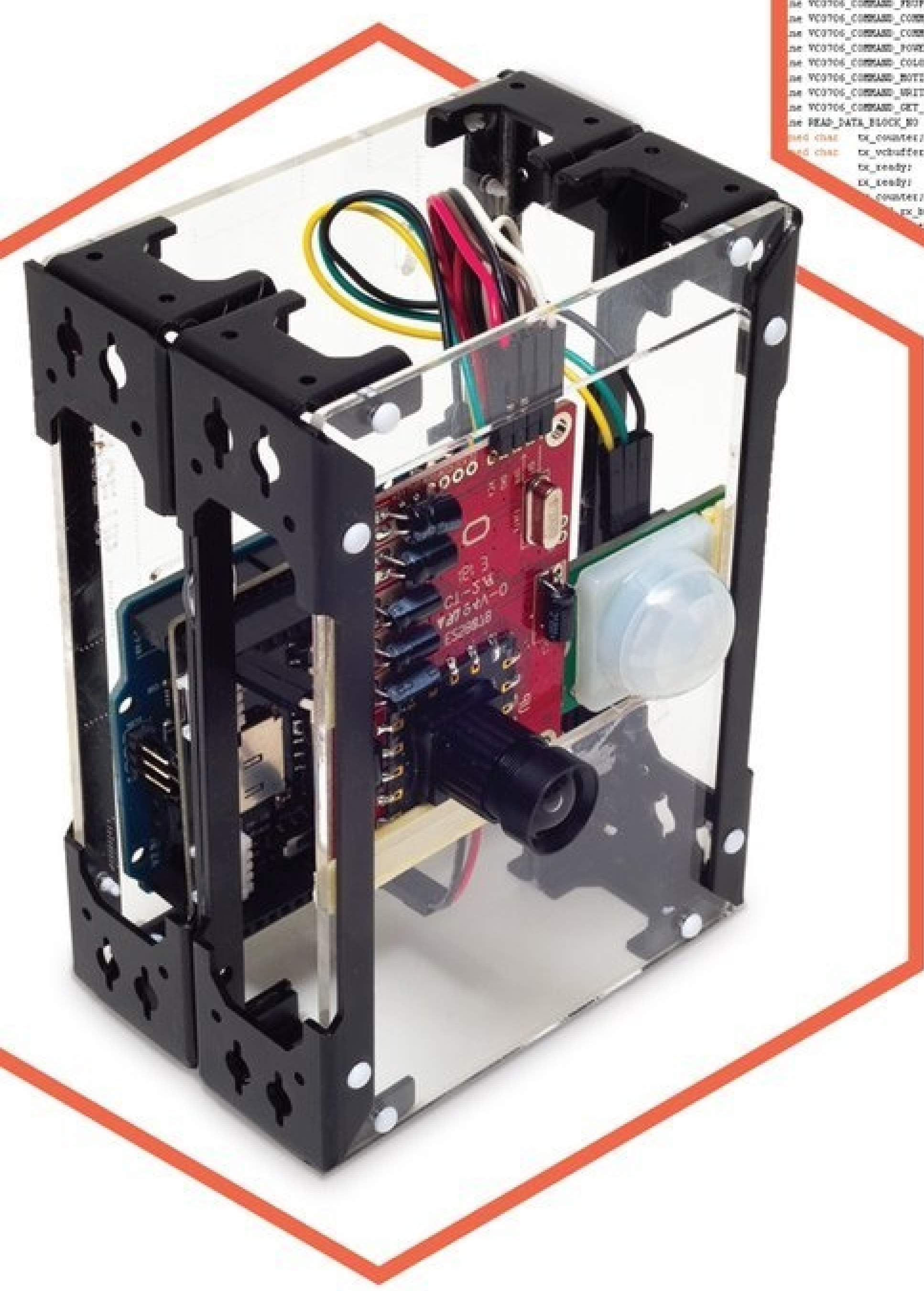
www.radioshack.com/DIT

PARTS

- ○ Arduino Uno 276-0128
- ○ JPEG Color Camera Board 276-0248
- ○ PIR Sensor Module 276-0347
- ○ SD Card Shield 276-0243
- ○ SD Memory Card
- ○ Enclosure Project Skeleton Kit 270-0183
- ○ Supermount Tape 640-2343
- ○ Power Supply 273-0357 and 273-0344
- ○ Jumper Wires 276-156
- ○ Zip Ties 278-0472

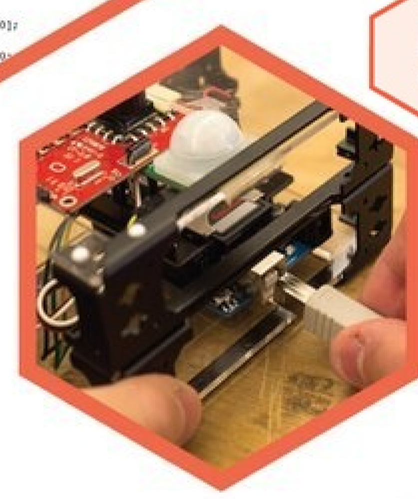
TOOLS

- ○ Mac, Windows, or Linux Computer
- ○ USB A/B Interface Cable
- ○ Arduino IDE Software
- ○ Hot Glue Gun



4

Download the sketch repository. You can modify the code as you like, for instance by changing the argument of VC0706_compression_ratio() to set the quality of the stored images.



5

Reconnect the Arduino to your computer. Upload the sketch and press the board's reset button. Your Crittergram Capture Cam will boot up and be ready to take pictures after a few seconds. Test it by waving your hand in front of the sensor.

6

Once you're sure it works, install the project enclosure skeleton kit. For indoor use, just add a wall wart and you'll be ready to go. Outdoors, you'll need to first weatherproof the enclosure and maybe add a battery pack. BONUS: The camera module is sensitive to infrared light—add an off-the-shelf IR illuminator, and you can take pictures in total darkness!

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Maker Shed Product Innovation Manager Michael Castor's PiPad. Photographed by Jeffrey Braverman and Gunther Kirsch.

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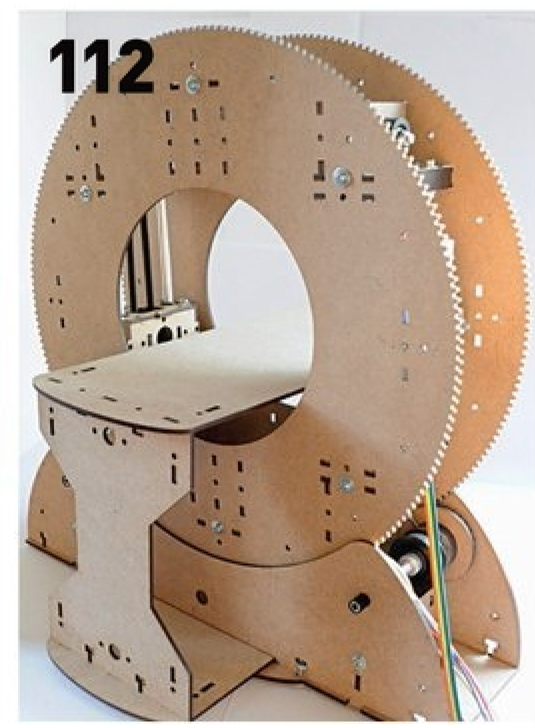

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"There is nothing worse than a sharp image of a fuzzy concept."
—*Ansel Adams*

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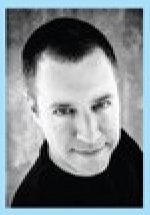
What maker accomplishment are you most proud of?

Rob Nance
Eugene, Ore.
(Remaking History and Skill Builder illustrations)
The maker accomplishment I am most proud of is a street sled, made from a furniture dolly, a piece of plywood, and a ratchet. Pulling my daughters to the neighborhood park is a blast.

Wynter Woods
Rohnert Park, Calif.
(Raspberry Pirate Radio, MAKE engineering intern)
As a maker, I am most proud of being involved in the ever-growing community, learning countless new things each day that I once believed I would never have the opportunity of knowing.



Udi Tirosh
Givat Brener, Israel
(Top DIY Photo Hacks)
That would be the Light Blaster (light-blaster.com) — it is a strobe-based image projector which is now a creative tool for photographers and marketers. It started as an idea, evolved into a prototype, and finally became a full-fledged product now sold at top photography stores.

Jenny Cheng
New York, N.Y.
(Video Game Plushies from 3D Models)
My proudest achievement was my contribution to Graphviz, a powerful open-source graph visualization software. It was the first time I realized my programming skills were good enough to improve high-profile open-source projects.

Lisa Trifiro
Berkeley, Calif.
(DIY Sriracha "Rooster" Sauce)
One of my most exciting maker projects was when I got to experiment with liquid nitrogen, but my all-time favorite is my DIY Spikey Pumps. I think it's totally sexy when women use power tools!

Jude Pullen
London, U.K.
(Wireless Ergo Mouse)
Solder Buddy — my first invention on my first website. I realized that solder and the bicycle brake cable could be used to switch the circuit — to power the motor. I'm also excited by the online interaction — with people building on the initial concept, making it far better than I imagined!

Year of the Maker

WRITTEN BY DALE DOUGHERTY, founder and CEO of Maker Media.

WHEN WE STARTED MAKE MAGAZINE nine years ago, we wanted to show that anybody can make things, and celebrate those who do it well — the makers. That is also what led us to organize the first Maker Faire and invite makers to showcase their work.

Maker Faire has become a global celebration of making that invites everyone to become a maker. In 2013, there were 100 Maker Faire events, 44 of which were hosted by museums, libraries, and schools. While the two largest Faires are the ones we organize in the Bay Area and New York City, with 125,000 and 75,000 participants, respectively, even more people are experiencing a local version of Maker Faire. Some 530,000 people attended a Maker Faire in 2013.

The majority of events are still in the United States. However, Maker Faire Rome, the first large European event, hosted 35,000 people and was a big success. France had its first Maker Faire in the town of St. Malo on the Brittany coast. Germany also had its first Faire in Hannover last August. Taipei, Shenzhen, Tokyo, and Seoul produced second-year events, as did Santiago, Chile.

Already, 2014 is off to a good start with Maker Faire Oslo in Norway having taken place in mid-January. I went to Oslo, where the organizers, Jon Haavie and Roger Antonsen, asked me to choose an Oslo Maker of the Year. I balked at first. I don't like picking favorites, but then I saw it as another way to celebrate makers.

My criteria for selection were simple. I wanted to choose a person who was enthusiastic, generous, and a true believer, as Mister Jalopy once phrased. Someone who represented the core values of the maker movement and engaged others in making in a playful way. Also I looked for originality — something that I hadn't seen other makers doing in the same way, or quite as well.

I gave the award to Erik Thorstensson of Gothenberg, Sweden (above right). Erik demonstrated a modular construction system he developed called Strawbees. An open-source design, Strawbees uses simple connectors, die-cut on demand from scrap plastic. I watched kids and adults walk up and build structures from straws — a hat, a wand, a diamond that folds in on itself, and a pyramid. Part of a network of designers called Creatables, Erik has boundless energy and enthusiasm, with a flair for showmanship, deriving his sense of purpose from understanding the educational value of making.

There are makers who deserve recognition in every community, both local and virtual. I will encourage the independent organizers of Maker Faires, who themselves deserve recognition, to follow Oslo's lead and select a Maker of the Year in their community. Some makers, like Erik, go from one community to the next to share what they do. (Mitch Altman probably tops the list of makers who will travel anywhere, anytime to introduce new people to hacking and making.)

Makers who've created successful businesses are increasingly in the spotlight, too. Bre Pettis had a great year, establishing MakerBot as the frontrunner in consumer 3D printing and then merging with one of the largest industrial 3D printing companies, Stratasys. Chris Anderson left *Wired* to go all-in as CEO of 3D Robotics and discover new commercial applications for drones. Ayah Bdeir has taken littleBits from a grad school project to a company with sights on putting an educational electronics play system in toy stores everywhere. Lisa Fetterman developed Nomiku, a sous vide cooker, following the increasingly common path from Maker Faire to Kickstarter to HXLR8R in Shenzhen, China, to commercial product.

Let us not forget small, independent maker businesses. Last fall, I visited Ken Burns of Tiny Circuits in Akron, Ohio, and in Detroit I met with the team of SeeMeCNC of Carmel, Indiana, makers of the Orion 3D printer (a Delta-style printer that I bought). David Lang published the *Zero to Maker* book and, with Eric Stackpole, began delivering OpenROV kits to the classroom. Designer Carla Diana published a children's book on 3D printing titled *Leo the Maker Prince*.

At Adafruit, Limor Fried and Phil Torrone went from successful business partners to lifelong partners, getting married on Halloween in 2013. Like Lenore Edman and Windell Oskay of Evil Mad Science, Limor and Phil are examples of what we might call Maker Couples, who live, work, and make together. Both of these couples have been leading advocates for open-source hardware.

Young makers also made their mark in 2013 with Super Awesome Sylvia demonstrating the WaterColorBot to President Obama at the White House. Quin Etnyre of Qtechknow was invited to Maker Faire Rome to give a talk titled "Lessons from a 12-year-old CEO." He tweeted that he had met the mayor of Rome and saw the Pope. The second annual virtual Maker Camp engaged millions of young makers, and Maker Corps organized summer internships for 108 college-age makers to engage young makers at 34 host sites around the country.

2013 was an awesome year for makers. Yet I believe that 2014 will be even better. Young maker Joey Hudy was part of President Obama's State of the Union address, and he was part of an announcement that the White House will host a Maker Faire in 2014. Let's find new ways to celebrate makers and elevate the maker community internationally.

Raygun Circuits, Free Beer, and the Quest for Long-Lasting 3D Printers

IN RESPONSE TO THE "RAYGUN VECTOR WEAPON" PROJECT FROM VOLUME 35

» I bought the Vector Weapon Kit from the Maker Shed for my 6-year-old son Desmond as a Christmas present. This was the first real electronics build we've done together. It was a good opportunity to show him a little bit about soldering and how some of the elements in the circuit work. It's really rewarding to do this kind of project with Desmond, as it gives us a fun way to spend time together, a creative way for me to teach him things, and of course, results in a unique toy that will hold memories we will both have for a lifetime.

—Genji Siraisi, New York City, N.Y.

Read more about their build and check out their fun videos: makezine.com/go/genji

» I had so much fun with this [Raygun Vector Weapon] circuit! I made an instrument with it and a modified version of Eric Archer's Mini Space Rocker circuit (vimeo.com/85130857). Right now it's a manually operated four-voice drum synth. I plan to add an external sequencer and a piezo trigger for fills and live play. Please give us more cool lo-fi audio projects. I got into DIY synths and noise circuits a few years ago after Collin Cunningham did a piece about the Atari Punk Console. After a quick trip to RadioShack I had a fun noise toy and I was hooked. Thanks MAKE!

—Chuck Stephens, Tampa, Fla.

IN RESPONSE TO OUR MAKE: ULTIMATE GUIDE TO 3D PRINTING 2014:

» I bought a printer after reading through the excellent 2013 version of the 3D printing guide — good advice and worth every penny. After several months of experience with the technology, here is what I would find useful: a side-by-side comparison of printers put through extended rigorous production. Simply running a test print off a model that is new and has been calibrated by the supplier is not adequate to evaluate how good a design really is. How long before each extruder clogged? How does each printer do running several 6 hour+ print jobs? How many failed prints did you have? How does each printer hold up after extended daily use for 30+ days? What parts shake loose, and what parts are inadequate for constant duty? My hope is to get another printer in the next year or so, but in my experience the $2,500 printers break down and suffer from poor design (especially in the filament handling) just like the $300 printers do. This industry will remain a tinkerer's playhouse so long as the large-print success rate is below 95% with printers more than 30 days old.

— Brian Cooper, Denver, Colo.

DIGITAL FABRICATION EDITOR ANNA KAZIUNAS FRANCE RESPONDS:

» Thanks for your feedback! Your comments raise some excellent points. We understand that long-term testing is critical to making hardware recommendations and evaluating performance. Future testing will be focused on exploring exactly those issues that you mention. We will also be increasing the frequency of our testing, as new printers are being developed at an astonishing rate. Look for them both online and in MAKE magazine shortly.

» What does "Free as in beer" mean? I have only recently discovered MAKE magazine, and am now reading my second issue. (I love them!) Both issues have contained the phrase. I live in Colorado, where beer costs money, especially the fancy microbrews. So what gives?

TECHNICAL EDITOR SEAN RAGAN RESPONDS:

» Great question! "Free as in beer" is a phrase that originates in the open software movement. It's used to make a point about the meaning of the word "free," which, especially when it comes to software, represents two very distinct ideas that often need to be separated for clarity. There's "free," in the sense of something that is given away ("free as in beer"), and there's "free" in the sense of freedom ("free as in speech"). Some software is given away for free but is nonetheless closed-source and proprietary, making it "free as in beer" but NOT "free as in speech."

MAKE AMENDS: In "Anatomy of a Drone" (Volume 37, page 34) some components in the bottom row of the diagram are mislabeled. The correct labels from left to right are: Motor (C), Electronic Speed Controller (H), Flight Controller (I), Receiver (K), Gimbal Controller (Q), and GPS Module (J). Thanks to MAKE reader Qameron Alforque for the tip.

We apologize to "Luminous Lowtops" (Volume 37, page 66) author Clayton Ritcher for misspelling his last name.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Engineering for Real World Problems

Ten tips on using your maker skills for humanitarian, environmental, and social causes. Written by Benedetta Piantella

BENEDETTA PIANTELLA (pictured with the head of a Maasai village in Narok County, Kenya) is a designer turned humanitarian technologist who has built partnerships with organizations such as the UN and UNICEF and has deployed projects in countries such as Uganda, Kenya, and Tanzania. She is currently a full-time faculty member at NYU-ITP.

IT ALL BEGAN FOR ME NINE YEARS AGO: I was a designer and artist interested in processes and new techniques, busy building interactive environments to provide complete sensory experiences for users, when I found myself in the midst of one of the most devastating natural disasters in our recent history: the Indian Ocean tsunami of 2004. Surviving such an experience and seeing firsthand what happens after an emergency, how the community reacts, and what kind of methods and efforts are implemented to provide relief triggered something inside of me. I knew I had found my calling.

Everything I had learned up until that day and any skill I possessed, from practical know-how to critical thinking, could very well be applied to help and address challenges involved in similar situations and more. Since that day, I've been involved in creating R&D companies to focus specifically on research, consulting, designing, and implementing custom solutions to humanitarian, environmental, wildlife conservation, and other social challenges worldwide. Here's what I've learned over the years.

1. Start with the problem. Often you'll hear of a problem from invested parties that have spent a long time overanalyzing the challenge and might be missing the point. Start by asking hard questions to identify the real core of the issue at hand. Don't fall for their assumptions.

2. Research a lot. Especially when dealing with a context or country you have no experience with, there's no such thing as too much research to get a better sense of the social, cultural, and economic aspects of the location you're designing for.

3. Sabali. Probably my favorite Bambara word, meaning patience. Everything takes longer than you expect when dealing with large challenges, so embrace it, be patient, and keep on your path. What would take you one day to accomplish at home might take weeks to accomplish in the field.

4. See it for yourself. The best way to learn about your challenge is to personally be involved and witness it. There's nothing like firsthand experience, so if you can travel to your location, do it. Everything will be much clearer and a lot of assumptions will automatically be dispelled.

5. Be creative with funding. Except for a few consolidated funding channels, which are often limited to nonprofit entities only, partners are still shy about spending money to fund research and development projects. But the good news is that there are a lot of creative ways to raise funds to take you and your project into the field, from design competitions to crowdfunding and grants.

6. Fail early, fail often, but please fail. A lot of things can and will go wrong once you get to field-testing and implementing a project in its intended environment, and this is where you learn the most. A lot of projects fail and people are ashamed to document them, denying others the chance to learn from their mistakes and not waste resources replicating those failures. Learn to let go of your ego and not get attached to your solution, but instead let the things that didn't work teach you the right path to success.

7. Be disruptive. Most work in this field is still championed by organizations that have been around for a long time and have a set way of doing things, often using a top-down approach of developing solutions in a silo and then expecting communities to adapt themselves in order to adopt them. Disrupt this method by developing a bottom-up approach that starts with your users, the community, and the local environment to design the final solution. The users hold the answers, so provide them an outlet to let their voices be heard.

8. Harness local innovation. Long-term solutions don't come in a box. Most of the resources for the right solution are already there — it's a matter of harnessing the local talent. There's plenty of innovation, ingenuity, and makers to be fostered locally, making the solution much more sustainable in the long run. Allow them access to resources and share skills with them to let them develop their own solutions.

9. Build sustainably. Importing materials and components that no one knows how to fix and maintain locally is a recipe for disaster that we encounter way too often. Most things developed this way break within the first six months (if lucky) and stay broken indefinitely. Design your solution with long-term goals in mind, considering locally available materials, in order to build things that will survive the environment and the course of time.

10. Never give up. This type of work represents a long, hard road to walk on. The hills are steep and the terrain is rough, so don't get discouraged. Just when you're about to give up, you might actually be closer than you think to making a real difference in the world and in the lives of others. Remember that really tough challenges can't be solved overnight.

John Simeonidis Jr.

California Crowdfunding

Written by Paul Spinrad

The state that celebrates innovation should support laws that do as well.

Nate Van Dyke

AS A CALIFORNIA RESIDENT, I'M SURPRISED THAT OUR STATE ISN'T LEADING THE WAY ON INVESTMENT CROWDFUNDING. On the contrary, we've fallen behind a growing list of states that includes Alabama, Georgia, Kansas, Michigan, North Carolina, Washington, and Wisconsin.

The JOBS Act of 2012, acronymically named for "Jumpstart Our Business Startups," legalized investment crowdfunding at the federal level. This legislation will let the public invest in makers, small businesses, and others through sites like Kickstarter, bypassing the expensive Direct Public Offering (DPO) process that's designed for large companies. Sites like Kickstarter have already sparked a wave of creativity among makers, and allowing the public to invest in garage startups promises to take their entrepreneurship to the next level. The Securities and Exchange Commission is still figuring out how they will oversee investment crowdfunding, so it isn't legal yet, but the green light is expected later this year.

Some people doubt that the federal rules will be useful, arguing that the burden and expense of all the required reporting and auditing will make investment crowdfunding under the JOBS Act not worth the trouble. Several companies are betting the other way, hoping to create a streamlined "TurboTax for investment offerings" that makes the process worthwhile — but only time will tell if they're successful.

In the meantime, several states have enacted new regulations and laws for crowd investing that are inspired by the JOBS Act but demand far less administrative overhead. They all operate under the long-standing intrastate securities exemption, which says that if a business offers stock to investors in its own state only, the sale is regulated by the state rather than by the SEC.

Kansas led the way on this with the Invest Kansas Exemption, which was enacted before the JOBS Act passed. That's no surprise, given the state's history — in 1911, Kansas passed the first-ever securities laws, and the "blue sky laws" that govern intrastate securities sales are named for its example.

Georgia followed with the Invest Georgia Exemption. Then Wisconsin and Michigan followed with similar exemptions — Michigan's passed on Dec 31, 2013. Meanwhile, investment crowdfunding bills have been introduced into the legislatures of North Carolina and Washington. Alabama promises to be next. Georgia-based Bohemian Guitars, which builds beautiful musical instruments out of oil cans, is one example of a new maker business that funded itself in this way.

So where's California, the land of startups and innovation? Like the USA itself, people come to California to reinvent themselves and pursue their dreams. And people come to crowdfunding for the exact same reasons — so I think we have a disconnect.

You don't need to be theorist and author Richard Florida to understand that the creative people who drive economic success move to places that support them, and leave the places that don't. That's why Georgia investing guru Knox Massey said, after Ohio regulators threatened Cincinnati-based funding platform SoMoLend, "Ohio startups, Ohio doesn't want you. Move to Georgia!"

PAUL SPINRAD is a broad-spectrum enthusiast, writer, maker, and dad who lives in San Francisco. He hatches schemes at investian.com.

+ For links to read more about the laws and concepts mentioned above, and to add your comment to the discussion, head to makezine.com/california-crowdfunding.

Encouraging Girls to Hack and Make

How I created a program in my community to share my love of technology. Written and photographed by Luz Rivas

I FIRST GOT INTERESTED IN ENGINEERING AND TECHNOLOGY 30 YEARS AGO WHEN I WAS IN FIFTH GRADE. My class had four Apple IIe computers, and my teacher taught us to program in Logo and BASIC. This was my first time using technology to create something, and I loved it. In sixth grade, my teacher continued teaching us to program and took some of us to what would now be called a hackathon for kids at our local university. When I entered middle school, I chose to take computer programming again since it was something I was already familiar with. These early experiences sparked an interest in me to pursue a technology career. After high school I was on my way to MIT to study electrical engineering.

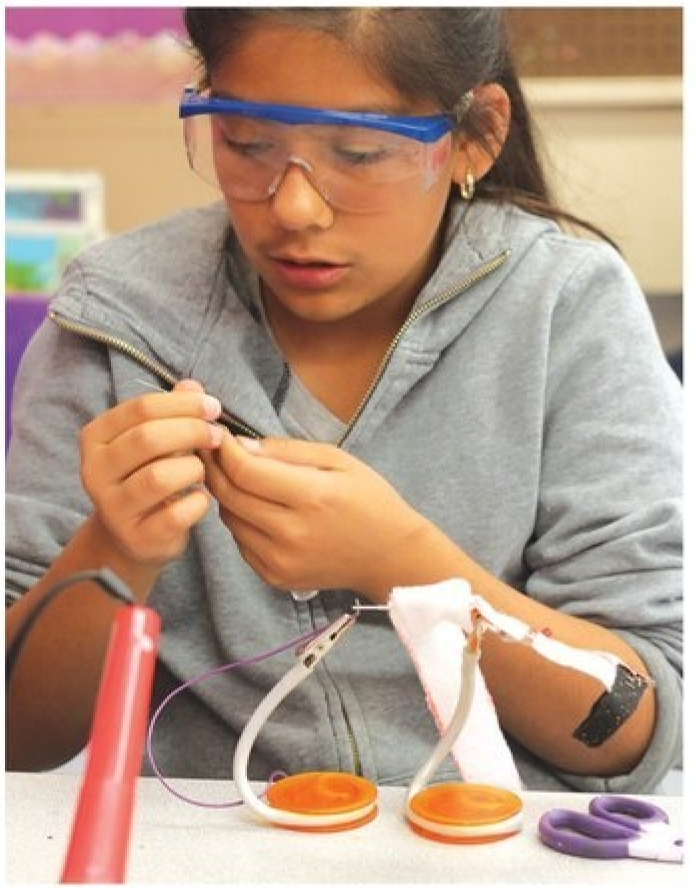
Unfortunately, my story is not so common for girls from Pacoima, an underserved community in the Northeast San Fernando Valley of Los Angeles. While most focus on stats that label my community as disadvantaged, we do have an advantage when it comes to making. Pacoima is a community of makers. Growing up, I saw both men and women making things, like their own furniture from scrap wood, toys for their kids, and elaborate dresses for quinceañeras, as well as hacking and fixing electronic household devices.

After working as a hardware engineer, attending grad school at Harvard, and working in science and engineering education for 10 years, I decided to go back to my community and start a program for girls. I wanted to make explicit the connection between making in their community and making with more advanced technology. To do this, I launched the DIY Girls after-school program (diygirls.org) for fifth-grade girls at my former elementary school. The school offered me a dedicated classroom, (which ended up being my own fifth-grade classroom!). With help from volunteers, friends, and teachers, I converted the classroom into a makerspace and recruited girls.

The DIY Girls program is designed to offer experiences that will attract young girls to technology, allow them to express themselves creatively, and give them confidence in their technical abilities. We aim to have an effect on the girls as they enter adolescence and start to form career interests. We meet with 30 students twice a week for two-hour sessions. Through hands-on making activities, girls in our program make real things, like their own toys, wearable electronics, and video games. They learn technical skills including soldering, computer programming, basic electronics, and 3D design. They then apply these skills creatively by designing their own projects and inventions.

Our program focuses on three areas:
Creative Electronics: Girls learn electronics though e-textiles and smart materials like conductive paint. The goal is to be creative while learning basic electronics. They also learn to solder, strip wire, build circuits on breadboards, and use multimeters.
Building and Tinkering: We teach girls to use the basic tools they need to build things. Girls take things apart and learn appropriate ways to use the tools, in addition to safety techniques. We aim to instill confidence through this session.
Product Design: Girls combine the skills developed throughout the year to design and create their own products using a 3D printer, MakeyMakey boards, and other materials. We culminate with a public showcase of the products for families and the community.

DIY Girls has been successful in creating a learning environment where girls take risks, build confidence, and work on projects that attract them to technology. If a girl gets frustrated one day because her program or project didn't work, she knows she'll have the opportunity to try again when she returns for the next session.



Girls love that they're learning real skills. Teachers, administrators, and parents have told us that they notice the increase in self-confidence.

I'm excited that the majority of our girls want to continue making things after they go through the program. I plan to teach them more advanced skills like programming and creating projects with the Lilypad Arduino. I'm working on growing the program to serve more girls at more schools and aim to offer summer camps.

LUZ RIVAS
has experience in engineering, STEM curriculum development, program management, and educational research. She has a B.S. in Electrical Engineering from MIT and a master's in Technology in Education from the Harvard Graduate School of Education.

MADE ON EARTH

#madeonearth

The world of backyard technology

Know a project that would be perfect for Made on Earth? Email us: *editor@makezine.com*

ETHEREAL FISH TANK LANDSCAPES

KIMKEEVER.COM

At first glance, New York artist **Kim Keever**'s landscapes look like traditional paintings. But when viewing them on his site, the aperture, camera, focal length, and shutter speed is noted for each piece. To what otherworldly land does Keever travel to photograph these stunning shots? No further than his studio, where he creates perfect miniature underwater landscapes in 200-gallon fish tanks. He then plays weatherman to his ecosystem by adding materials like paint, plaster, and Mylar to the water; hones in the dreamy lighting; and shoots away, capturing the ethereal motion of the clouds, frozen in time.

— Goli Mohammadi

Kim Keever

FROM PEST TO BIOPLASTIC

JEONGWONJI.COM/BIOELECTRIC.HTML

When life gives you mitten crabs, make bioplastic.

The Chinese mitten crab, an invasive species from East Asia, gets its name because it looks like it's wearing a pair of furry mittens on its claws. But it's not so cute. The crab negatively impacts native wildlife in Europe and the U.S., where it's labeled an "injurious species."

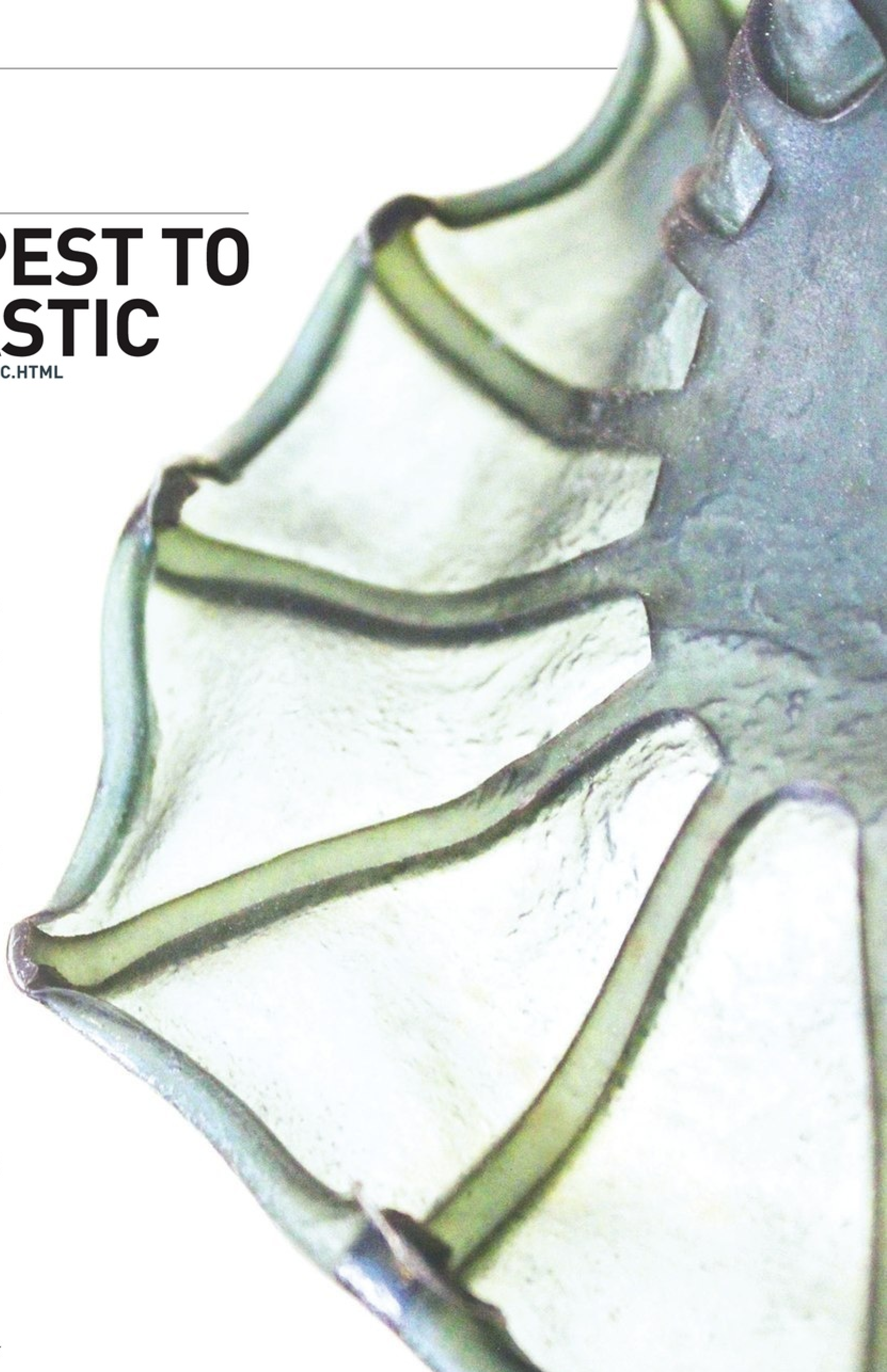
London-based industrial designer **Jeongwon Ji** has come up with a practical solution to combat the crustaceous invaders. She crunches up their shells and makes a biodegradable plastic she calls "crustic." The material is made of red algae, glycerine, water and chitin, a long chain polymer that makes the shells hard.

Ji has incorporated crustic in a series of electronic enclosures, formed on wooden molds. She calls the series BioElectric.

"Although production time is longer, this nontoxic process can improve the work life of those who manufacture our electronics," she says.

The finished product has a pebbled, coarse texture that evokes its natural origins.

— Stett Holbrook



Daniel Thomas Smith

STRETCHED PERSPECTIVE

JONTYHURWITZ.COM/ANAMORPHIC-SCULPTURES

There's more to the curious sculptures of London-based artist **Jonty Hurwitz** than first meets the eye, which becomes apparent when a reflective surface steps in to put things into perspective. Hurwitz utilizes mathematical algorithms in conjunction with historic methods of manipulating the perspective of an image in order to create anamorphic sculptures that hide realistic images in plain sight. These mind-bending sculptures depict objects that have been elongated and distorted in three dimensions, so the intended image is only revealed when seen from the correct angle in the reflective cylinder. In programming terms, it is as if Hurwitz' imagery has been encrypted with an anamorphic code that has to be decoded by the appropriate optical devices.

— Andrew Salomone

Niina Keks and Otto Pierrotto

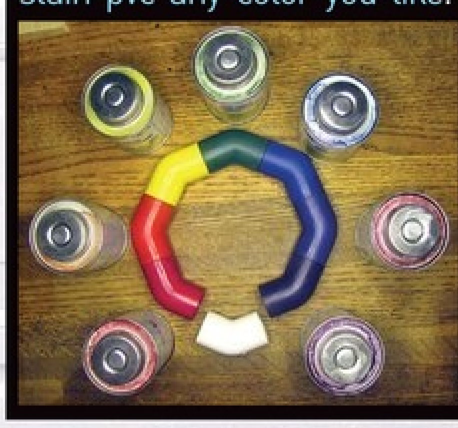
MUSICAL PVC PIPES

PROJECT: BUILD YOUR OWN PVC PIPE INSTRUMENT — SEE IT IN ACTION AT MAKEZINE.COM/PROJECTS/PVC-PIPE-INSTRUMENT

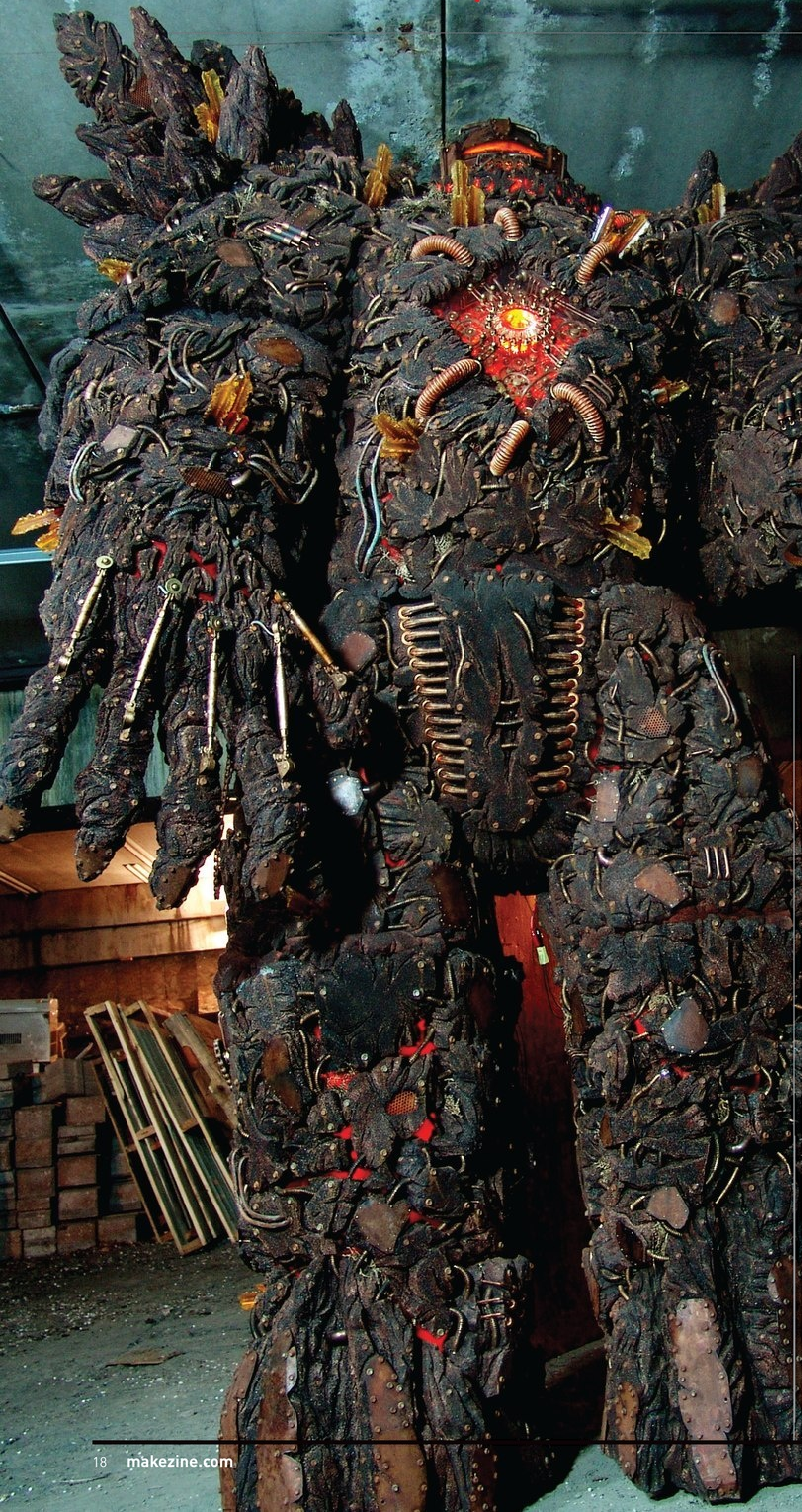
Thirteen-year-old **Jason Duckering** showed off his PVC Pipe Instrument at last year's Maker Faire Bay Area and as a guest during last summer's Maker Camp, playing classic songs like Ozzy Osbourne's "Crazy Train" and Europe's "The Final Countdown." With 11 pipes tuned to notes in a C major scale, the instrument packs more than 80' of 2" diameter pipe in a 24"x40" footprint, a configuration he planned out on graph paper. For the custom paddles he uses to strike the tops of the pipes, he experimented with scrap pieces of foam duct-taped to sticks and even flip-flops covered in socks, but he finally settled on foam rubber backed with Plexiglas for rigidity. Next up: an upgraded three-octave instrument.

— Craig Couden

Jason spray painted his PVC pipes, but to achieve longer-lasting color, learn to stain PVC with this handy tutorial: makezine.com/projects/stain-pvc-any-color-you-like.



Brian Duckering



Shannon Chappell

HE LIVES!

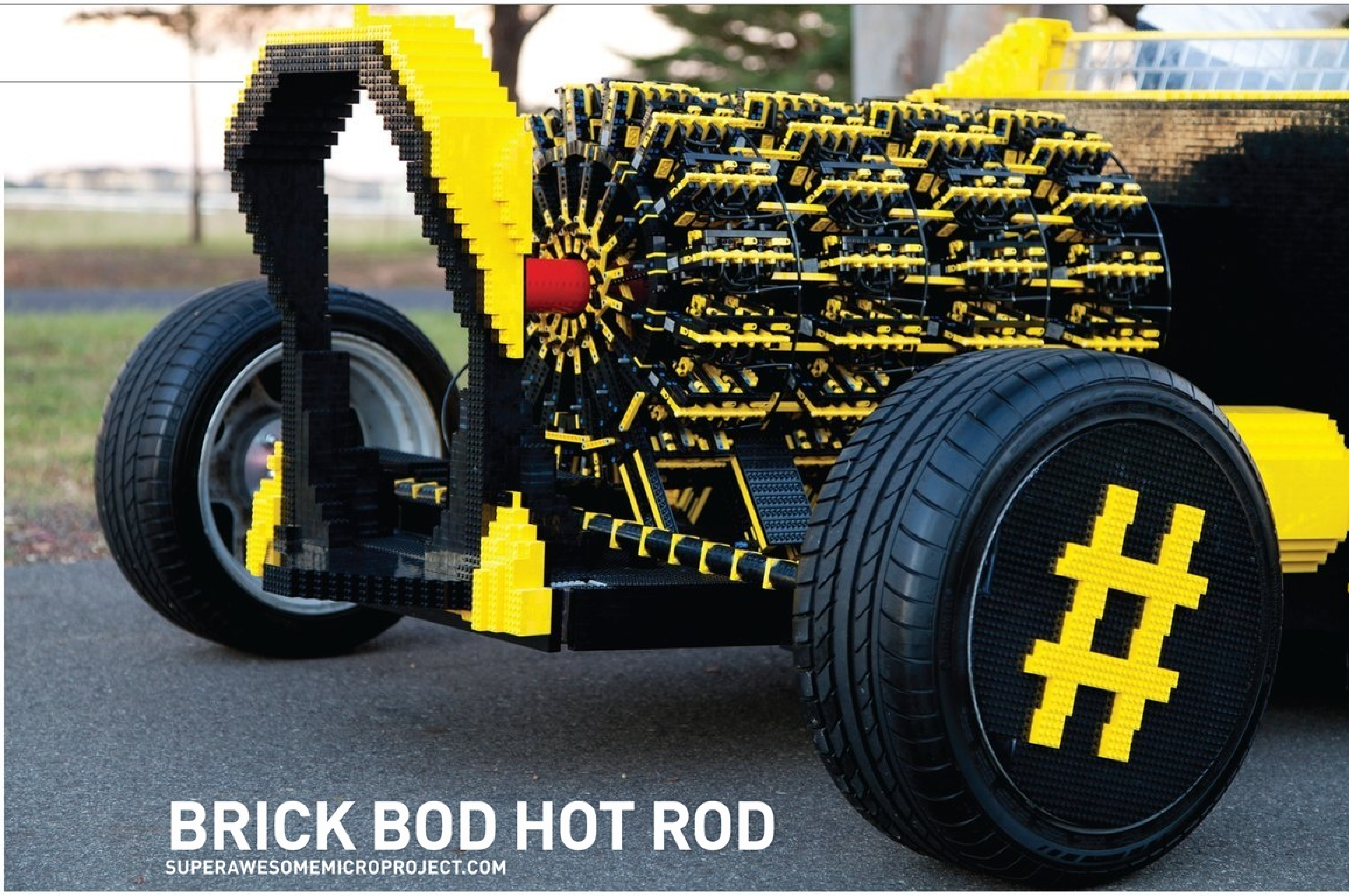
MAKEZINE.COM/GO/STEAMPUNKGOLEM

Meet Golem, an 11'-tall "steampunk rock" creature by Canadian sculptor and maker **Shannon Chappell**. "A Golem is an animated creature created out of inanimate matter. In this instance, a magical will was put into a pile of rocks and antique machine parts to bring this Golem to life."

Magic ... or maybe a lot of hard work! To wear it, an operator climbs in through the lower back, locks his feet into ski boots mounted on 3'-tall stilts, and fires the light, sound, and smoke effects from inside a spaceship-style cockpit. The Golem walks! Gears on the chest spin, and the Gatling gun spins and lights up. Strips of pulsating LEDs threaded between the rocks create a lava effect.

Chappell, a hotel handyman, had been making on his own for years before being introduced to the maker community by Calgary Mini Maker Faire producer Shannon Hoover. Since then, the Golem's electronics — initially hacked from dollar store toys — have been vastly upgraded and the project now has a crew of roboticists and technicians.

— Sabrina Merlo



BRICK BOD HOT ROD

SUPERAWESOMEMICROPROJECT.COM

Never underestimate the power of Twitter. Without mentioning the word Lego, a single, purposely nebulous tweet attracted enough capitol to fund this full-size, working Lego hot rod. The brainchild of self-taught Romanian engineer **Raul Oaida** and savvy Australian marketer **Steve Sammartino**, the 256 tiny pistons arranged in four radial engines are powered by compressed air and propel the car to speeds of 12–18mph. Any faster and Oaida is afraid it might fall apart. Except for the air tank, gauges, and a few structural elements, the car is made entirely out of more than 500,000 Lego pieces. That's around $60,000 in Lego.

— Craig Couden

Josh Rowe

MUSICAL TOYS OF THE '80s

Written by Bob Knetzger

REMINISCE ABOUT THE MELODIC TOYS OF YESTERYEAR — AND LEARN HOW TO MAKE YOUR OWN.

BOB KNETZGER is a designer/inventor/musician whose award-winning toys have been featured on *The Tonight Show*, *Nightline*, and *Good Morning America*.

THE 1980S BROUGHT BIG CHANGES FOR ELECTRONIC TOYS. Advances in integrated circuits meant electronics became inexpensive enough to be used in toys of all kinds, especially in musical toys. Instead of plastic ukuleles or plinky pianos, these musical toys were something new, with new sounds, new methods of playing, and new toyetic forms.

Playskool's cheap and cheerful entry into musical preschool toys was Major Morgan (A). He had a keypad with overlays that showed how to play a tune using color-coded grids. Just swap out his overlay for a new song. The hard keypad offered no tactile feedback (oww!), and the sound circuit produced just a single note at a time, but no matter: Kids had fun with this musical soldier.

Mattel was aiming for an older crowd with their Rhythm Machine (B). This cute keyboard featured two disco-licious features: a pitch-bending wheel (*wow-weEEEee!*) and a toy version of a beatbox with three different drum-and-bass loops. Choose disco, Latin, or pop beats and adjust the tempo. The synthesized rhythms featured a busy bass line with a synth drum. Play along on the mini piano keys. This instantly kitschy music toy was used by the group Kraftwerk on their hit song "Pocket Calculator" in 1981.

Mattel's Star Maker Guitar (C) promised "hot" sounds, but with only one string, musical choices were limited. Pluck the thick string and press it against the molded plastic frets to change pitch. The best part was a built-in "fuzz tone" effect for a fat, distortion-soaked sound. Unlike its real-world counterpart with magnetic pickups, this toy guitar had an optical pickup that "saw" the motion of the vibrating string. The speaker was mounted directly underneath the string, producing endless feedback and long sustain. Young would-be Eddie Van Halens, shred on!

How about a drum set — without any drums? Nasta's Hit Stix (D) were a big hit that didn't actually hit anything. Kids could play "air drums" with a big sound. Inside the tip of each drumstick was an inertial switch that triggered the snare drum sound circuit when the stick was hit or shaken. It also triggered a trend in other "air" instruments.

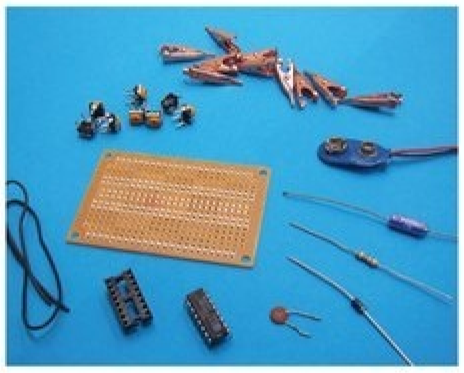
One of the weirder toys was Hasbro's Body Rap (E). Strap on an array of little switches and then slap your own thighs, ankles, wrists, and head to beat out a rhythm of sampled drums, cymbals, and even the spoken words "body" and "rap" — '80s hairdo not included.

Perhaps the most iconic '80s music toy was the Magical Musical Thing (F) from Mattel. The TV commercial featured a kid playing melodies with one finger on the toy's keypad strip — and finishing by playing it with his head! It featured a sound circuit that was designed around the cheapest and most basic building block of digital electronics: the 4049 CMOS hex inverter chip.

Usually used for decoders and multiplexers, the lowly 4049 was re-imagined by Mattel's thrifty engineers to create musical tones. Three of the IC's six logic gates were linked head-to-tail with a resistor and capacitor to create a simple, self-oscillating on-off/on-off square wave generator. The output of this oscillator was hooked up to the remaining three inverters in parallel. Their combined outputs were just enough to directly drive a speaker, with no audio amplifier needed!

A network of resistors created the various musical tones. This was done using a cleverly designed membrane switch pad. The top and bottom layers were made from a single, folded piece of Mylar, printed with conductive silver traces connecting strips of resistive paint. The middle layer was a die-cut insulated spacer with holes positioned to make touch points, each labeled for a different color-coded musical note. Touching the membrane pressed together two conductive strips, which completed the circuit through a path of resistors, producing a single musical tone. The shorter the path, the less electrical resistance, the faster the circuit oscillates, and the higher the pitch! *Beep boop!* Follow the color-coded notes to play a song, or slide the "Thing" over your body for a flourish of notes.

Jeffrey Braverman



Materials

- » **Hex inverter IC, 4049 type**
- » **IC socket, DIP-16** as the CMOS inverter is static sensitive
- » **Capacitor, 0.1μF**
- » **Resistor, 10MΩ**
- » **Power diode, 1N4001**
- » **Capacitor, 4.7μF, 35V**
- » **Trimmer pots, 10kΩ, mini (8)**
- » **Battery clip, 9V, with leads**
- » **Mini alligator clips (10)**
- » **Proto board or perfboard**
- » **Wire**
- » **Speaker, 8Ω, small**
- » **Mylar film**
- » **Tape, double sided**
- » **Ribbon cable, 3", 10- or 12-conductor**
- » **Keypad templates** online at makezine.com/magicalmusical

FOR HOUSING:

- » **Wood or foam** for pattern
- » **Styrene plastic sheet, 0.060"** for vacuum forming

Tools

- » **Soldering iron and solder**
- » **Continuity tester**
- » **Craft knife**
- » **Ruler**
- » **Marker, thin, permanent ink**
- » **Conductive ink pen**
- » **Hole punch**
- » **Wire stripper**

Build Your Own Magical Musical Thing!

Now you can make your own custom version of this classic '80s toy. Wire up the circuit, paint a membrane keyboard, and make a housing (or put it in a repurposed container). This DIY redo has a new added feature: a circuit-bending touch point.

1. This exact reproduction circuit is quite simple, with a minimum of components. You can easily solder it up with point-to-point wiring on a perfboard. Layout isn't critical, but I placed the 8 trimmer pots in one neat row (**Figure A**).

Assemble your board (**Figure B**), then cut it down to a minimum size.

2. Instead of the fixed, printed resistors, this version has a trimmer pot for each of the 8 notes so you can tune them individually. Strip the ends of the ribbon cable and solder one wire to each of the trimmers and a mini alligator clip to each of the other ends (**Figure C**).

3. Test the circuit: Add the battery and touch the clip at point A to each of the other clips. You should hear a beeping tone for each clip. Twist the trimmer pots to adjust the musical tones' pitches.

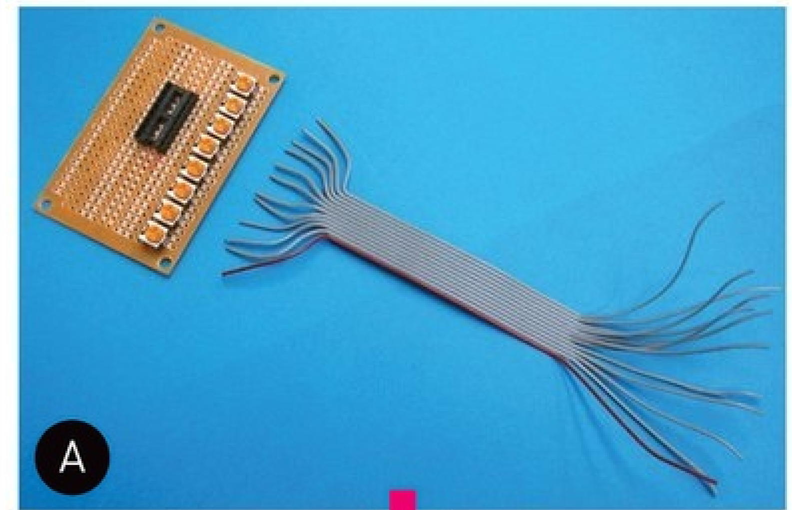
4. To make the keypad's bottom layer, tape a piece of Mylar over Template #1 (**Figure D, middle**). If you're using frosted Mylar, be sure to lay it frosted side down. Trace the cut outline with a thin permanent marker.

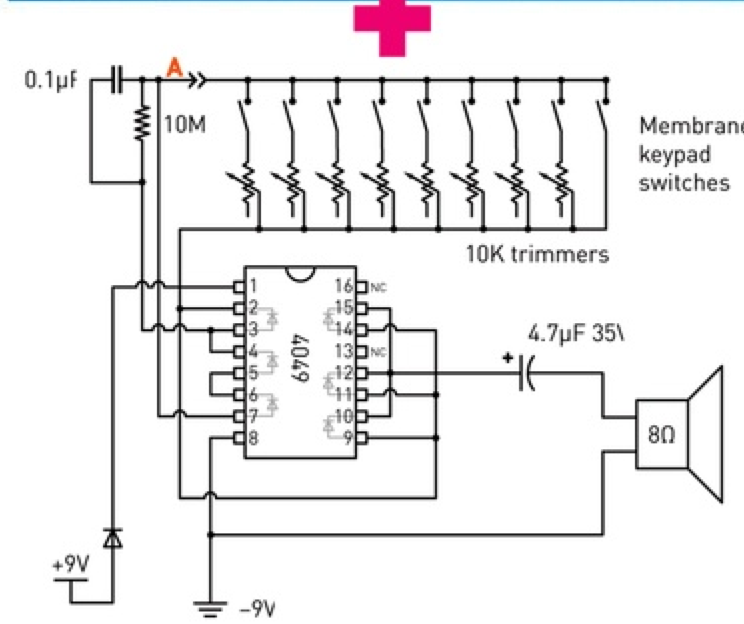
Use the conductive ink pen to trace the circuit layout. Be sure to shake the pen well between strokes — there's a ball inside that works as an agitator. Gently squeeze the barrel while pressing the valve tip down, as you pull the pen across the Mylar — that will make a uniform, generous line.

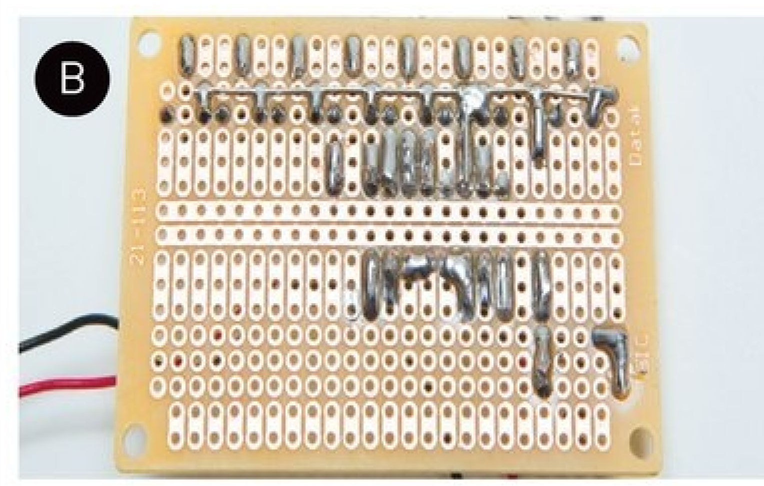
Join line segments while still wet for best conductivity. Don't puddle the paint on too thick — it'll crack instead of flex when the Mylar is curved. When the paint is dry, test each of the traces with a continuity tester and touch up with the conductive ink as needed (**Figure E**).

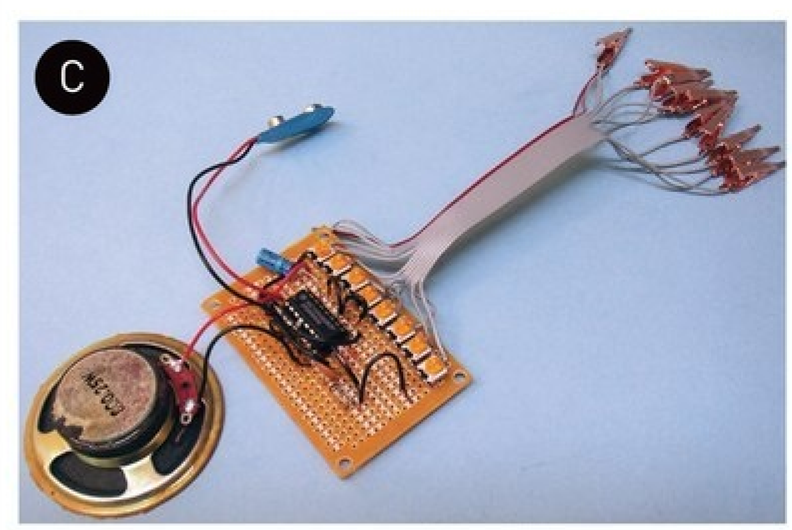
5. Use Template #2 to make the top layer of the keypad. Template #3 needs no conductive ink — just trace the outline and cut out the holes for the middle spacer layer.

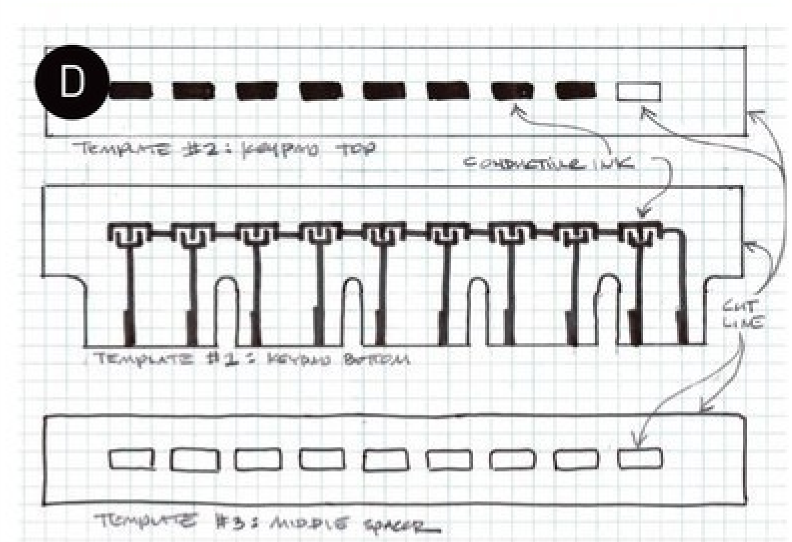
Tape the layers together temporarily and hook up the clips (**Figure F**). Press the switches to test your circuit. Again, touch



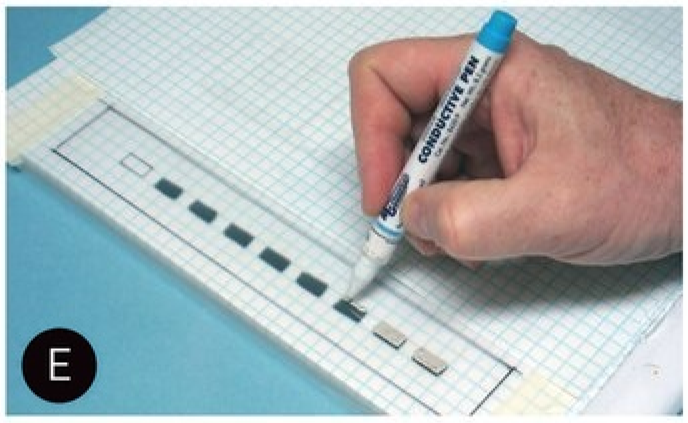
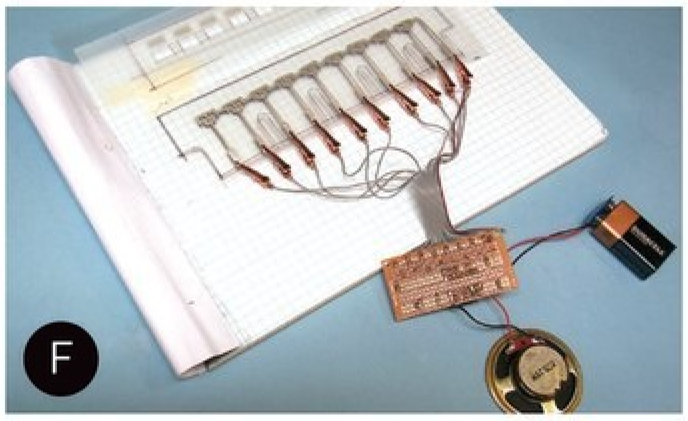


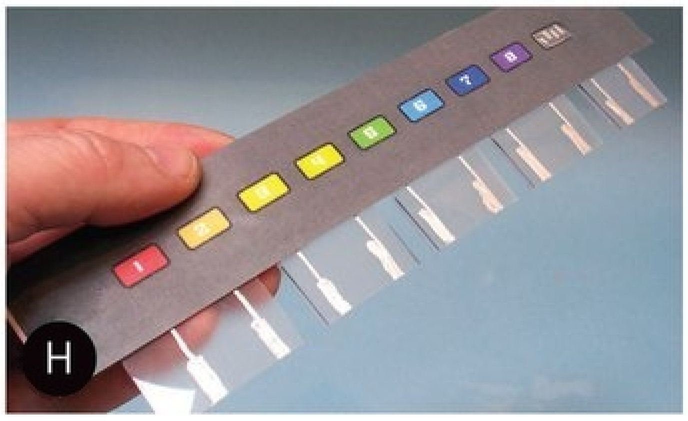
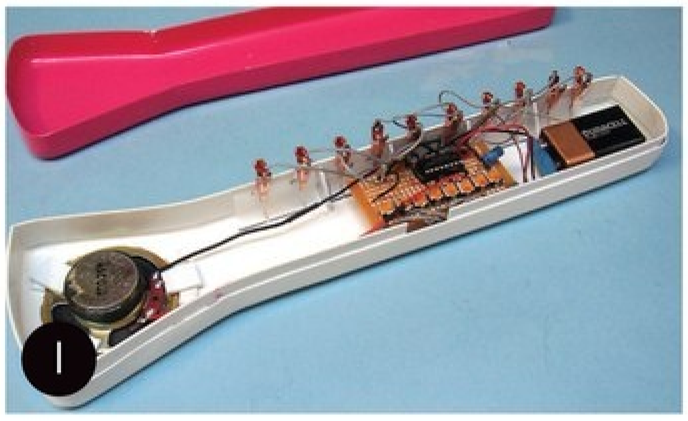






Bob Knetzger

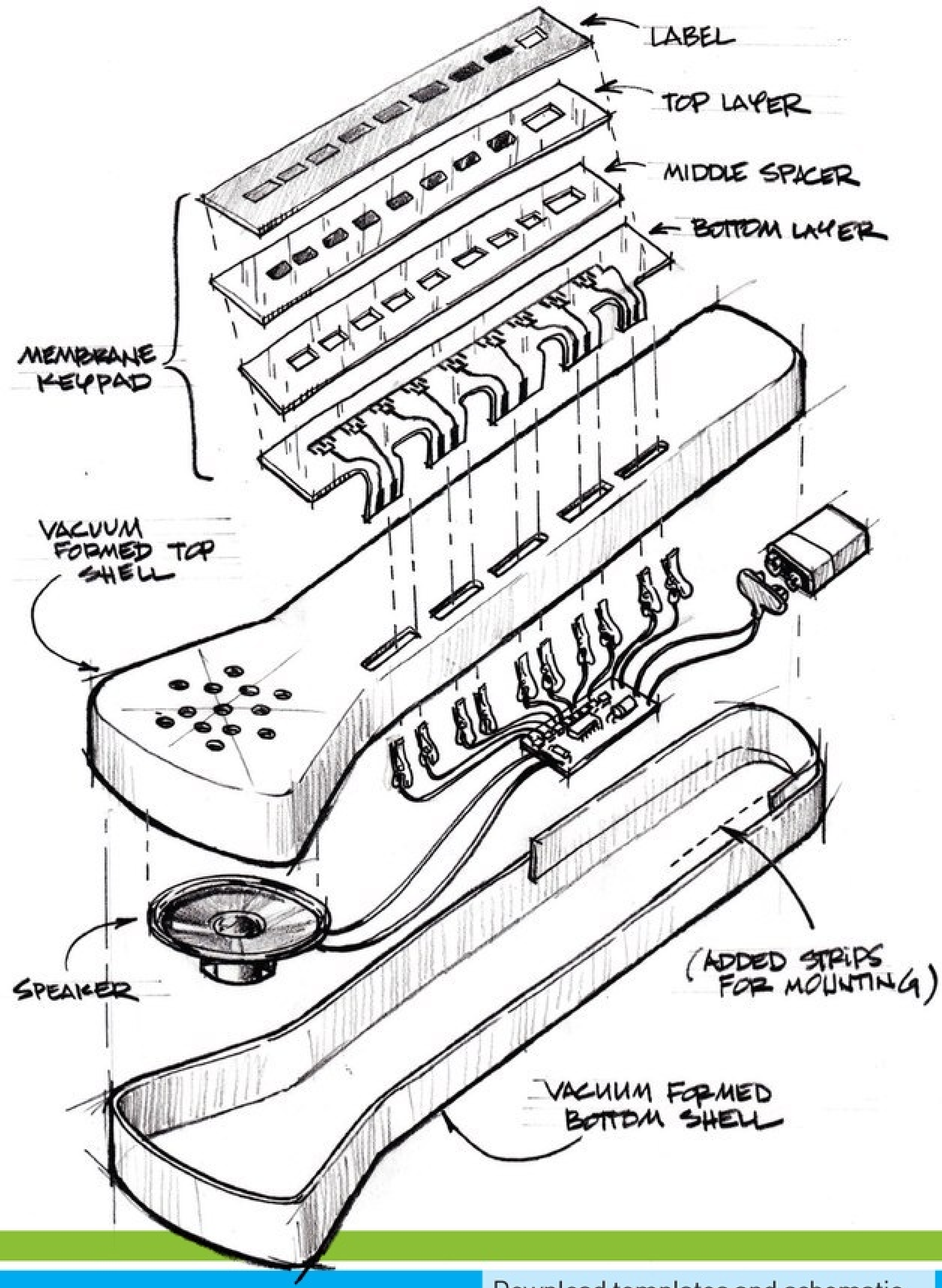

up any traces or switch pads with a little extra conductive ink, if needed.

6. Trim the layers to size with your craft knife (**Figure G**). On the bottom layer, use the paper punch to make radiused inside corners as strain relief. Use double-sided tape to fasten the membrane switch layers together, but don't put tape over any traces. I added a colorful label on top with numbered touch points (**Figure H**).

7. Reconnect the clips and play away! Use a guitar tuner app to adjust the trimmer pots for the notes you want. Tune the 8 notes to a "do-re-mi" scale for a most useful set of notes. Or you can tune them to anything you want — including the first 8 notes of any song for easy autoplay. Just swipe your finger across the keypad to play!

Lick your fingertip and touch the last position for fun circuit-bending sounds, from a low growl to a high squeal.

8. To finish, install it in a sturdy housing, like this mini version of the classic toy (**Figures I and J**). I made a symmetrical wooden pattern and used it to vacuum-form the top and bottom shells (makezine.com/kitchen-floor-vacuum-former). I trimmed them and milled slots for the keypad's hookup, then mounted the speaker, circuit board, and battery inside. I taped the keypad in place and attached the clips before closing the shells. Alternately, you can repurpose a container or 3D print a custom case. Looks and plays great!



Download templates and schematic at makezine.com/magicalmusical
Share it: *#musicaltoysofthe80s*

Luky's Hardware

MAKER FRIENDLY HARDWARE STORES

WHEN FACED WITH A TOUGH TECHNICAL CHALLENGE, YOU CAN ALWAYS DEPEND ON A NEIGHBORHOOD SHOP.

Written by Bob Parks

BOB PARKS
(bobparkswriter.com) is a frequent contributor to MAKE, Runner's World, and Wired magazines. He lives in Vermont with his wife and two children.

IT'S A GOOD THING THAT A LOCAL HACKER NAMED SKUNK BROKE DOWN in front of Boston's legendary Masse Hardware Company one day while driving his chainsaw-powered bicycle. His bike featured a small, 38cc chainsaw engine attached to the back using a series of belts and rotors. Everything was going fine when a rack holding the engine vibrated loose. The Masse staff — Dave, Manny, Joe, and Lee — came out to examine Skunk's ride, sold him a Lexan bushing to fix it, then brought Skunk into the back room and helped file it to size. They even waved to him as he ripped off down the road. Total sale: 85 cents.

Sadly, Masse closed its doors in late 2013 after 125 years in business. It may be an apt time to celebrate the small, independent hardware joint. When faced with a tough technical challenge, shopkeepers of longtime establishments know how to bring their eclectic inventory and long-standing experience to bear. "Describe what you're up to," marvels Don Dunklee, a Michigan-based creator of solar-powered scooters, "and these rare individuals get inside your head and figure out what you need."

We talked to some of the great mind readers in hardware stores across the country and offer a look at four of them. In most cases, we asked members of local hackerspaces in various cities where they turn when stumped by a thorny technical issue. People knew their favorite store instantly, or else knew there wasn't one nearby.

We chose independent stores for this list because of their diverse inventory. While national chain stores can certainly be a good resource for hardware, their wares are usually standard. But franchise stores, such as Ace or Do-It-Best, have independent ownership so they stock items according to local customer needs or whims.

Most of the examples listed are remarkably similar in their layout: aisles supersaturated with strange tools and devices, just the kind of chaos that shakes loose creativity.

A MCGUCKIN HARDWARE

Boulder, Colo. • Established: 1955 • Size: 60,000 sq. ft. • Collective Experience: 117 years

Strangest Project Assist: Ball Aerospace and Technologies spacecraft

McGuckin's is the nation's largest independent hardware store; its size rivals a big-box store and its inventory exceeds most national retailers. "They have everything, literally everything," says Steve Garran, chief creator at makerspace Club Workshop in Denver. On a trip to Boulder for a robotics event, Garran desperately needed an obscure fine-threaded metric bolt, late on a Saturday afternoon. "Those guys have one of everything and they know where it is," he says. "McGuck's leads you to want to move to Boulder."

Even though the store is huge, with 275 employees, it still manages to retain the local flavor of its start. Dogs are allowed as long as they're on a leash. One of the founders of the store, Dave Hight, still comes in with a feather duster in his back pocket, cleaning off shelves and telling dirty jokes.

Of all the things he's sold, Randy Barker, a store manager, is most proud of the McGuckin items used by engineers from local

McGuckin Hardware

Luky's Hardware

Alonso del Arte/Brooks Lumber

Highland Woodworking

firm Ball Aerospace and Technologies. "We have bolts, hoses, and connectors floating around in space right now," he says. Other technical challenges arise from University of Colorado engineering professors as well as the various makers visiting the store. "You need a giant slingshot?" asks Barker. "You come tell me how big."

B LUKY'S HARDWARE AND SURPLUS COMPANY

Los Angeles, Calif. • Established: 1999 • Size: 3,000 sq. ft. • Collective Experience: 65 years

Strangest Project Assist: The Batmobile

A few times a week, Luky (LOO-Key) Salcedo gets a message from a major aerospace company, most often Boeing or Lockheed. It lists all the parts the companies have removed from their factories as part of the government contracting process. Salcedo submits a bid, and if she wins the lot, she and her husband pick it up on enormous wooden pallets.

That's been her routine for 34 years, and Salcedo can't think of anything she'd rather do. "I love to call up a customer and say, 'Look, I got test equipment from NASA for you. It's a foot high, all stainless, with hoses coming out everywhere. I don't know what it is, but it's a beautiful piece!'" She began working at age 14 for legendary salvage retailer Joe Factor, who taught her the business. Factor, who died in 2005, helped her as she struggled as a single mom in her 20s, and assisted her in establishing her own store when he closed his in 2000.

Customers appreciate the family atmosphere of Luky's and the weird items there. "I get fasteners, carburetor parts, and aluminum pieces for cents on the dollar for what it cost the government," boasts A.J. Elias, a builder of reproduction V-8 hot rods.

L.A. provides Salcedo with a diverse clientele. Parts from the store were used in movie props for blockbuster film series such as *Batman*, *Transformers*, and *Fast & Furious*. Racing car and truck builders pore over her inventory to find things like aircraft seat belts and carbon fiber panels. But she gets first look, of course — the store owner recently brought home gleaming aircraft hose clamps to use as napkin rings on her dining room table.

C BROOKS LUMBERS

Detroit, Mich. • Established: 1896 • Size: 6,000 sq. ft. • Collective Experience: 93 years

Strangest Project Assist: Power Wheels Racing Series vehicle

Brooks feels like a second home to makerspace Ribbon Farm. "They are three blocks away, so we're in there three to four times a day," says Ribbon's co-organizer Brian Mulloy. "The guys there are maker consultants, with tons of personality, history, and knowledge when talking about the things they sell."

Baseball fans may know Brooks because it's across from the old Tiger Stadium. In 1961, Mickey Mantle hit a baseball out of the stadium and into the Brooks parking lot, one of the longest home runs of his career. "We were here before Tiger Stadium and after," says co-owner John Marroquin. "We went through the Depression, both world wars, the '67 riots, the '68 World Series, and the '84 World Series." Marroquin says that they still keep in the warehouse the large plywood sheets used to protect the windows after the Tigers won in '68 and '84.

Because of the store's age, some items have been in the inventory for decades. "When you're an old store, you accumulate a lot of stuff," says Marroquin, reaching down to pick up a pair of horseshoe nippers. "Our inventory is ridiculous." Brooks is also the only lumberyard left in Detroit, and all of its wood is protected under roofs. It sells new hardware stock, including fasteners, tools, and adhesives — all of which came in handy when Ribbon Farm built their under-$500 toy electric car entry in the Power Wheels Racing Series competition during Detroit Maker Faire.

> "DESCRIBE WHAT YOU'RE UP TO AND THESE RARE INDIVIDUALS GET INSIDE YOUR HEAD AND FIGURE OUT WHAT YOU NEED."

D HIGHLAND WOODWORKING

Atlanta, Ga. • Established: 1978 • Size: 8,000 sq. ft. • Collective Experience: 73 years

Strangest Project Assist: Shotgun renovation

"You won't get Arduino boards there," cautions My Inventor Club founder Shane Matthews. "But it's the best specialty woodworking store in the country. Everyone who works there is a professional woodworker." Started by a couple who graduated from Georgia Tech in the '70s, Highland gravitated from general-purpose hardware store to woodworking center over the last decade. But staff member Sidney Dew says that you don't have to be a woodworker to shop there. "We're not highfalutin'. People come in here all the time to tap our expertise."

Matthews came in looking for a way to trim out fiberglass and left with an oscillating cutter that worked perfectly for the job. A Georgia Tech team relied on Highland for tips to put their ultralight hang glider together. One customer learned how to build a wagon wheel, and another fixed a crack in a shotgun.

+ Check out more maker-friendly hardware stores and tell us about your favorite at makezine.com/maker-friendly-hardware-stores.

MAKERS ON ICE

IN ANTARCTICA, MAKER SPIRIT IS THE KEY TO SURVIVAL.

Written and photographed by Joe Mastroianni

JOE MASTROIANNI is a Silicon Valley engineer, polar explorer, entrepreneur, builder of large musical tesla coils, science fiction writer, mountain biker, musician, husband, and father.

POLAR SOLAR: The team's TAISU carbon-sensing device, with wi-fi observation camera, at the top of the Bonney Riegel in the Antarctic Dry Valleys.

ANTARCTICA BREAKS THINGS. Stuff that should be bulletproof just dies, and the nearest replacement part is more than 2,000 miles away, on a much warmer and more civilized continent. During my six trips to Antarctica (2001–2006) as part of a team prototyping alternative power designs, we quickly learned it was mission critical to travel with a full set of tools and a full set of spares.

Four of my deployments were to various locations in the Antarctic Dry Valleys, so called because there has been no appreciative precipitation for the past 25 million years. In these remote field camps, you have only what you've brought with you, or requisitioned, and Murphy's Law is more than just bad luck — it's the way of life.

So you're always fixing things or realizing you have to do something you never planned for back at home, like coming up with ways to calibrate your loads on a generator without any form of digital voltmeter handy (e.g., 60W light bulb in a 120V circuit = 0.5A purely resistive load, if you can actually find a light bulb). Or filing down a screwdriver to make it a hex wrench. Happens every day.

I once fixed a diver's lifeline with a Leatherman and black electrical tape so he could complete a dive under a glacier (those guys were really brave). The line held, the diver made it back alive, and the autonomous undersea camera that team member Jeff Blair had designed and built back home was secured in the sea 90 feet under the ice. The camera, dubbed ROMEO (for "remotely operable underwater micro-environmental observatory"), spent an entire year recording pictures of sea life for biologist Dr. Sam Bowser, providing the first-ever winter pics of Antarctica's underwater world.

Producing what we now call "green power" for various science programs on the ice was ostensibly the purpose of our small team. Our team leader, Dr. Tony Hansen, was an atmospheric scientist who invented a device called the Aethalometer to measure airborne particulates, and his premise was that if scientists could power their equipment without polluting the air they were trying to study, the data would be more accurate.

Most lab gear for use in North America requires a 110V 60Hz source. Your typical atmospheric scientist isn't overly concerned with where that power comes from. When he plans his data collection expedition, he requisitions a helicopter, tents, sleeping bags, camp stoves, food — all the requirements to sustain life. Finally, at

1. The ROMEO underwater observatory being sent with a diver through a hole in the ice at Cape Evans, Antarctica, on its shakedown test.

2. TAISU device being hauled by helicopter to its location in the Antarctic Dry Valleys.

3. Preparations underway at New Harbor, Antarctica: a huge trench in the ice made for the optical cable to receive underwater photos from ROMEO.

some point, he requisitions a 30kW diesel generator to power his vacuum apparatus and spectroscopy gear, never imagining that the diesel exhaust spewed by the generator creates a massive Heisenberg effect. You become what you are measuring. Any data he collects is measured against the massive chemical noise introduced by his generator. So you have this huge DC offset (to use an electrical term) to the data, and any small signals are completely covered.

We mocked up a device Dr. Hansen called a TAISU (transportable autonomous instrumentation support unit) that generated a continuous 50W all summer long via solar, and even more via wind. Along the way we discovered we had some power to spare at times, so we added various remote webcams. We wound up creating the first 801.11 network in the Taylor Valley by putting a Cisco wireless access point and some high-gain antennas on the TAISU, thereby linking scientists with the main U.S. government network through McMurdo Station. Literally, scientists could open their laptops in a tent and order new hiking boots from REI.

We had live cams, which could be accessed by the general public, but they got shut down for two reasons. Reason 1: After 9/11, Homeland Security didn't like the fact that live data was being sent from a government network to the civilian world for any reason at all. Forget the fact that the bandwidth to the Mars Observer was higher than we could get from an actual spot on planet Earth — security is security. So you could no longer get live pictures from our green-powered network. (There are others who duplicated the concept but went to Iridium as the backbone instead of the government network. Those devices still transmit but at a terribly reduced bandwidth.) Reason 2: No scientist — or anyone, for that matter — wants to work under the prying microscope of an active webcam.

Our team built a number of other devices for the scientific community. Blair designed and deployed an autonomous camera that was used by scientists to observe a penguin colony that had been stranded, having had their access to the sea cut off by a giant iceberg. Blair's cameras, both Penguin Cam and ROMEO, were standard Sony security cameras housed in specially designed acrylic casings. We used PIC microcontrollers to both modulate power consumption and drive the cameras through either network control or through a preprogrammed set of shots, and then stored the pictures on a memory card. Our philosophy was always to use standard off-the-shelf parts. We designed and constructed the devices in our homes, and then had the utter thrill of watching them deployed in places as remote and hostile (sometimes) as the surface of Mars.

We built and deployed a miniature version of the TAISU box, that was designed to be tossed out of aircraft with a payload of a scientific instrument. The device communicated back to "the world" through an automated low-bandwidth (300-baud) Iridium modem connection.

The last thing we tried, in 2006, was to develop a means to power a remote sensor through the long, cold Antarctic winter. Unlike planetary probes, which can be powered with small nukes, we had to figure out a way to keep something warm and running with off-the-shelf material. Dr. Hansen eventually settled on using standard organic PCM (phase-changing material) paraffin, which we heated and poured inside a large Dewar flask used to contain liquid nitrogen in laboratories. We placed the instruments into this inert liquid and then buried it in the ice near the South Pole Station. The instruments (simple temperature and power consumption meters) ran for about six months of the nine-month winter season before dying. We were heading back to the drawing board when our program ended.

I haven't been back to the ice since then. Dr. Hansen continues to work on polar projects as well as his own carbon-sensing company. Blair has also started his own company doing various forms of instrumentation.

But the maker spirit lives on in Antarctica. Our colleagues on the ice have designed and built remarkable things: underwater ROVs with cameras and sensor technologies that are small enough to slip through narrow holes in the ice, devices to track the large icebergs that are calving from the continent, and sensors to pick up the gaseous NOx components that come from melting ice.

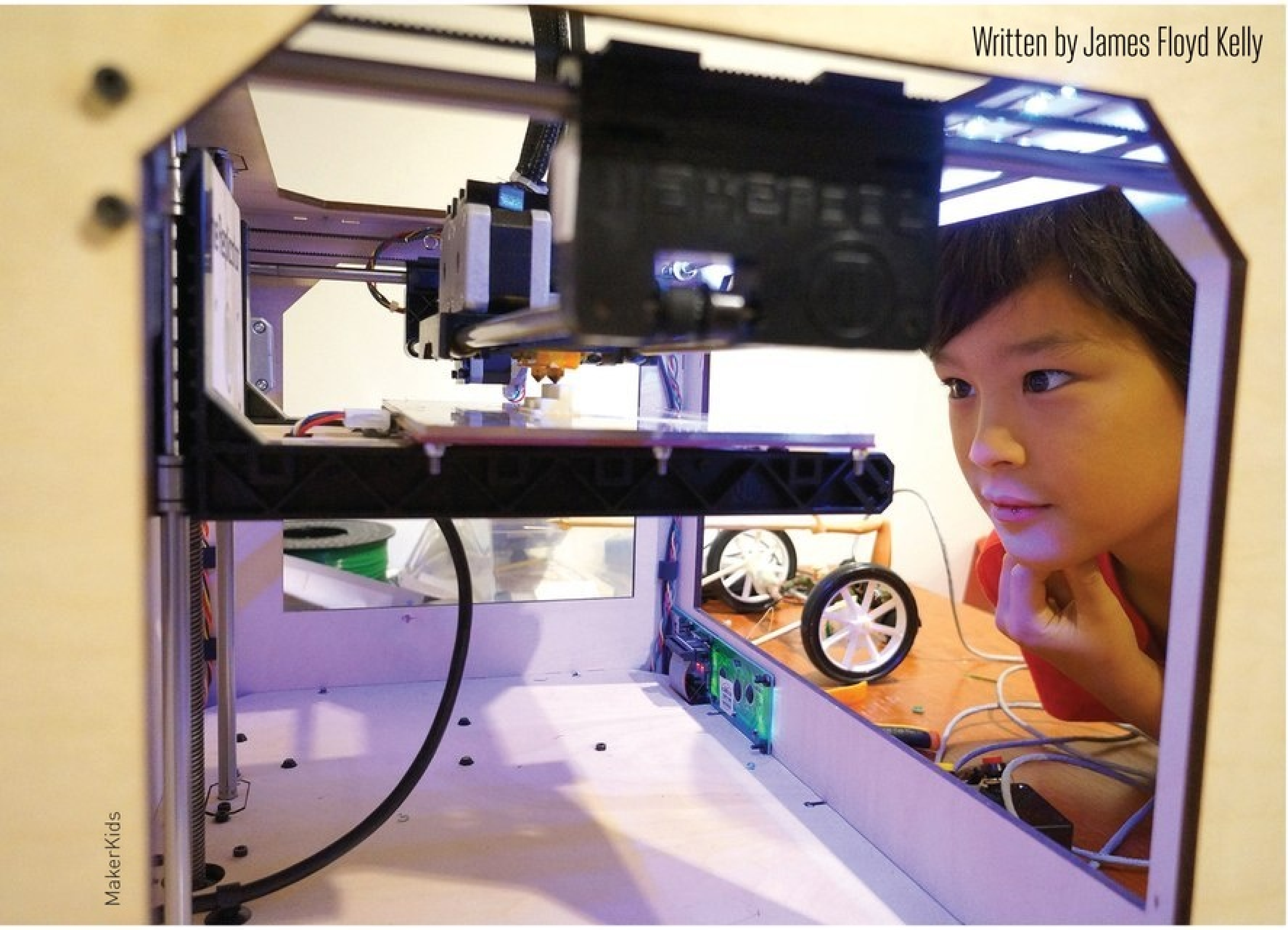
All of those things get their start in someone's garage or small lab. Very few maker thrills can beat watching a helicopter deploy the device you built on a remote hilltop in Antarctica, while the soldering iron burns on your hands are still healing.

+ Check out the ROMEO at bowserlab.org/antarctica/romeo.

KICKSTART A KIDS' MAKERSPACE

James Burke

Written by James Floyd Kelly


MakerKids

JAMES FLOYD KELLY (jamesfloydkelly.com) is a freelance technology writer in Atlanta. He has written numerous books for students on subjects such as Arduino, Lego robotics, and game programming.

YOUNG MAKERS GROW UP AND BECOME WORLD-CHANGING ENGINEERS AND LEADERS, and they in turn encourage new generations of young innovators. The world needs young makers. And these young makers need makerspaces.

How many of the nation's 54 million elementary and secondary students have access to the state-of-the-art tools that can spark creativity, nurture curious minds, and ignite the next wave of innovators? Probably less than 1%. Even assuming a generous 5%, that leaves more than 51 million U.S. students without any hands-on time with tools that are nothing short of inspirational.

Fortunately, tool prices have dropped and fundraising has never been simpler. Let's take a look at what tools are a good fit for a kid-focused makerspace and how organizations can achieve funding to get more kids into the workshop and making things.

THE TOOLS

3D PRINTERS

What kid wouldn't love to print something in 3D that he or she designed from scratch? With free, easy-to-use design software such as Tinkercad, Autodesk 123D, and 3DTin, kids can jump right in, create and modify and print.

The $300 Printrbot Simple (Figure A) and the $2,200 MakerBot Replicator 2 (Figure B) both print with enough quality to make a kid smile. Let's grab two Simples and one Replicator 2 for a basic Kid Makerspace, and double that for a larger Kid Makerspace. And let's budget for filament too (see "Costs" chart, following page).

LASER CUTTERS

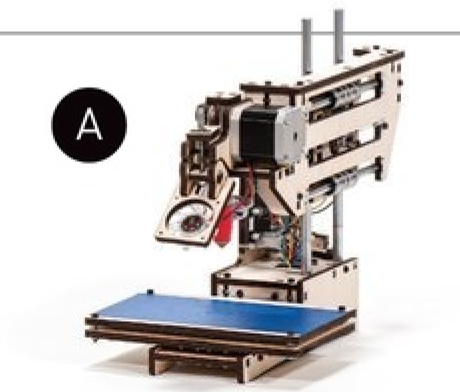
For kids who aren't yet comfortable designing in 3D, the simplicity of drawing a 2D shape and seeing it cut precisely from wood or plastic is quite appealing. I like the fully assembled Blacktooth Laser Cutter (buildyourtools.com) for $2,100 with integrated computer (**Figure C**).

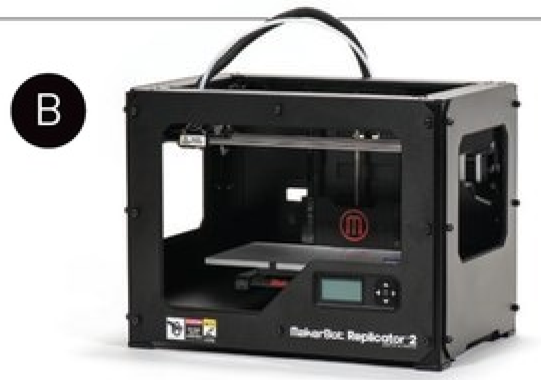
CNC/MILLING MACHINES

Not only will kids learn to carve shapes in wood or plastic, they'll also learn to use CAD/CAM applications — as well as see the value of staying awake during math class. Let's put a ShopBot Desktop (shopbottools.com) in the larger Kid Makerspace (**Figure D**), and a BlueChick CNC router (buildyourcnc.com) in the smaller (**Figure E**).

HAND TOOLS/POWER TOOLS

Kids need basic hand tools such as wrenches, screwdrivers, and saws. Power tools such as drills, sanders, and maybe even a table saw and a router should also be considered. Find your own best mix for an initial purchase and consider adding more as the space grows





and needs are determined. Discount stores such as Harbor Freight or Northern Tool & Equipment can really stretch those dollars — these might not be pro-grade tools, but it's all about hands-on time.

ELECTRONICS

No Kid Makerspace should ignore the value of hands-on learning by tinkering with electronics. Basic tools such as multimeters, breadboards, and soldering irons are inexpensive, as are basic components and supplies (jumper wires, solder, resistors, etc.). Consider ready-made kits such as those found in the Maker Shed.

I cannot recommend highly enough Charles Platt's book *Make: Electronics* (makershed.com/platt) — pair it with its two companion Parts Packs and you've got a portable electronics primer that will get any kid (or adult) up to speed fast.

Arduino microcontrollers are inexpensive too (and clones are even cheaper), and there's no shortage of free online tutorials for learning to wire up and program these popular boards.

WHAT ELSE?

We'll need computers and software, including keyboards, mice, screens, and maybe a printer or two (the ink kind). Free software is everywhere, but let's anticipate specialty software upgrades when the kids outgrow the starter stuff.

For less than $100, you get the OWI programmable robot arm and the software to program it via USB.

Toss in a 1-year subscription to MAKE magazine — it includes digital access to all back issues.

Extraordinaires Design Studio (extraordinaires.com) is a design training game that sparks creativity by asking players to brainstorm and sketch product ideas for various superhero characters.

No doubt you have your own favorite tools, books, and accessories that you'd choose. Don't discount tinkering tools like Lego, Erector, and even Tinkertoys for the younger makers.

PAYMENT OPTIONS

If you're keeping score, our basic Kid Makerspace has a price tag of $11,000, and the larger Kid Makerspace $23,340. Taxes and shipping are going to bump it up. How to pay for all of it?

If your school is open to the idea of outfitting a Kid Makerspace, you're 25% of the way there. Sadly, many schools are likely to be resistant, for reasons of safety, insurance, or legal issues. It might take some very vocal parents, teachers, and kids to get organized and demonstrate the value of a makerspace. But once you've got the approval, raising the funds doesn't have to be a mountain to climb.

Appeal to Parents Unless you know a real-life Tony Stark, your odds of finding one person to contribute $11,000 are very long. Instead, ask 1,000 families to each contribute $11.

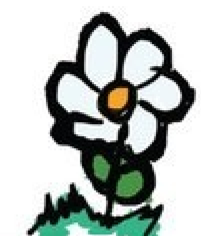
Local Businesses Reach out to businesses and organizations in your area that may contribute to worthwhile educational causes. Create a presentation that can be given to parents, the school board, and local business leaders.

Crowdfunding Spreading costs over a large group of people and organizations is the idea behind websites like Kickstarter (kickstarter.com) and Indiegogo (indiegogo.com). You create a video outlining your goals and the funding you need, then backers chip in to help. You're not offering a tangible product, so you'll have to get creative on ways to reward backers — look at other campaigns for makerspaces (see sidebar) for ideas. Lots of backers donate $5 or $10 just to be part of something important.

It's time to take the makerspaces to the kids and not the other way around. It will require school administrators, teachers, and parents to fight the excuses and break through the red tape so that all kids have an opportunity to join the Maker Movement if they desire.

COSTS: BASIC VS. BIGGER KID MAKERSPACES

	Basic Kid Makerspace		Bigger Kid Makerspace	
ITEM	QUANTITY	COST	QUANTITY	COST
3D printer, Printrbot Simple	2	$600	4	$1200
3D printer, Replicator 2	1	$2200	2	$4400
Filament	varies	$200	varies	$400
Laser cutter, Blacktooth	1	$2100	2	$4200
CNC cutter, BlueChick	1	$1750	--	$0
CNC cutter, ShopBot Desktop	--	$0	1	$5000
Hand tools / power tools	varies	$1000	varies	$2000
Make: Electronics book & parts	2	$500	4	$1000
Arduino	varies	$200	varies	$400
Electronics tools	varies	$200	varies	$400
Computers, software, printers	varies	$1500	varies	$3000
Software upgrades	varies	$500	varies	$1000
MAKE magazine 1-yr subscription	1	$35	1	$35
OWI robot arm	1	$100	1	$100
Extraordinaires design game	2	$90	4	$180
TOTALS		$11,000		$23,340



SUCCESSFULLY FUNDED

They did it — so can you. These makerspace campaigns achieved their crowdfunding goals on Kickstarter or Indiegogo:

LOS ANGELES MAKERSPACE
California, by Tara Tiger Brown, Ariel Levi Simons, and others
lamakerspace.com

BAGHDAD COMMUNITY HACKERSPACE WORKSHOPS
Iraq, by Bilal Ghalib and GEMSI (Global Entrepreneurship and Maker Space Initiative)
gemsi.org

BIOCURIOUS HACKERSPACE
Mountain View, Calif., by Network for Open Scientific Innovation
biocurious.org

HOUSTON MAKERSPACE
Texas, by Maclean Smyth
houstonmakerspace.com

HOBART HACKERSPACE
Tasmania, Australia, by Patrick Burns, Shane Dalgliesh, and others
hobarthackerspace.com

HIGH-TECH DIY

BUILDING YOUR OWN LAPTOP, TABLET, OR CELLPHONE MIGHT SOUND IMPOSSIBLE. IT'S NOT.

FROM vacuum-tube amplifiers to homebrew computers, amateurs with wily gumption have traditionally conquered self-built electronic gadgets in short order. Recreating the spectacular capabilities of today's pocket-sized devices at home has been a bigger challenge, but new access to shrinking hardware and open-source software is now helping eager makers assemble their own cutting edge mobile devices in their home workshops.

Want to make your own laptop, tablet, or Google Glass? Then fire up your soldering irons and read on.

HOW I BUILT A RASPBERRY PI TABLET

I couldn't find a tablet computer that ran Linux and was powered by a Raspberry Pi – so I made my own PiPad.

Written by Michael Castor

IT SEEMS THAT EVERY DAY A MANUFACTURER COMES OUT WITH A NEW TABLET COMPUTER. Thinner, lighter, faster — but it also seems that they all look about the same and accomplish roughly the same things. When I set out to build my Raspberry Pi tablet I wanted something different. I wanted an all-in-one system that was usable, portable, and Linux based. Additionally, it had to look good. I wanted to use it on flights, meaning the device couldn't freak out the TSA or the old woman sitting next to me.

A PROLIFERATION OF POTENTIAL PARTS

I started determining and accumulating parts in early 2013. I had already selected Raspberry Pi to be the brain of my tablet, and since it runs off of 5V I knew it could be powered from a cellphone charger. Most touchscreens I could find were 12V though, making the electrical work more complex. After a bit of searching I finally found what I was looking for: a touchscreen monitor with a 5V HDMI to LVDS converter from Chalk-Elec.com. I plugged the screen in as soon as I received it, and to my delight it worked perfectly with the Pi, even its capacitive touchscreen. Now I knew my dream of a Raspberry Pi tablet was possible.

According to Parkinson's Law, "Work expands so as to fill the time available for its completion." Thus was the case for my Pi tablet, until I found a deadline. Two weeks before Maker Faire Bay Area, I was assisting a guy in the Shed Tech Support queue who needed some help with his Maker Faire project. Working with him got my creative juices flowing, and I decided I wanted a Maker Faire project too. Crazy, right? I had all the parts, and now I had an ambitious target date that couldn't allow for expansion. Fortunately I had started some preliminary design work so I *kind of* knew what I was going for. I happened to have access to a CNC machine, some ½" Baltic birch plywood, and a relatively large sheet of scrap carbon fiber lying around to form the basis of the frame.

After several days working until 4 a.m., I completed the Raspberry Pi tablet (aka, PiPad) the day before my flight. The build wasn't without its issues — I had to remove one USB port and the Ethernet jack due to clearance problems — but everything worked and I was happy with the results.

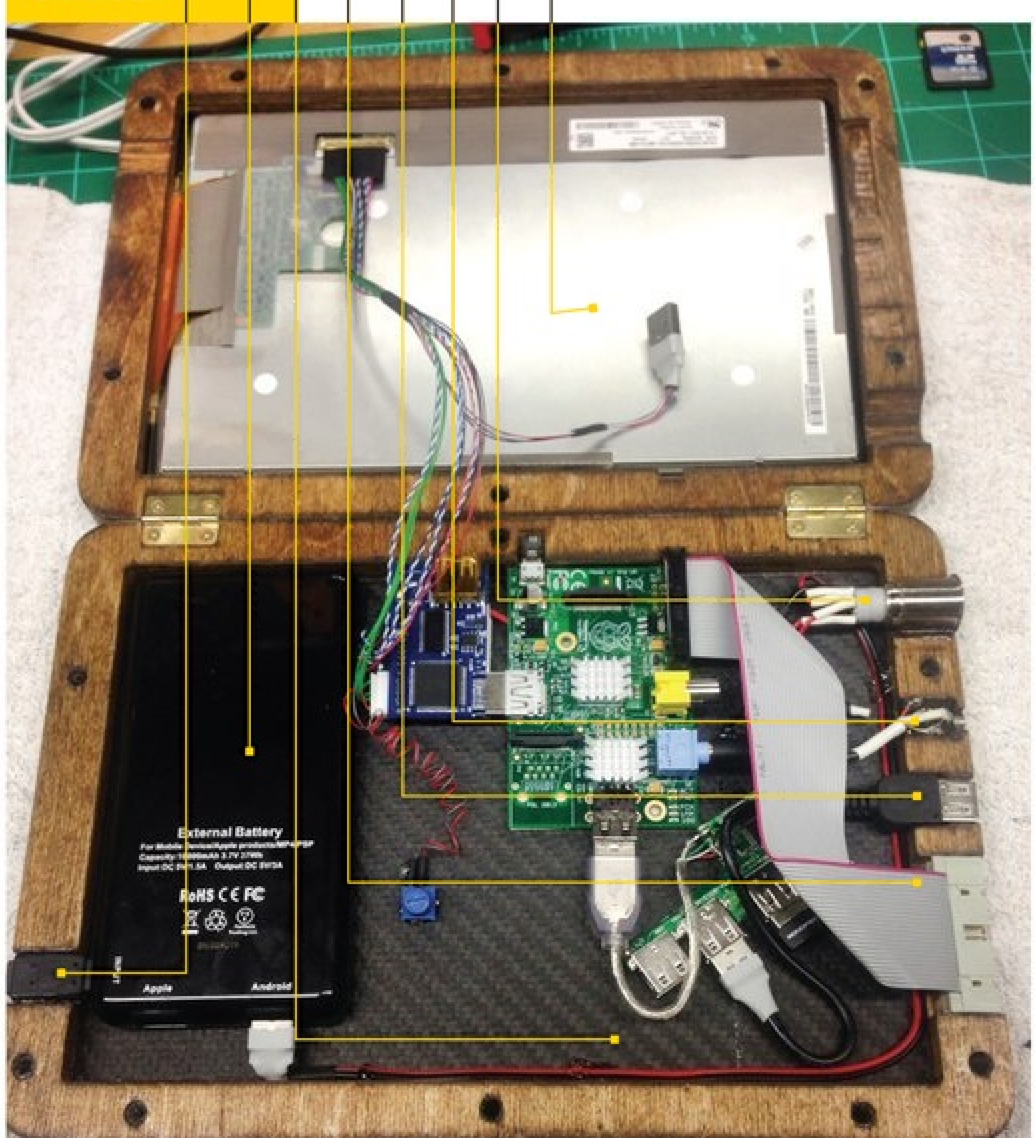
MICHAEL CASTOR is the product innovation manager for the Maker Shed. He is a tinkerer at heart and has a passion for solving problems and figuring out how things work. When not working for MAKE, he can be found falling off his unicycle, running in adverse weather conditions, skiing down the nearest hill, restoring vintage motorcycles, or working on his car.

Jeffrey Braverman

LOOK INSIDE

CNCed Baltic birch and carbon fiber give the case a distinct look, while a variety of components give many interface options.

TOUCHSCREEN
SWITCH
AUDIO LINE-OUT
USB
GPIO
CARBON-FIBER BACKPLATE
BATTERY
CHARGER



Michael Castor

BUT WHAT ABOUT THE TSA?

My new tablet didn't raise an eyebrow going through security. On the plane though, a flight attendant kept walking by, looking closely at the home-built gadget I had on my lap. At one point I could feel her looking over my shoulder and was sure the jig was up. She nudged me and said, "I love that movie — you're coming up to the best part!" It turns out that she'd been catching glimpses of *Talladega Nights* that I'd been playing using RaspBMC. I've taken the PiPad on most flights since and no one has said a word.

I'd emailed Raspberry Pi Foundation founder Eben Upton a few times for work but didn't have the chance to meet him until Maker Faire New York in September. Eben is probably the most humble, down-to-earth person I've ever met. I really can't say enough good things about him. After a long chat I showed him the PiPad. He gave it several compliments and after a few minutes of playing with it, he graciously signed the back at my request. His signature looks amazing on the carbon fiber!

FUTURE UPGRADES

Overall, I'm very happy with my Raspberry Pi tablet. It does what I want it to do and has been a great way to demonstrate the capabilities of the Raspberry Pi at Maker Faires. The 10,000mAh battery provides a usable six hours of runtime and the device gets constant compliments from makers (including Bunnie Huang!). I do wish I had used a battery that provides power while plugged in, though. Other changes I'd make would be mostly software related. It's difficult to double-click on icons reliably, and the N-Trig touch driver isn't supported by RaspBMC (but can be compiled into the kernel if I could ever get it figured out). I've also considered adding a camera and an IR sensor — maybe if I build another one.

Bill of Materials

These three items are crucial to making the PiPad — we encourage you to experiment with new approaches for peripherals and enclosures. Make sure to share your results with us!

- **Raspberry Pi Model B** Ethernet and 1 USB port removed for clearance
- **10" capacitive touchscreen with LVDS adapter** from Chalk-Elec.com
- **Anker Astro3E 10,000mAh battery** puts out 3A at 5V and gives about 6 hours of battery life

Build Notes:

- The hardest part of building the PiPad was determining the most efficient use of space — too-close components making even slight contact with the touchscreen caused glitches and required repositioning. I advise laying out the electronics and determining fit as thoroughly as possible before committing to any cuts. Vectric's incredible Aspire CAD/CAM package helped me make an accurate recreation and ensure clearance.
- I didn't realize it until I finished, but the Anker Astro E3 does not provide power to the Pi while charging. You may want to choose a battery pack that has this feature.
- The GPIO port was actually a last minute addition. Originally I thought I'd never use it, but it turns out I was wrong. I've used it several times for prototyping — it's extremely handy!
- The heat sinks might be overkill but will help the Pi stay a little cooler in the enclosed space.
- You don't need to use carbon fiber for the backing — guitar pickguard material, acrylic, or other flat, non-metallic substance will work. I just happened to have some scrap carbon-fiber plate lying around.
- If CNCing plywood for an enclosure, use a spiral downcut bit and cut slightly into your spoil-board to avoid splintering.
- Just because the PiPad looks legit enough for air travel, use common sense and don't go opening it up where it might make people nervous.

Find step-by-step instructions at makezine.com/how-i-built-a-raspberry-pi-tablet

Share it: ***#pipad***

Proto "Glass" hacker Steven Roberts and the "Brain Interface Unit" for his 1991 nomadic "BEHEMOTH" bike project. The BIU offered a heads-up data display (via The Private Eye), a head-gesture-controlled mouse, radio communications and entertainment audio, spot and flood lights, a rearview mirror, and even a helmet liquid cooling system.

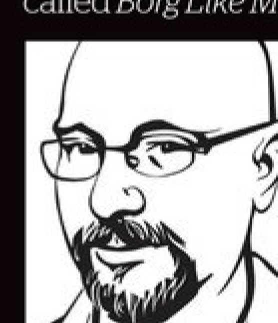
Mel Lindstrom/Nomadic Research Labs

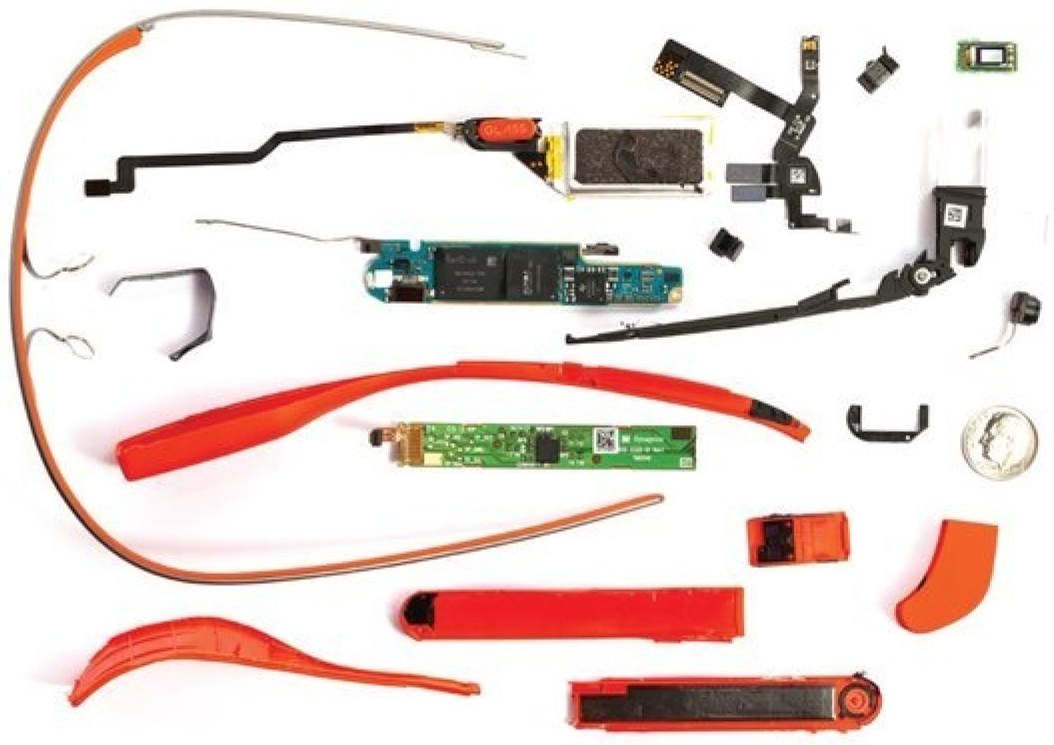
How makers around the world are modding, hacking, and building their own versions of Google's geeky goggles.

THE (GOOGLE) GLASS MENAGERIE

Written by Gareth Branwyn

GARETH BRANWYN is a freelance writer and the former editorial director of Maker Media. He is the author or editor of a dozen books on DIY tech and geek culture, including the first book about the web (*Mosaic Quick Tour*) and the *Absolute Beginner's Guide to Building Robots*. He is currently working on a best-of collection of his writing, called *Borg Like Me*.





Scott Torborg and Star Simpson

THE ALLURE OF WEARABLE COMPUTING HAS BEEN WITH US ALMOST AS LONG AS THE PERSONAL COMPUTER. Look through old PC magazines and you'll find ads for ahead-of-its-time hardware like The Private Eye, a '90s-era head-mounted display (HMD). We can also look to early examples of DIY "cyborgs" like Steven Roberts, the "high-tech nomad," Steve Mann, the "father of wearable computing" who's lived as a computer-augmented human for the past 35 years, and Professor Thad Starner of Georgia Tech, coiner of the term "augmented reality," who's worn a HMD for the past 20 years. Starner even served as a technical lead on the Google Glass project. These maker pioneers didn't bother to wait for Glass. They used the technology available at the time — costly, limited, and unwieldy as it may have been. They made the wearables they wanted to see in the world, as soon as they imagined them. And now, with the advent of Google Glass — the first widely available, affordable, net-connected computer glasses — today's makers are being inspired to explore this emerging technology, to create their own alternatives, and to tear down, hack, and augment Glass itself.

SO WHAT EXACTLY IS GLASS?

Basically, Glass is an Android computer that you wear like a pair of glasses. There's a tiny head-mounted display in the upper right corner of your field of view and a touchpad that runs from your right eye to your ear along the stem. You use a combination of head gestures, touch, and voice commands to operate the system. The display is described as the equivalent of a 25" hi-def screen from 8' away. There's a built-in 5-megapixel still and 720-dpi video camera, plus on-board wi-fi and Bluetooth so Glass can sync to your phone or a nearby network. Sensors include a 3-axis gyro, a 3-axis accelerometer, a 3-axis magnetometer (compass), and ambient light and proximity detectors. The latest version of Glass offers the option of adding prescription lenses to the (ironically) glassless Glass frame, plus an optional earbud (to use instead of the built-in bone-conduction audio).

THE DIYERS

As soon as the invitation-only "Glass Explorer" program was launched, enterprising makers around the world hit their workbenches and began cobbling together their own versions based on Google's promotional media and early demos. Searching

CYBORG DIY

Like all wearable tech, the head-mounted display market has struggled for years to find a foothold. Consequently, numerous commercial HMD systems have come and gone. This has been unfortunate for widespread adoption of wearables but a boon to hardware hackers looking for cheap tech to cannibalize, hack, and reimagine. Historically, input devices have been a major stumbling block for HMDs. Once you start adding air mice, chord keyboards, and/or handheld or wrist-borne keyboards/track pads, you quickly end up with a system that's too clunky to be practical. The advent of widespread and reliable speech-to-text and voice-command software may finally get us there; a practical HMD input system is no longer that difficult to achieve, even for DIYers, who can use voice-enabled phones and other devices for control.

DOING IT YOURSELF

To create a bare-bones head-mounted display for your smartphone, all you really need is ...

1. A video display. There are a number of commercial video glasses out there. One of the more commonly hacked is the MyVu Crystal 701. It's fairly easy to get one camera module and optics out of these glasses to use as a monocular HMD. Crystal glasses can be found on eBay and will run you from $100–$150, less if you get lucky. You'll need to remove the camera module and optics for one lens and the cabling/connector.

2. Something to mount it on. You can use a pair of safety glasses frames, 3D-printed frames (see Joris Van Tubergen), or possibly your prescription glasses.

3. Something to mount it with. Glues, screws, zip ties, rivets, thumbtacks, possum spit, or whatever else gets the job done.

4. Cables/connectors/adapters. As needed to get your display to connect to your phone.

5. Voice-control software. Siri-equipped iPhones work pretty well for a lot of voice nav functions (and there are apps like Hands-Free Control that allow you to awaken jailbroken phones with a voice command). You can also use the button control on your headset to access Siri. On an Android, there are apps such as Utter and Tasker.

"DIY Google Glass" nets a bizarre catch of phony Glass-like display demos, ridiculously clunky proof-of-concept hardware experiments, and humorous takes on Glass, as well as a number of interesting, earnest homebrew HMD projects.

NATHAN MYERS

Myers, an Australian IT pro, tried to get a spot in the Glass Explorer program but got turned down and decided to roll his own. He's now gone through six iterations, experimenting with different displays (chiefly using the MyVu Crystal 701), brains (iPhone, Nokia N9, Samsung Galaxy S, Beaglebone Black, and an Android HDMI TV stick), and frames. For the Android builds, he uses the apps Utter and Tasker to create a voice-controlled system that makes his glasses nearly hands-free. Versions 1–5 didn't include a camera, but version 6 (which runs on the Android TV stick) includes a cannibalized webcam.

Myers sees potential applications for his glasses among the hearing-, sight-, and motion-impaired, as his project uses voice and (eventually) eye-tracking, not touch or gesture. He's hoping to attract interest from investors so he can develop his ideas further. Myers originally called his project Flass ("Fake Glass") but changed it to MiDisplay after a run-in with Google IP.

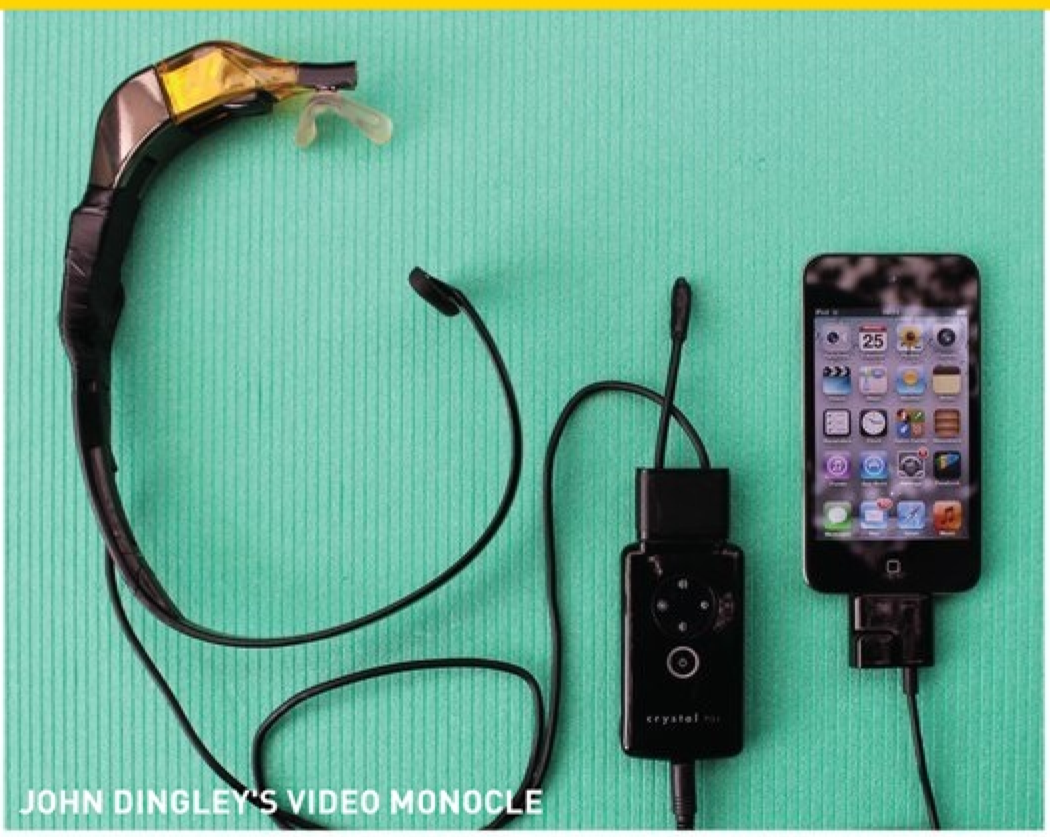
ROD FURLAN

Furlan was another maker who didn't want to wait for the "official" version of Glass. He created a very respectable homebrew HMD, also using MyVu Crystal for the optics. The display is mounted on a pair of safety glasses with a Looxcie Bluetooth camera, and uses an iPod Touch as the brain. Furlan passed on voice control, instead relying on iPod's touchscreen for navigation, with a custom app to automate and aggregate common notifications (Facebook, Twitter, stocks, email, etc.) so he wouldn't have to be constantly taking the device out of his pocket.

Furlan says that though he started out skeptical of the technology, after wearing it for awhile he began to feel attached — taking it off produced a noticeable sense of loss. Even though his build is crude by Glass standards, it still gave him a taste of what's to come. You can read in more detail about Furlan's build on spectrum.ieee.org.

JOHN DINGLEY

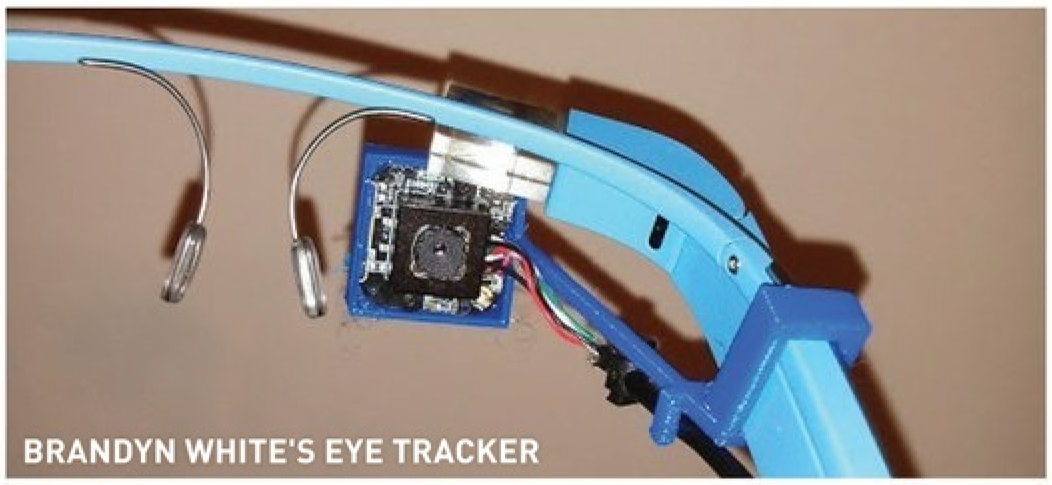
Dingley was looking for a simple way to watch the BBC iPlayer and other net-based media during activities that didn't require his full attention. He too used the MyVu Crystal, cutting the display just to one side of the nose bridge to create a video monocle. Attaching the frame from one side of the glasses to the springy band of a gaming headset allows the rig to stay firmly on his head. Hooked up to his iPod Touch, Dingley is now free to move about the house, watching movies and TV while pretending to be productive. His build is well-documented on Instructables.



JOHN DINGLEY'S VIDEO MONOCLE

DEQING SUN'S GLASS LIGHT

SUN'S TRINKET



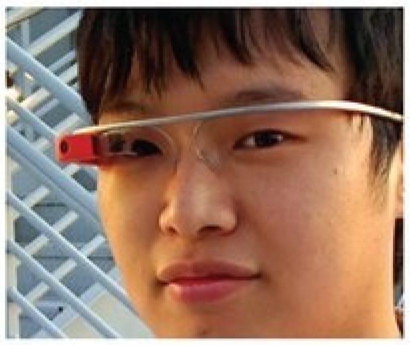
BRANDYN WHITE'S EYE TRACKER

JORIS VAN TUBERGEN

When Van Tubergen created his "faux" Google Glass printable 3D model and uploaded it to Thingiverse, the idea was probably more of a joke than anything else — a way for those who didn't get into the Explorer program to steal some of the limelight from early Glass owners. But it turns out that a number of DIY HMD builders (like Nathan Myers) have ended up using Van Tubergen's model as the structural basis for their projects. To date it has been downloaded almost 15,000 times, and more than a dozen Thingiverse users have uploaded pictures of their own prints. Van Tubergen's model, in turn, is based on an earlier SketchUp 3D Warehouse model by French maker Cathy Tritschler.

THE HACKERS

Among makers lucky (and well-heeled) enough to gain early access to Glass through the Explorer program, quite a few impressive hacks, mods, and augmentations have appeared.



DEQING SUN

Former NYU/ITP student Sun has done several Glass-based projects, including a software-controllable clip-on LED flashlight. The prototype simply used a pin on the Glass' micro-USB port to power a white LED and had to be manually plugged in when you wanted to use it. For version 2.0, Sun discovered that Glass supports USB-OTG ("On the Go"), allowing it to act as a host for other USB devices. With it, Glass could issue commands to the light. He managed to find a tiny USB controller and fit the circuit inside of right-angle USB jack housing. On the software side, Sun had to get root access to his Glass, then install an app that translates voice-to-USB commands. Now his Glass has a handy voice-activated flashlight at the ready, and Deqing's open-source project stands as a great jumping-off point for other custom hardware developers.

Building on his success with "GlassLight," Sun developed "Glass Trinket," a project that uses Glass as a USB host for Adafruit's tiny, inexpensive "Trinket" mini AVR microcontroller board. Connecting an external microcontroller opens up all sorts of possibilities for additional sensor input and other augments. Predator-style heat vision, anyone?

Sun has also built a Glass remote control for use in very windy conditions, while wearing a scarf, in extreme cold, or when otherwise unable to use voice input. It's built around Adafruit's Bluefruit EZ-Key keyboard controller.

BRANDYN WHITE

Some of the most exciting Glass-based development going on right now comes from a group of hackers who call their project OpenShades. Project lead Brandyn White and his team have been hard at work putting together WearScript, an Android app that allows you to write Glass apps using JavaScript. The scripts are shared on Weariverse.com, where the group hopes to create an avid community of users and developers. White says they're about to relaunch the app/site with added support for even more advanced "wearable device topologies" — stuff like multiple HMDs with smartphones, smart watches, microcontrollers, servo communications, and other devices all talking with each other. Their introductory video is a good place to start learning more.

Other projects by White's group have included a $25 eye-tracking unit that mounts to Glass, an exclusively eye-controlled Mario Bros. video game, a Makey Makey-based Glass input controller, head- and touch-gesture-based Arduino and servo control, and Glass-based animatronics. They also created a pair of applications designed for use by the visually impaired: Question-Answer uses "cloud workers" to answer visual "what is this?" questions, and Memento compares streamed video frames against a database of images with descriptive voice annotations, which are read back to the user. "We are all very excited about the potential of wearable computing," enthuses White. "The companies that make these devices are often focused on their own products. What we want to do is help fill in the gaps with free software, and hopefully, push things forward a bit faster."

"NOT OK, GLASS"

Given that Glass can so easily and surreptitiously take photos and videos without those around knowing it, the technology has raised a lot of privacy jitters. Some bars and restaurants in Silicon Valley have even started posting "No Glass" signs. Artist and engineer Todd Blatt was quick to respond to these concerns (and poke a little fun at the Glass phenomenon at the same time) by creating a line of 3D-printed accessories. These include a brightly colored camera lens privacy shield (so people can see your camera is blocked), an old school "On Air" sign, and some other whimsical add-ons like cyborg-targeting crosshairs. Blatt says his original inspiration was the privacy shield (which he calls GlassKap), "But why stop there? If anticipating Glass has taught us anything, it's that people have bold aspirations when it comes to tricking out their tech. Once I began, ideas flowed like Klingon Blood Wine."

SAD TROMBONE

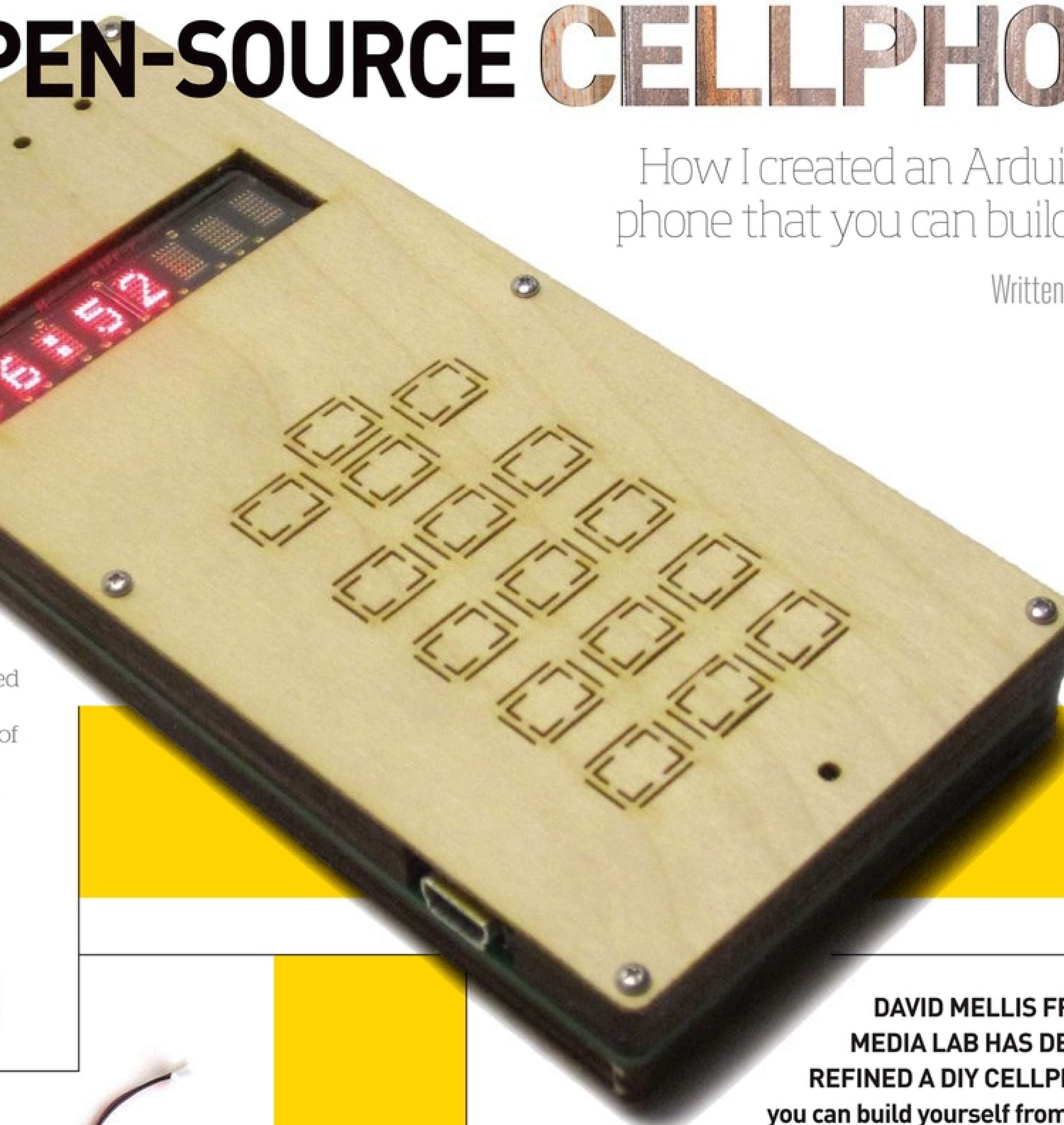
Unfortunately, on a DIY HMD, you can't currently access official Glass apps, which are designed, among other things, to feed you content preformatted for tiny heads-up displays. The APIs were open for awhile, but Google has since moved all the code into libraries designed to thwart their use on competitor devices. Some builders, like Rod Furlan, have made their own software, creating simple apps that feed them alerts and headlines and make their homebrew HMDs more "Glass-like." As the hardware continues to proliferate, the software options are likely to open up again.

IF YOU COME, THEY WILL BUILD IT

Before anyone had donned Glass, Rod Furlan had already cobbled together his own HMD and tested the impacts of regularly wearing such a device, drawing his own (slightly different conclusions) as to why it's relevant. Early on, he concluded that the real utility of Glass was going to be in the photographing and recording aspects, more than augmenting reality. Furlan imagines a future in which you record everything you do and can then play back your memories — an idea he calls "augmented cognition." Though Google plays down the recording/photographing aspect over the AR features, augmented cognition is something wearable pioneer Thad Straner has been championing for years. It's still unclear what the general public will make of Glass or whether wearables in general will finally enjoy their breakout moment. But for makers, this emerging space is a great sandbox for trying things out on-the-cheap, expanding the limits of the technology ahead of corporate R&D, and moving toward a new technology on their own terms.

Share your build at : makezine.com/DIYglass
Share it: *#DIYglass*

THE OPEN-SOURCE CELLPHONE



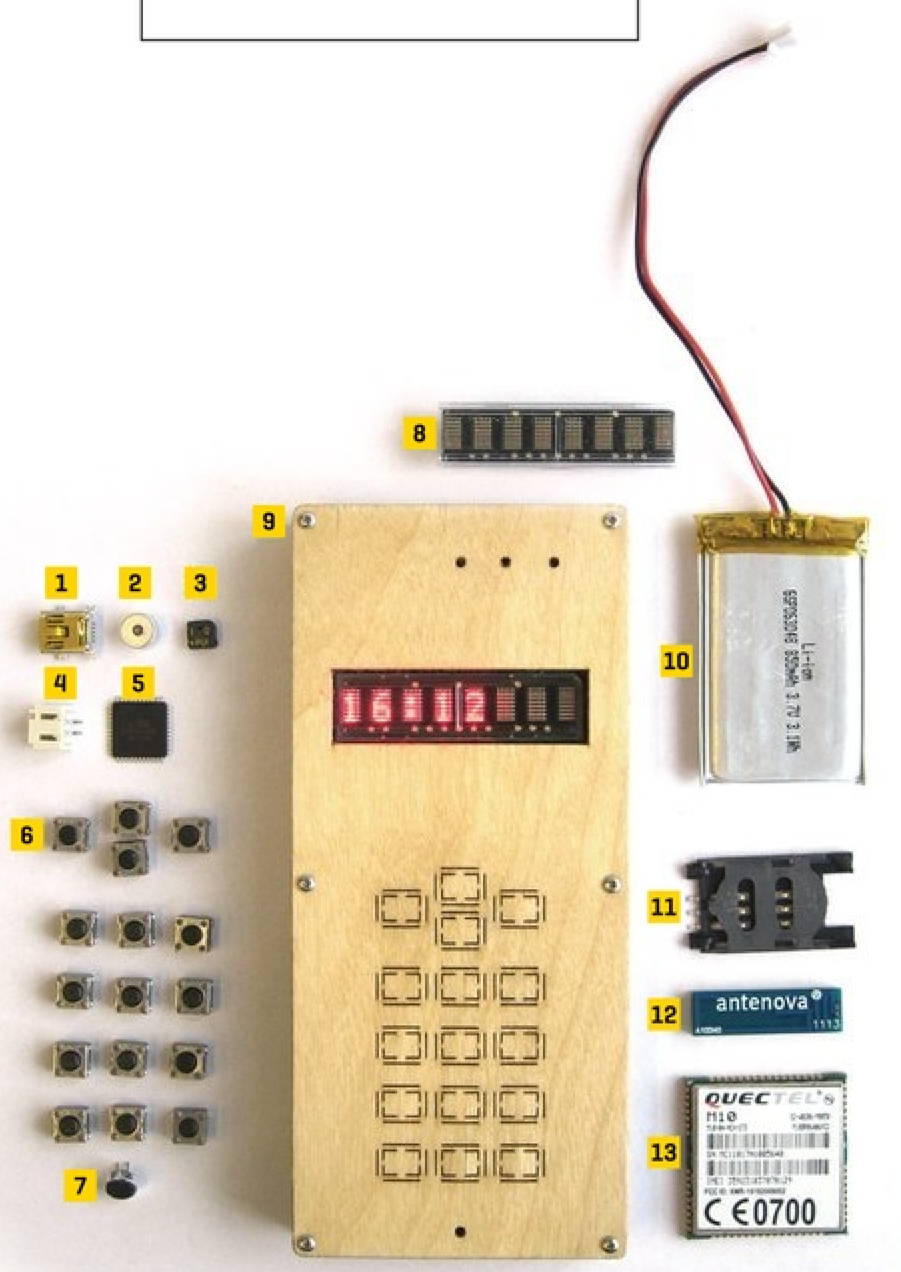
How I created an Arduino-based phone that you can build at home.

Written by David A. Mellis

DAVID A. MELLIS is a PhD student in the MIT Media Lab. He studied at the Interaction Design Institute Ivrea and is one of the creators of Arduino.

DAVID MELLIS FROM THE MIT MEDIA LAB HAS DESIGNED AND REFINED A DIY CELLPHONE that you can build yourself from his open-source design files and code. A "difficult, but potentially do-able project," the phone has the basic features you'd expect: You can make and receive calls and text messages, and it has a phone book for storing numbers. I asked David about the accomplishment, the difficulties, and where it goes next.

—Matt Richardson



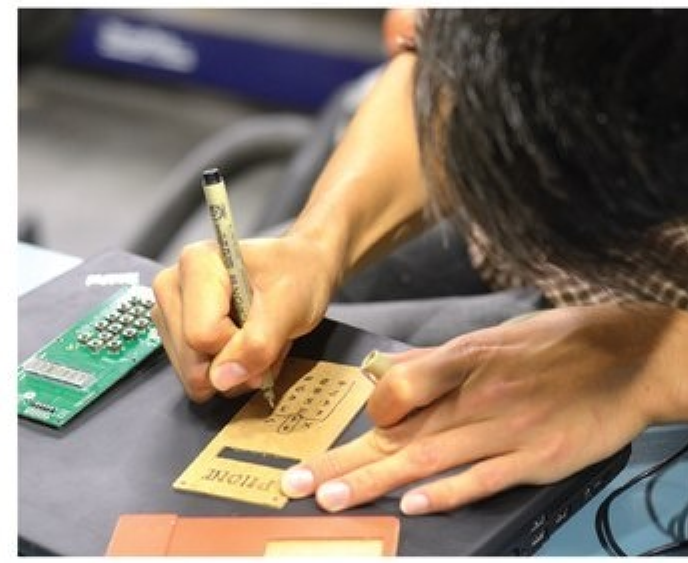
1. USB
2. SPEAKER
3. BUZZER
4. BATTERY CONNECTOR
5. ATMEGA1284P MICROCONTROLLER
6. TACTILE BUTTONS (16)
7. MIC
8. LED MATRIX
9. LASER-CUT WOOD CASE
10. LIPO BATTERY
11. SIM SOCKET
12. ANTENNA
13. GSM MODULE

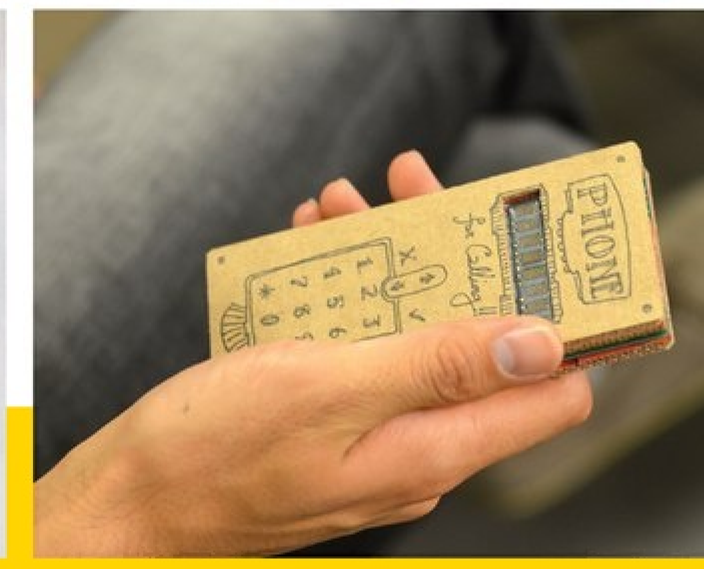
CHALLENGES: BIG AND SMALL

The biggest challenge in designing an open-source cellphone has been balancing the desire to make a functional phone while keeping it as easy as possible to assemble by hand. Mostly, this was a question of sourcing the right components: parts small enough to fit into a reasonable overall size but still big enough to solder manually. For example, I was lucky that the GSM module from the Arduino GSM shield (the Quectel M10) was fairly small but with reasonably big solder joints.

Finding a small and robust screen was also a challenge: The LCD I used initially would break after a month or so of use. The LED matrix I'm using now has been fairly stable but only shows eight characters. Similarly, I managed to find a nice small speaker, but the audio quality isn't amazing.

This problem is a lot harder when you're trying to make something that you're going to carry in your pocket every day.





FEATURES, FUNCTIONS, AND FABRICATION

The phone has gone through a lot of iterations — circuit, enclosure, and software. The changes to the circuit itself have mostly been small tweaks and additions: For example, adding a reset button in case the software crashed, or connecting the buzzer straight to the microcontroller so I could use it as an alarm (not just a ringtone). For the enclosure, it's been a lot of playing with different materials and fabrication processes. People have made cases from cardboard, 3D-printed plastic, CNC-milled wood, even silk-worms.

The software probably had the tightest back-and-forth between design and use: I've discovered lots of problems while using the phone. Early versions were missing a lot of features (like not showing the name of a person when they called), and I've gradually added the most pressing. But using the phone every day has also made me realize how much functionality you can live without. For instance, the current version of the software doesn't save old text messages, and I've just gotten used to it.

I've been surprised at how reliably the phones connect to the network. I'm using an off-the-shelf antenna, and I borrowed the circuit for connecting it to the GSM module from the Arduino GSM shield — but still, I expected the RF portions of the circuit to present more of a problem.

LOOKING FORWARD

I'm less interested in adding specific improvements to the phone itself than in exploring other ways to help people make their own devices. For example, I'm working on a GSM module that's effectively a cellphone and an Arduino in one, so people can build their own cellphone interface or form factor. I'd also like to find ways to make PCB design appealing to new groups of people — I'm curious to see how we might be able to place it in a design context rather than an engineering one. I'm also interested in finding ways to get the phone itself out to more people, whether by having them build it themselves or otherwise distributing it.

While I started, to some extent, by creating DIY replacements for existing devices, I think the most interesting possibilities are in creating new, custom devices. With the increasing accessibility of embedded computation and digital fabrication, it's more and more possible for an individual to create not just prototypes, but robust, reproducible devices they can use in their daily lives. So I think we'll see increasing numbers of unusual, one-off, or small-volume devices that appeal to specific people or needs but that don't make sense for mass production. For example, I'd personally like to build a couple of devices that perform specific, internet-enabled functions like showing the weather or playing a particular podcast. I don't see these particular devices as the next big thing (even for my own work) but simply as examples of the many different kinds of things it's now possible to build.

Find detailed build notes, source files, parts list, and more at makezine.com/open-source-cellphone

Share it: ***#opensourcecellphone***

SCRATCH-BUILDING YOUR OWN LAPTOP

Our open-source machines are made from off-the-shelf parts and see near-daily use. Written by Bunnie Huang

ABOUT A YEAR AND A HALF AGO, I ENGAGED IN AN ADMITTEDLY QUIXOTIC PROJECT TO BUILD MY OWN LAPTOP. By I, I mean we — namely, Sean "xobs" Cross and me. Building your own laptop makes about as much sense as retrofitting a Honda Civic with a 1,000hp motor, but the lack of practicality never stopped the latter activity, nor ours.

My primary goal in building a laptop was to make something I would use every day. The project was also motivated by my desire to learn all things hardware, and my passion for open hardware. I'm a big fan of opening up the blueprints for the hardware you run — if you can't hack it, you don't own it.

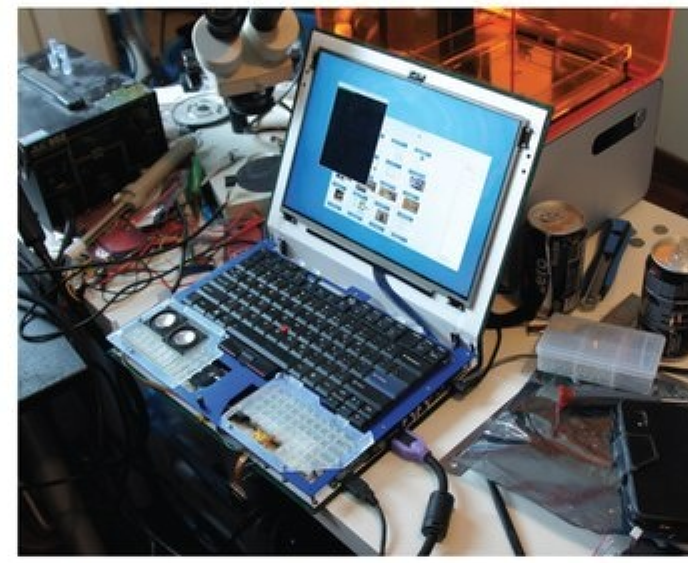
Back when I started the project, it was me and a few hard-core open ecosystem enthusiasts pushing this point, but Edward Snowden changed the world with revelations that the NSA has in fact taken advantage of the black-box nature of the closed hardware ecosystem to implement spying measures — "good news, we weren't crazy paranoids after all."

Our Novena Project (makezine.com/go/novena) is of course still vulnerable to Trojan techniques such as "silicon poisoning," but at least it pushes openness and disclosure down a layer, which is tangible progress in the right direction.

While these heady principles are great for motivating the journey, actual execution needs a set of focused requirements. And so, our principles boiled down to the following requirements for the design:

I'm always behind a keyboard!

The first two prototypes are wrapped in red sheepskin leather, and green pigskin suede.



A DIY laptop parked in front of the Form 1 3D printer used to make its body panels.

■ All the components should have a reasonably complete set of NDA-free documentation. This single requirement alone culled many choices.

■ Low cost is not an objective. I'm not looking to build a crippled platform based on some entry-level single-core SoC just so I can compete price-wise with the likes of Broadcom's nonprofit Raspberry Pi platform.

■ On the other hand, I can't spec in unicorn hair, although I come close to that by making the outer case from genuine leather (I love that my laptop smells of leather when it runs). All the chips are ideally available off the shelf from distributors like Digi-Key and have at least a five-year production lifetime.

■ Batteries are based on cheap and commonly available packs used in R/C hobby circles, enabling users to make the choice between battery-pack size, runtime, and mass. This makes it hard to answer the question of "what's the battery life?" — it's really up to you — although one planned scenario is the "Trans-Siberian railroad trek," which is a weeklong trip with no power outlets.

■ The display should also be user-configurable. The U.S. supply chain is weak when it comes to raw high-end LCD panels, and, in order to address the aforementioned Trans-Siberian scenario, we'd need the ability to drive a low-power display like a Pixel Qi but not make it a permanent choice. So, I designed the main board to work with a cheap LCD adapter board for maximum flexibility.

■ No binary blobs should be required to boot and operate the system for the scenarios I care about. This one is a bit tricky, as it heavily limits the wi-fi card selection, I don't use the GPU, and I rely on software-only decoders for video. But overall, the bet paid off; the laptop is still very usable in a binary-blob-free state. We prepared and gave a talk recently at 30C3 using only the laptops.

■ The physical design should be accessible — no need to remove a dozen screws just to pull off the keyboard. This design requires removing just two screws.

■ The design doesn't have to be particularly thin or light; I'd be happy if it was on par with the 3cm-thick ThinkPads or Inspirons I used back in the mid 2000's.

■ The machine also must be useful as a hardware hacking platform. This drives the rather unique inclusion of an FPGA into the mainboard.

■ The machine must be useful as a security hacking platform. This drives the other unusual inclusion of two Ethernet interfaces, a USB OTG port, and the addition of 256 MiB DDR3 RAM and a high-speed expansion connector off the FPGA.

■ The machine must be able to build its own firmware from source. This drives certain minimum performance specs and mandates inclusion of a SATA interface for running off an SSD.

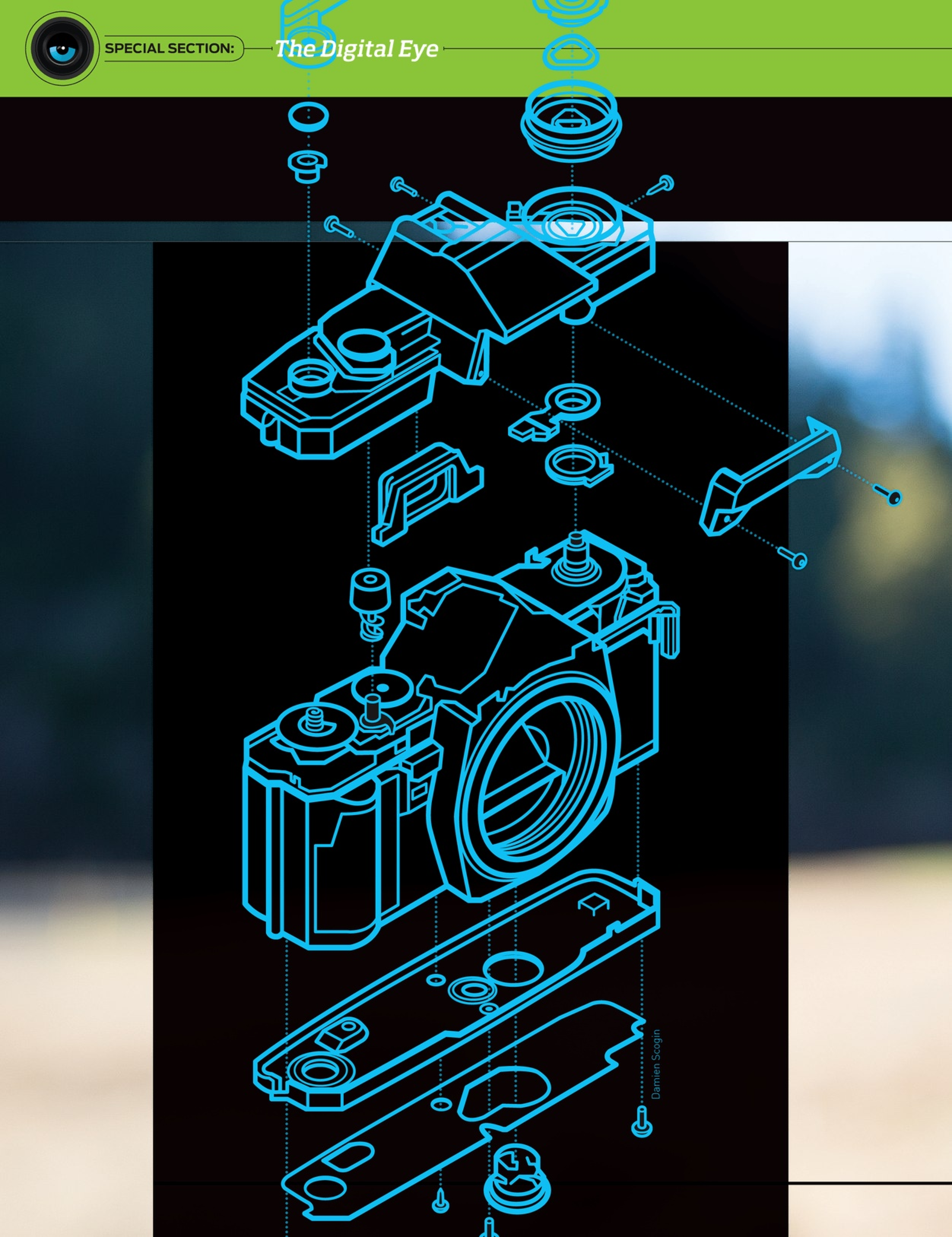
After more than a year and a half of hard work, I'm happy to say our machines are in a usable form. The motherboards are very reliable, and the display is a 13-inch, 2,560×1,700 (239 ppi) LED-backlit panel. The cases have an endoskeleton of 5052 and 7075 aluminum alloys, an exterior wrapping of genuine leather, an interior laminate of paper (I love books and papercraft), and cosmetic panels 3D-printed on a Form 1. The design is no ThinkPad X1 Carbon, but our machines have held together through a couple of rough international trips, and we use them almost every day.

I was surprised to find the laptop was well received by hackers, given its homebrew appearance, relatively meager specs, and high price. The positive response has encouraged us to plan a crowdfunding campaign around a substantially simplified case design (think "all-in-one PC" with a battery): That's right, the final design will not look like these early, hand-built prototype cases. Follow @novenakosagi for updates on our progress!

BUNNIE HUANG
serves as a research affiliate for the MIT Media Lab and technical advisor for several hardware startups and for MAKE magazine. He blogs about his experiences manufacturing hardware in China at bunniestudios.com.

Share your thoughts and learn more at makezine.com/building-an-open-source-laptop

Share it: *#opensourcelaptop*


Damien Scogin

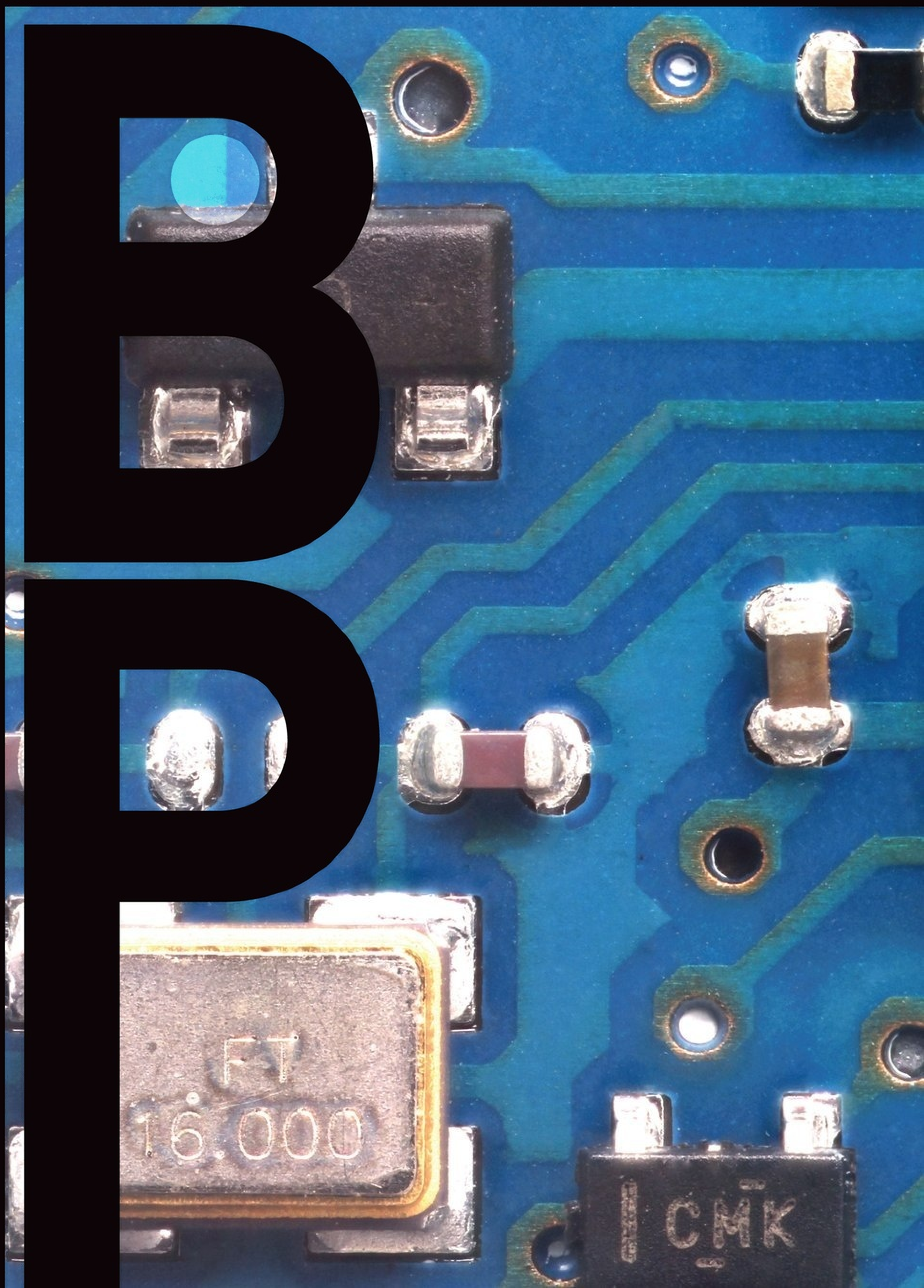
THE DIGITAL EYE

IN 1500, A CLOCK WAS A MACHINE THAT FILLED A ROOM IN A TOWER. TODAY, CLOCKS ARE BUILT INTO ALMOST EVERY MACHINE WE MAKE. THE SAME THING IS HAPPENING TO THE CAMERA: WE'VE COME FROM THE *CAMERA OBSCURA* TO THE MODERN SMARTPHONE AND ARE FAST APPROACHING A WORLD IN WHICH EVERYTHING WE BUILD CAN SEE. NOW IS THE TIME TO START PLANNING FOR WHAT WE'LL MAKE OF IT.

Jeffrey Braverman

THE BIG PICTURE

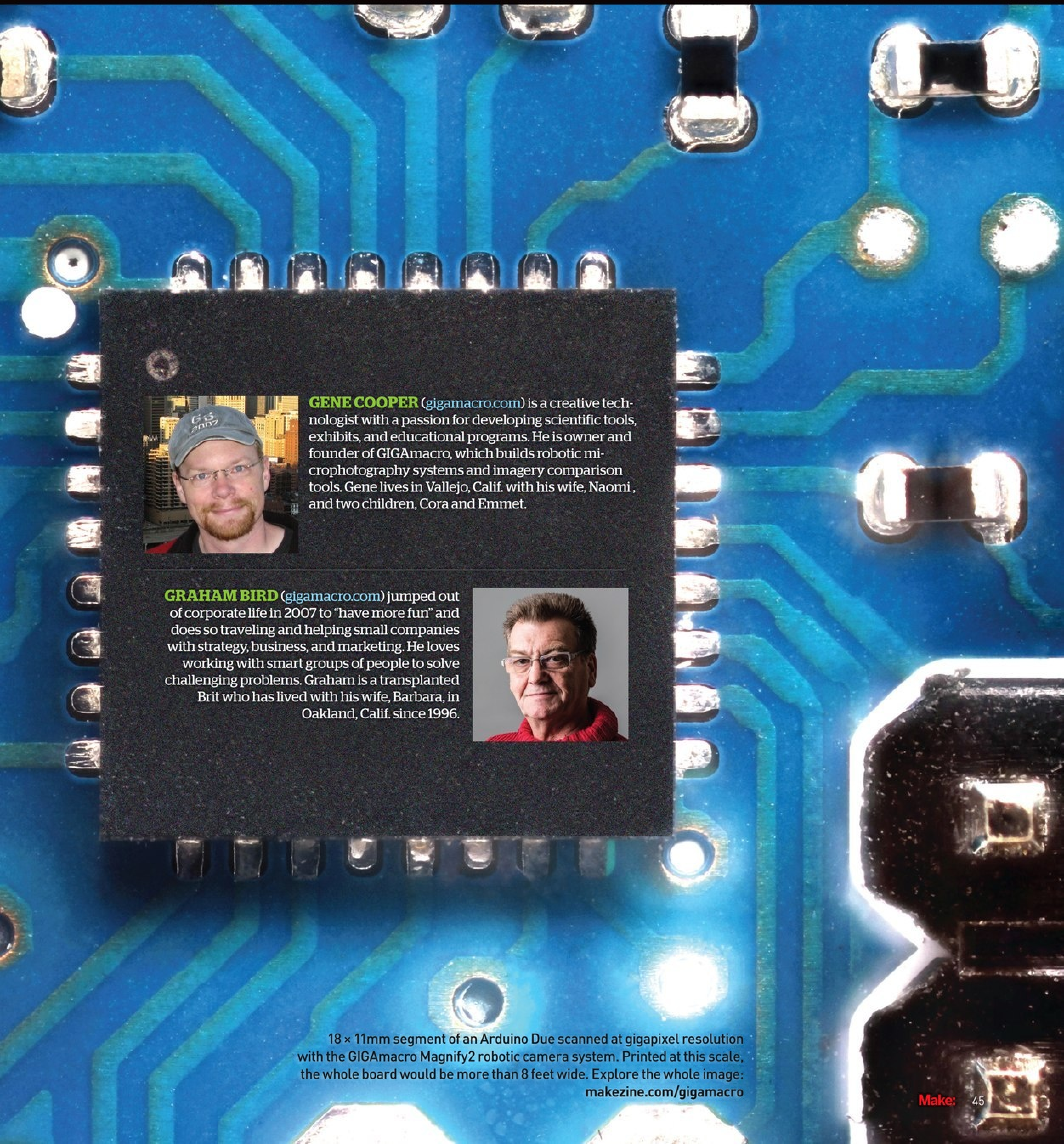
Written by Gene Cooper and Graham Bird



Time Required: 8 Hours
Cost: $500–$1,000

Build a low-cost supermacro stacking and stitching rig.

Taking a 100+ megapixel macro photo with a basic digital camera.



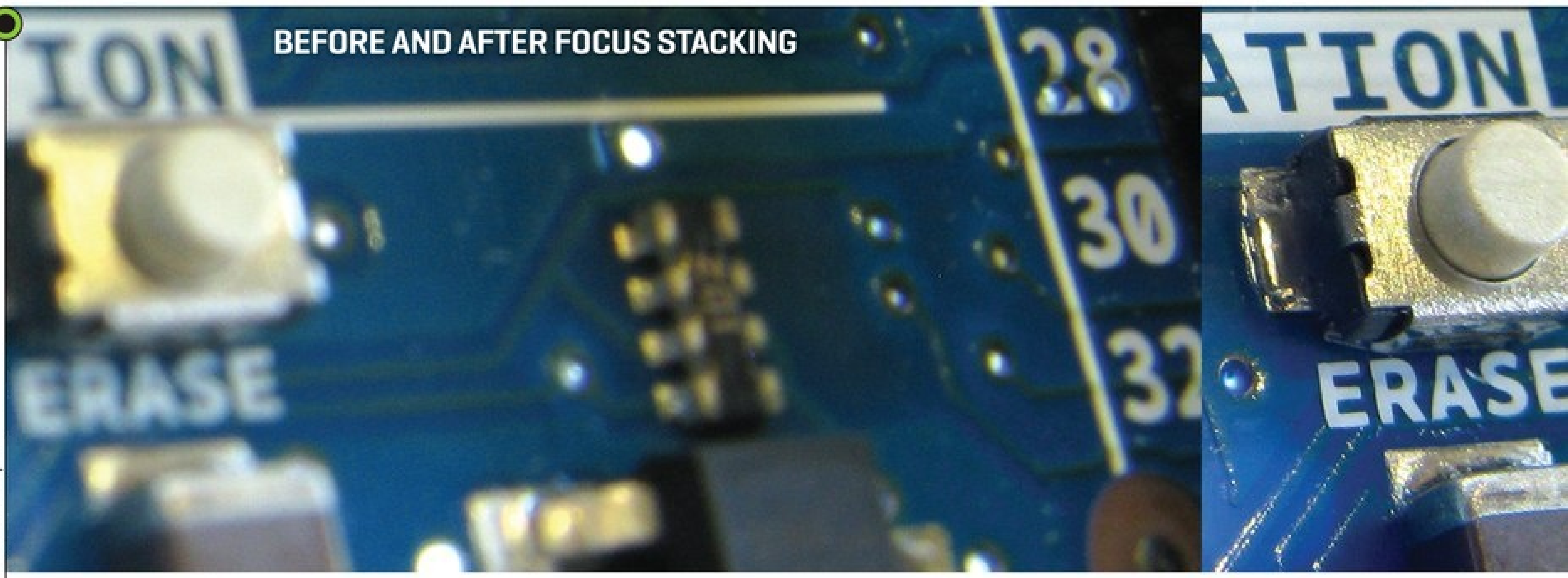
GENE COOPER (gigamacro.com) is a creative technologist with a passion for developing scientific tools, exhibits, and educational programs. He is owner and founder of GIGAmacro, which builds robotic microphotography systems and imagery comparison tools. Gene lives in Vallejo, Calif. with his wife, Naomi, and two children, Cora and Emmet.

GRAHAM BIRD (gigamacro.com) jumped out of corporate life in 2007 to "have more fun" and does so traveling and helping small companies with strategy, business, and marketing. He loves working with smart groups of people to solve challenging problems. Graham is a transplanted Brit who has lived with his wife, Barbara, in Oakland, Calif. since 1996.

18 × 11mm segment of an Arduino Due scanned at gigapixel resolution with the GIGAmacro Magnify2 robotic camera system. Printed at this scale, the whole board would be more than 8 feet wide. Explore the whole image: makezine.com/gigamacro

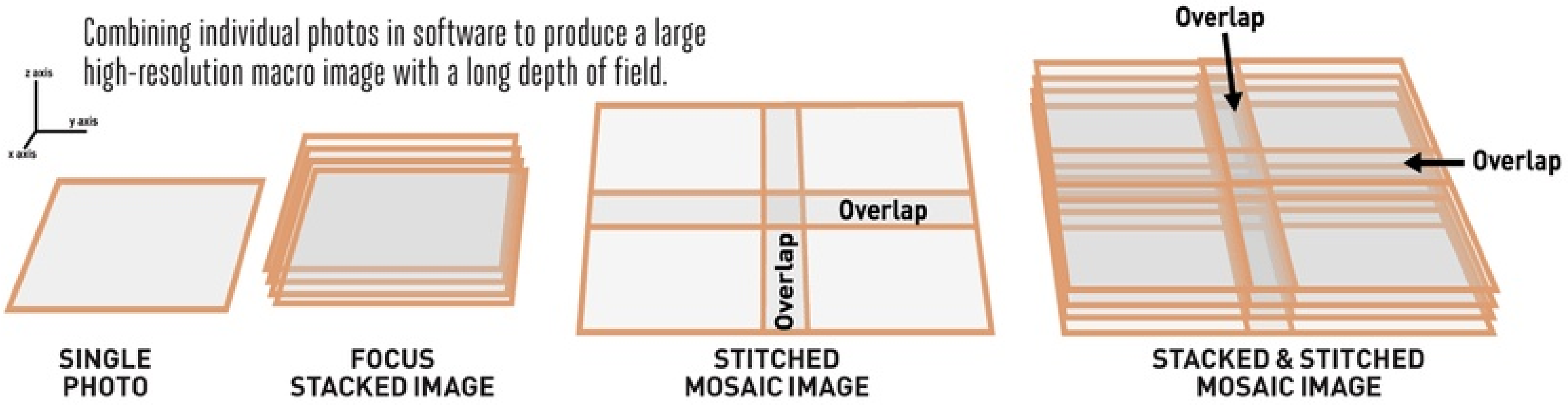
Tools

- **» Camera and lens** with manual focus adjustment, manual exposure settings, self-timer, and the ability to focus on objects less than 1" from the lens. Here we're using an older Canon PowerShot G9 with a 12MP sensor.
- **» Panoramic bracket** You can buy a readymade bracket (like the Nodal Ninja 3 series) for $100–$200, or you can make your own. If you want to go the DIY route, download our plans from makezine.com/gigamacro, then laser-cut, mill, or jigsaw the parts. It should cost about $5-$10.
- **» Tripod (optional)** for use with a readymade bracket.
- **» Computer** PC or Mac
- **» Focus-stacking software** Photoshop CS5 or later works fine for this, but we prefer Zerene Stacker. It has a number of advanced options that allow you to output stereo pairs and depth maps, plus more options for complex subjects. Other available programs include Helicon Focus, Combine Z, and ImageJ.
- **» Image-stitching software** Photoshop has a lot of great tools for manual or automatically stitching and working with your photographs to create high-resolution panoramas. For advanced setups, we use AutopanoGiga, PT Gui, and Gigapan Stitch. These offer a wider range of options and can handle extremely complex scenes.



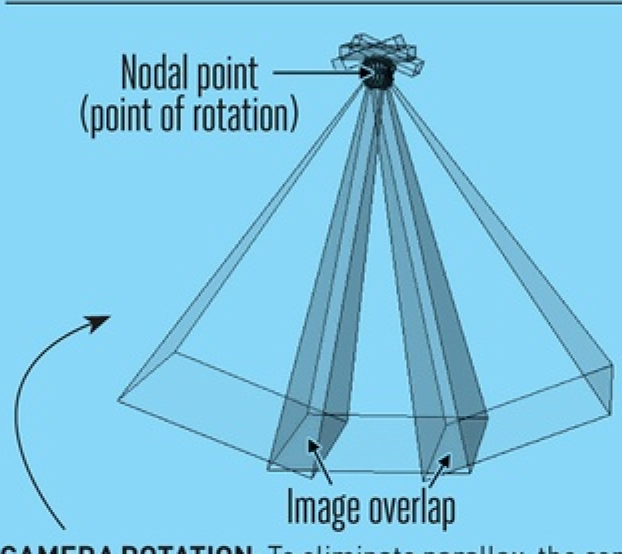
BEFORE AND AFTER FOCUS STACKING

Gene Cooper



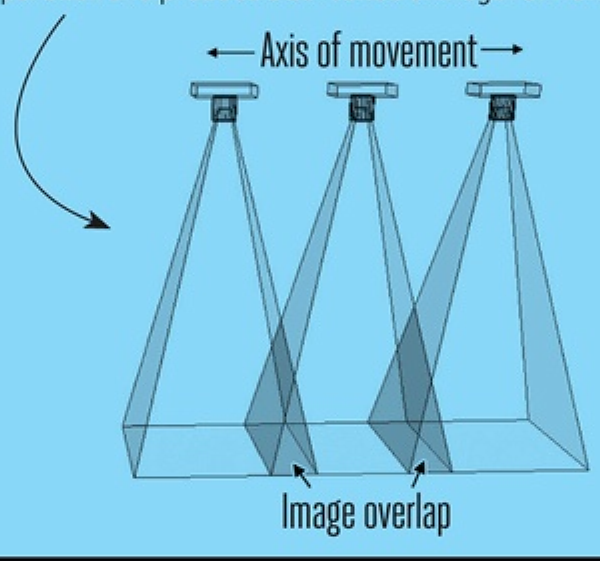
Combining individual photos in software to produce a large high-resolution macro image with a long depth of field.

TWO APPROACHES TO IMAGE STITCHING



CAMERA ROTATION: To eliminate parallax, the center of rotation should be the "nodal point" of the lens. A panoramic bracket, which keeps the center of rotation from changing between shots, is required for accurate macro work.

CAMERA TRANSLATION: Standard lenses work well for flat subjects like maps. For objects with depth, a special "telecentric lens" is required to eliminate perspective and parallax and produce a so-called orthogonal view.



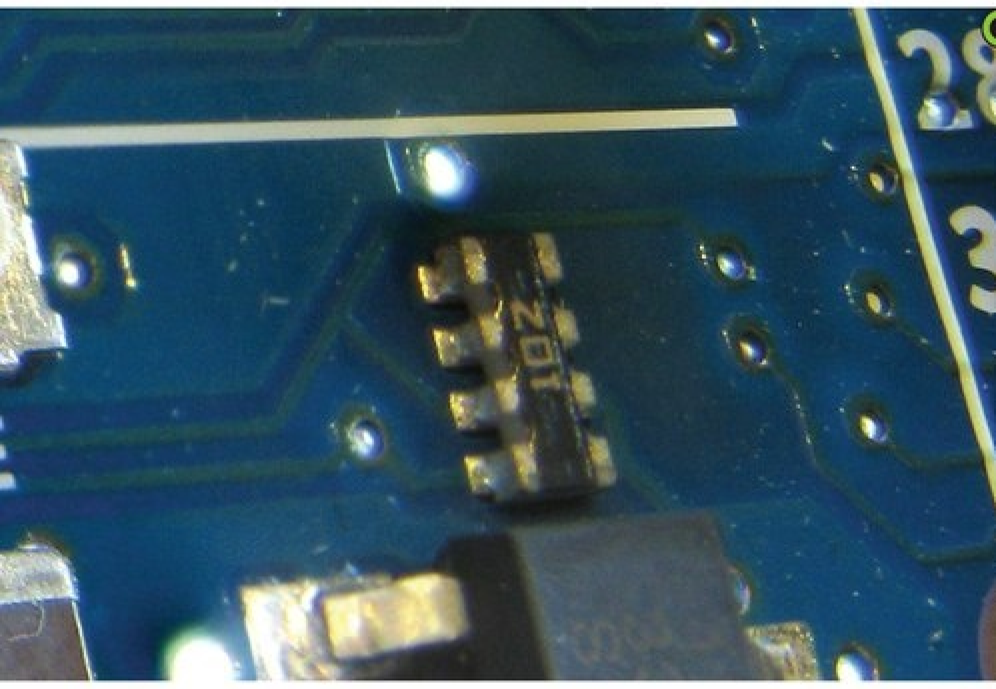
SEEING SMALL DETAILS IS HARD. AS THE EYE GETS CLOSER TO A SUBJECT, the depth of field (the distance through which details are clearly focused) gets shorter. At about 70mm away, most human eyes can no longer focus at all. In fact, only about 2 degrees of our field of vision is actually in focus at any given instant. The rest of what we "see," from moment to moment, is virtually constructed by our remarkable brains.

The process for making a very large digital macro image — sometimes called "stacking and stitching"— is actually similar. "Stack" is derived from "focus stacking" (which combines many images taken at different focal lengths into one image with a long depth of field), and "stitch" from "image stitching" (which combines side-by-side images with overlapping fields of view into a single continuous picture). The final product has both a long depth of field through the entire subject and a high level of detail or resolution.

For practical purposes, the achievable resolution depends only on how many images you're able to combine. In this project, our goal is 100 megapixels (MP), which will require stacking and stitching about 200 images. A challenge using manual equipment, but by no means insurmountable.

STEP 1: CONFIGURE THE CAMERA

Figure out how close you can place your subject



and still focus the camera. (Most likely, you'll find the camera has the highest magnification when fully zoomed out.) Turn off all automatic exposure adjustments, and set the F-stop between 6.3 and 8. Turn on the built-in self-timer or set up a remote trigger release so you don't jostle your images pressing the shutter button.

STEP 2: POSITION THE CAMERA

Mount your camera on the bracket so that it rotates around the "nodal point" of the lens. Finding the nodal point can be a bit tricky. Check makezine.com/gigamacro for tips.

STEP 3: POSITION THE SUBJECT

Center the thing you want to photograph under the nodal point as best you can. Get the camera as close as you can and still focus, then make sure that it will not bump into the subject even when rotated to the limits of the bracket's motion.

STEP 4: LIGHT IT UP

For lighting, we recommend diffused natural daylight. For the Due image, we also added a couple of 12V LED dome lights below a translucent panel underneath the board to give some backlighting.

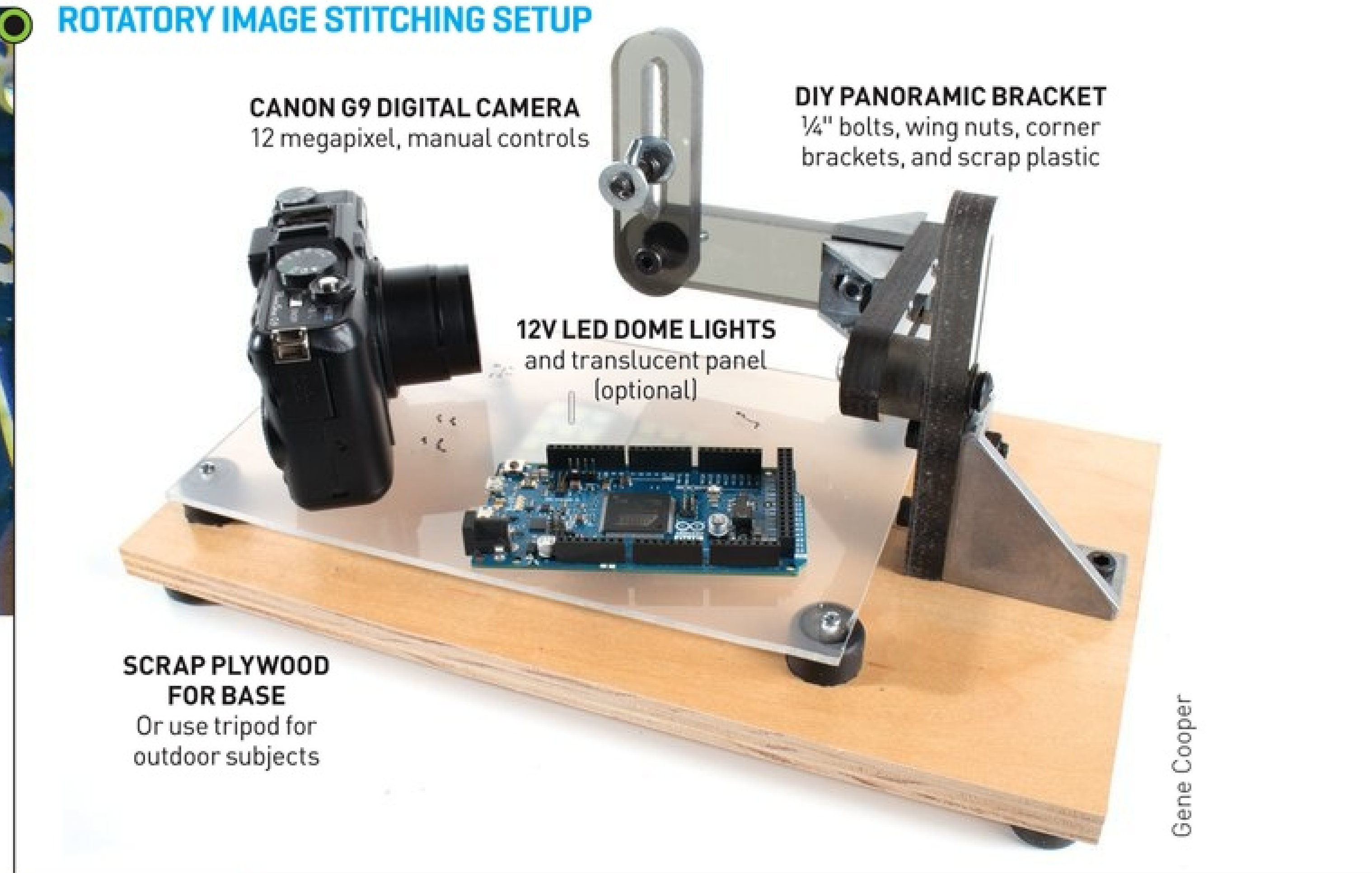
STEP 5: TAKE SOME TEST SHOTS

Before we shoot hundreds of images, let's try a sample stack to verify the focus-stacking process. Adjust the camera view to an area of the subject with lots of depth. Secure the bracket and take 8 images focused at different depths. Jump ahead to steps 7 and 8, and verify that the post-processed images look right before proceeding.

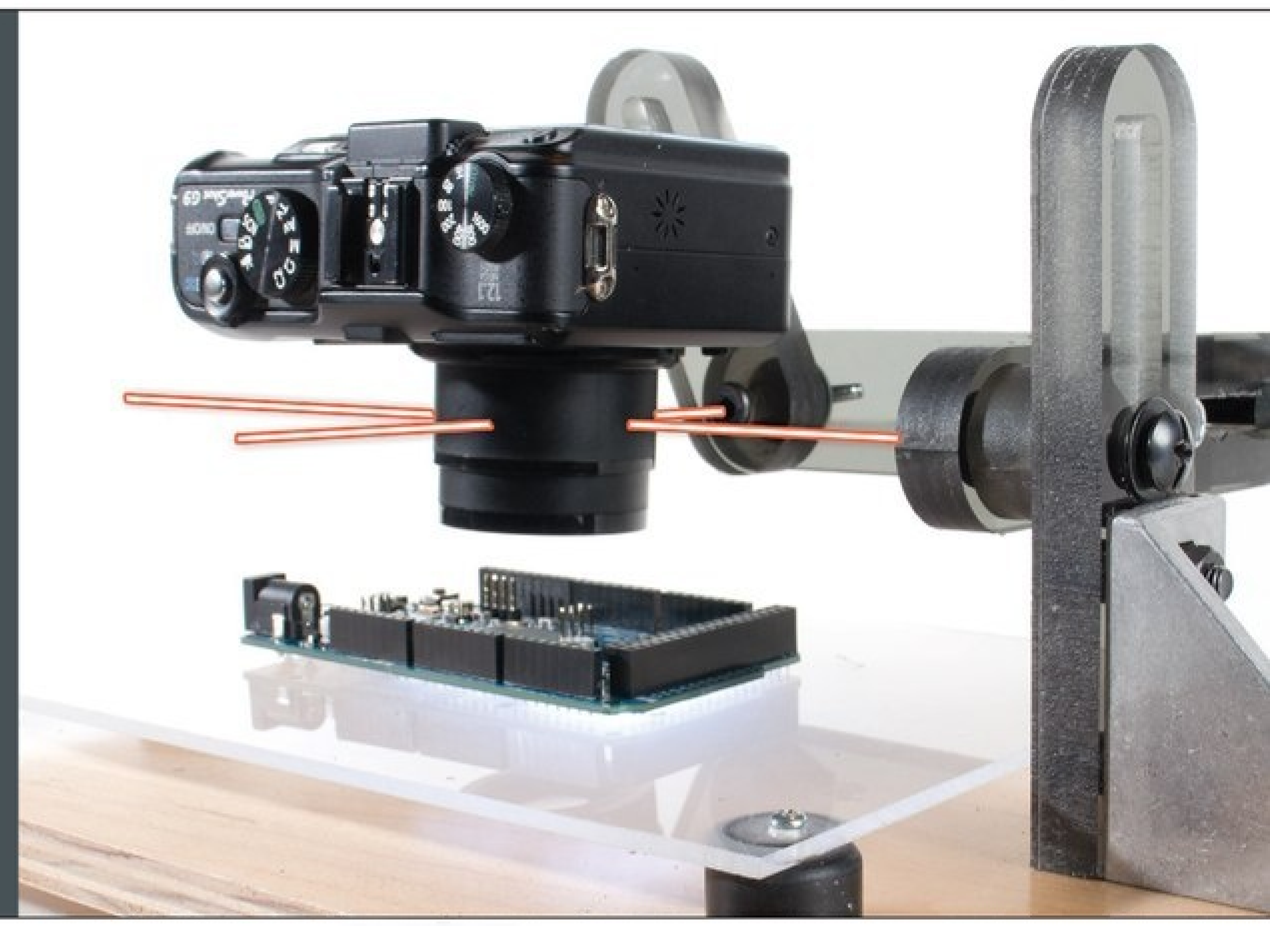
STEP 6: TAKE WORKING SHOTS

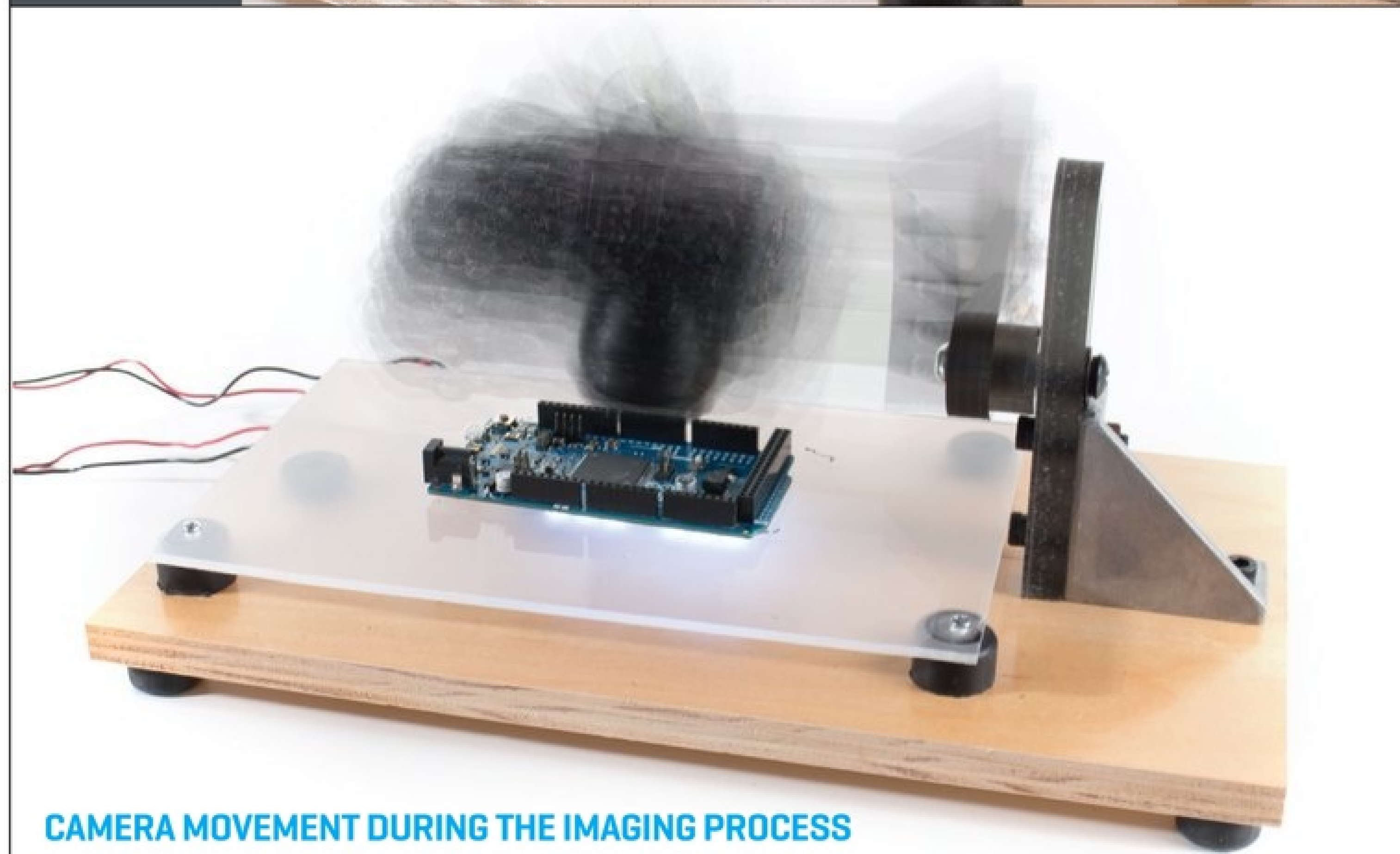
You'll be shooting anywhere from 200 to 800 photos. Be patient.

ROTATORY IMAGE STITCHING SETUP

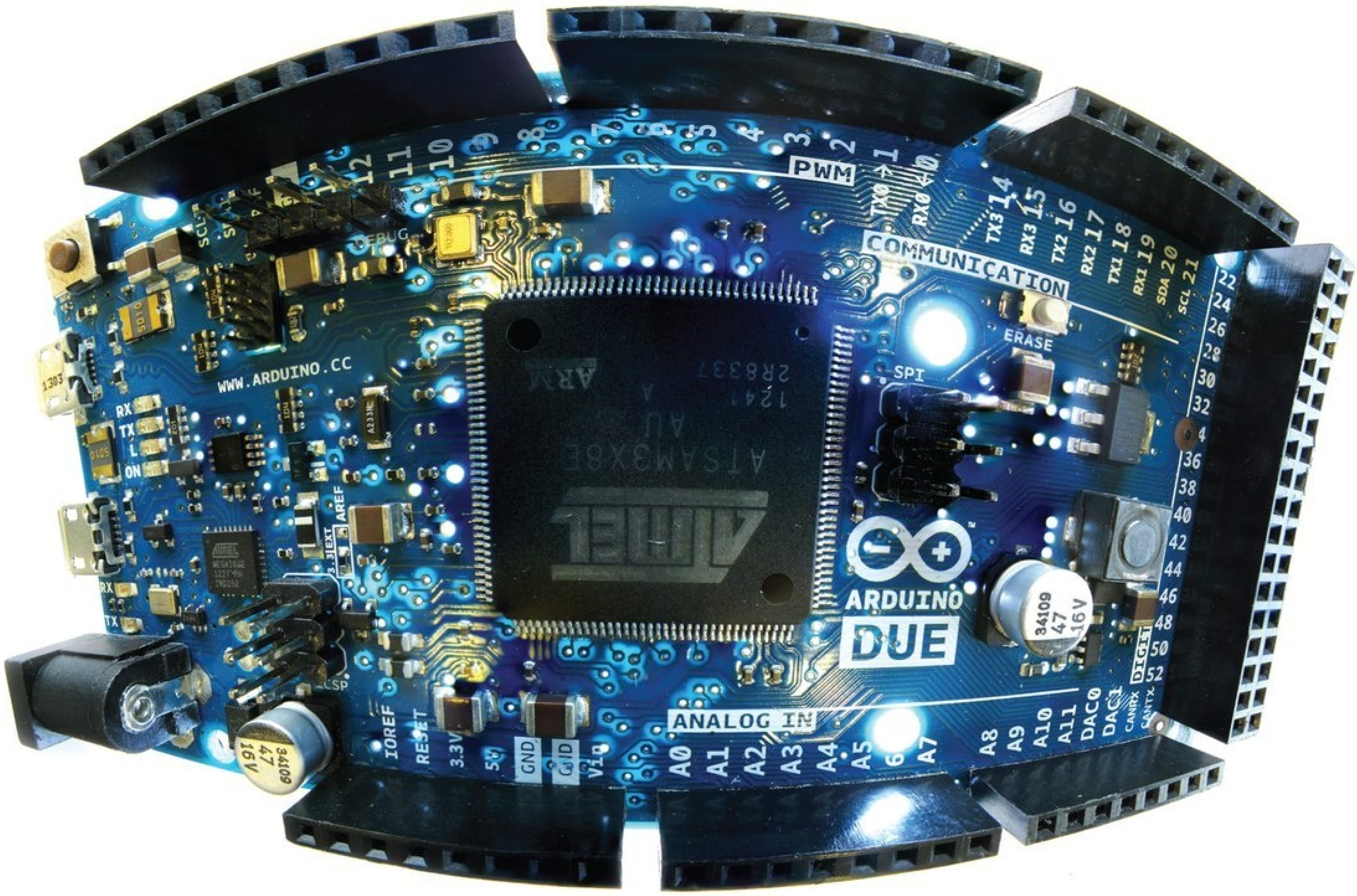


PARALLAX describes how near and far objects appear to change position when you change your field of view. It causes inaccuracies and undesirable artifacts in panoramic photos, but can be eliminated by rotating the lens about its nodal point.





CAMERA MOVEMENT DURING THE IMAGING PROCESS



The result produced by Photoshop. The spherical projection setting works well to stitch images shot by rotating the camera around a pivot point, but does not automatically correct for spherical distortion.

6a. Position the camera. It doesn't really matter where you start or where you end; all that matters is that you have complete coverage when you're done. I usually start dead center under the camera.

6b. Shoot a stack of images. Start by focusing at the nearest depth, on the features closest to the camera. Take a picture then change the focus slightly, working "deeper" into the image. How many images you take for each stack can vary between subjects and between different parts of a subject; just make sure that every feature in frame is well focused in at least one image in each stack. For the Arduino image, I shot an average of 8 images per stack.

6c. Rinse and repeat. Work your way out in a grid pattern until you've covered your entire subject. When you move the camera, shoot for 40-50% overlap from the last image. Covering the Arduino shown here required 25 stacks. It took about 30 minutes to take all the pictures.

STEP 7: FOCUS THE STACKS

Transfer the images from your camera to your computer and open Photoshop or other stacking software. For each "stack" of images taken at a particular position, the Photoshop workflow goes like this:

7a. Select File → Scripts → Load Files into Stack. Select only the photos from a single camera position. Check the "Align automatically" box. Click OK, and the files should load, each one in a separate layer.

7b. Select all layers in the Layers panel. Then select Edit → Auto-Blend Layers, and choose "Stack Images" for your blend method. Click OK.

7c. Save the stack to a PSD file. I like to name these files with column and row numbers to make them easier to keep track of.

STEP 8: STITCH 'EM TOGETHER

When you've saved the focus-stacked images from each camera position, clear your workspace and proceed as follows:

8a. Select File → Scripts → Load Files into Stack. Choose the focus stacked images you just saved and click OK. The files will load in different layers as before.

8b. Highlight all the layers in the Layers panel, then select Edit → Auto-Align Layers. Choose "Spherical" projection and check the "geometric distortion" box. Click OK, and the files will be aligned and the canvas area automatically adjusted.

8c. Highlight all the layers again, then select Edit → Auto-Blend Layers. Choose the "Panorama" blend method and click OK. Each photo will have a mask that you can edit or change if desired. When you're happy with the finished image, save in whatever format you like.

GOING FURTHER

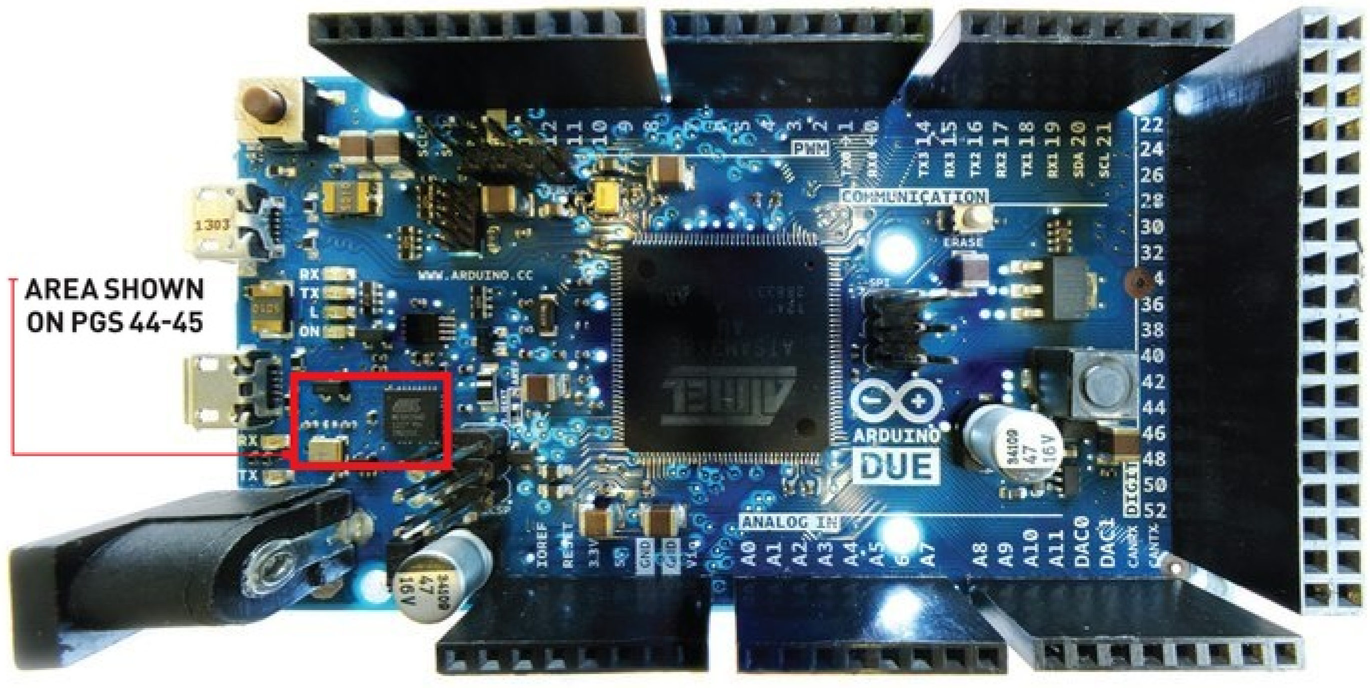
This setup works wonderfully for showing incredible details on many items — experiment with insects, flowers, and coins to reveal rarely seen aspects.

Beyond 100MP, hardware and software automation becomes a practical necessity. As magnification increases, the image count rapidly climbs into the thousands. With gigapixel macro photos my company commonly combines 25,000 or more shots into a single image. We also produce equipment to help automate shooting, including off-the-shelf and custom robots. Look for the first terapixel macro photo from us in 2014!

For advanced techniques and to share your photo closeups, visit makezine.com/gigamacro

Share it: ***#gigamacro***

The result produced by AutopanoGiga. In this instance, we used the software's automatic planar projection feature to remove spherical distortion.



Our GIGAmacro Magnify2 is specifically designed for automated capture and processing of gigapixel macro photographs.

TOP DIY PHOTO HACKS

Written by Udi Tirosh

Eight easy-bake tips 'n' tricks for pro-quality shots on a DIY budget.

A MAKER AND A PHOTOGRAPHER HAVE MORE IN COMMON THAN YOU MIGHT THINK. Many photographers build their own gear, and many makers are great photographers. There is so much creativity and innovation at the intersection of these two communities that I decided, back in 2006, to start an entire blog dedicated to chronicling them. Presented below are just a few of the cleverest, most inspiring, and most useful maker-photographer projects I've seen in my eight years at the helm of diyphotography.net.

UDI TIROSH
In 2006, fed up with his day job, Udi Tirosh decided to turn his love for photography into a career. Besides taking pictures, he began blogging about his efforts to come up with creative, low-cost DIY solutions for common photography problems. Eight years later, Udi's blog is still going strong, and has evolved into a general-purpose online photography community celebrating everything photo-related, from inspirational work right down to the hands-on technical nitty-gritty. Udi's passion for building photo equipment has also led to a sideline as a product development entrepreneur. The Bokeh Masters Kit and the Light Blaster are some of his original offerings.

For more hacks, how-to links, and example images made using this equipment, check out makezine.com/diyphotohacks

Share it: ***#diyphotohacks***

Gunther Kirsch

LASER LENS SMARTPHONE MACRO

Smartphone cameras have evolved to the point where most of us are carrying semi-pro cameras around in our pockets all the time. One area where they fall short, however, is extreme macro photography, and that's unlikely to change anytime soon due to the relatively small demand for this kind of photography among most users. But if you're a macro junkie, this easy hack, using the laser lens from an old CD or DVD player, makes it possible for your phone to capture amazing close-up details you've never seen before. Just perform a "lensectomy" on an old DVD player or optical drive, optionally mount the laser lens on a piece of cardboard for easy handing, and fix it temporarily over your phone's built-in lens with a bobby pin and/or piece of tape.

rchillphotography.com

FLASH PHOTOBOMB PROJECTOR

If you stop to think about it, a camera and a projector are basically the same thing, only in reverse. Instead of tossing your old camera, convert it into a slide projector by fixing a strobe where the back used to be. Since the projected image only exists for a fraction of a second when the flash fires, this device can be used to project backgrounds and other images into photographs that are not visible to onlookers. Equip it with an optical slave strobe (which fires when it detects the light from another flash) and you can even "photobomb" other cameras, projecting images into other people's photographs that will probably not be noticed until the pictures are examined. Use with care!

Udi Tirosh

ACE OF SPADES "FLASHCARD"

You know how all party photos look the same? Flat, pale, overexposed faces with red eyes? That's what happens when you use a direct flash. The strobe head on top of your camera is too bright and too close for close-quarters portraits. Quick 'n' easy fix: Attach a playing card to the flash with a rubber band. Most of the light bounces off ceiling and walls for softer indirect light, while a much smaller part hits the subject directly, removing eye shadows. Rotating the card back or to one side may give interesting effects, depending on your environment. Experiment!

Benny Johansson

SHAMPOO BOTTLE LENSCAP CLIP

Hand to heart, how many times have you lost a lens cap? Left it behind on a bench or on the ground? A common problem, of course, and though there are scads of lens-cap-finders and -minders on the market to combat it, this quick, eco-friendly, DIY version cut from the side of an old shampoo bottle is my personal fave. You can customize the shape to suit your style, and maybe even add a small hole at the bottom to hang your keys while you're at it.

Udi Tirosh

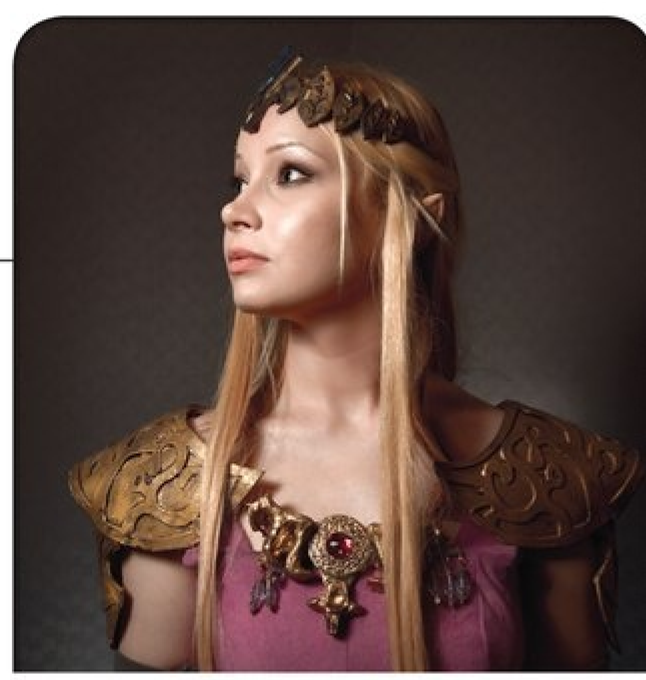
DIY BOKEH

This is probably my all-time favorite photo hack, and certainly the most popular we've ever shared on the blog. It's quick, it's easy, and it's so gratifying as to be almost magical. All you need is a piece of cardboard and a sharp hobby knife. Cut out whatever shape you want, put the cardboard over the lens, and shoot through your custom "pinhole." Any out-of-focus light in the photo will take on the shape you cut into the card.

Maciej Pietuszynski

SHOWER-HEAD TILT SHIFT LENS

Tilt-shift is a photographic effect that can be imitated in software (à la Instagram), but it is best as an in-camera effect. It creates a beautiful "miniature" feel, making full-size vistas look like small diorama or model-railroad layouts. Optically, it requires a lens that is slightly off-axis from the camera's focusing plane which — as you can imagine — is something most manufacturers strive to avoid! Since the internet tilt-shift craze, companies like Lensbaby have started providing off-the-shelf tilt-shift lenses, and though I love my Lensbaby, I will always have a soft spot for this DIY version made by mashing up a Canon "Nifty Fifty" lens, a shower head, and a heavy-duty rubber glove!



Michael Carian

TURKEY PAN BEAUTY DISH

When it comes to taking portraits the light is at least as important as the camera and lens. Bad lighting makes even the comeliest subject unpleasant to look at, and conversely, beautiful lighting can make even the ah, less well-formed among us look downright handsome. One of the most useful tools for this purpose is called, sensibly enough, a "beauty dish." Like a lot of pro-line tools, a purpose-manufactured beauty dish is pricey and can set you back as much as a couple hundred bucks. You'd be shocked how close an effect you can get from a $3 disposable turkey pan and a bit of hacking. PRO TIP: Take the turkey out of the pan before mounting it on your flash. (Maybe clean it first, too.)

Turn the page for more light painting!

Laya Gerlock

TABLET LIGHT PAINTING

Light painting — in which flashlights, sparklers, LEDs and other lights sources are used to "paint" streaks of glowing light onto long-exposure photos — could have a whole book of hacks unto itself. However, this simple trick of using a tablet or smartphone screen to create a science-fiction look for gadget or product photos remains one of my personal favorites. It gives amazing effects with very little specialized gear. After all, who doesn't have a smartphone these days? Besides the tablet or other video-enabled device, all you need is a tripod, a dark room, and a camera that can be set to take long exposures. Then you just trip the shutter and "paint" the light from the screen onto the subject by slowly walking or otherwise moving the screen around it.

LIGHT PAINTING

Written By
Jason D. Page

Dana Maltby

THE COLD CATHODE WAND

Dana Maltby has hacked cold cathode tubes — the neon light's cheaper, safer younger brother — to be battery operated for light-painting use. Building one just takes an 8×AA battery holder, a switch, and some simple tools. Swipe, slash, or wave it in the air to create colorful bands of light.

JASON D. PAGE is a light painter and founder of lightpaintingphotography.com. Jason lives and works in Tequesta, Florida, and is an avid outdoorsman who often seeks out desolate places for his work. When he is not in the woods, you may find him in the sea, surfing or free diving. He has been a photographer for 20 years.

Tips, tools, tricks, and techniques from the renaissance of long-exposure photography.

LIGHT PAINTING IS AN ART FORM CREATED BY MOVING A LIGHT SOURCE AND CAMERA IN RELATION TO ONE ANOTHER DURING A LONG EXPOSURE. Though light painting is almost as old as photography itself, it has seen an explosion in popularity since the advent of the digital camera. Modern light painters have developed a rich variety of original tools and methods to create their art. Here are just a few of my personal faves.

THE ORB

All you need is a string of battery-operated holiday lights and some duct tape. Tape 10 or so lights at the end of the string into a bunch, then tape over the remaining bulbs to block the light. To use, open the shutter of your camera and swing the lights around in a circular motion while rotating your body through 360°. You can also add colored gels for effect.

THE PERFECT CIRCLE

The tool is made from a skateboard wheel, a paint-roller handle with extender, and a crank handle bent from scrap. Just attach your cold cathode, RGB LED contraption, sparkler, or other light-emitting device. Then start the exposure, put the pole on the ground, fire up the lights, and turn the crank.

Jason Page

Dana Maltby

Andrew Whyte

Darren Pearson

THE DOME

Andrew Whyte's dome-painting rig is built from a bike wheel with an axle that extends the length of the wheel's radius on one side. Holiday lights are mounted along the rim. To use, just tip it over on the axle, start the exposure, turn on the lights, and give it a spin. The wheel rolls in a circle around the axle, and the lights on its edge trace out a beautiful dome.

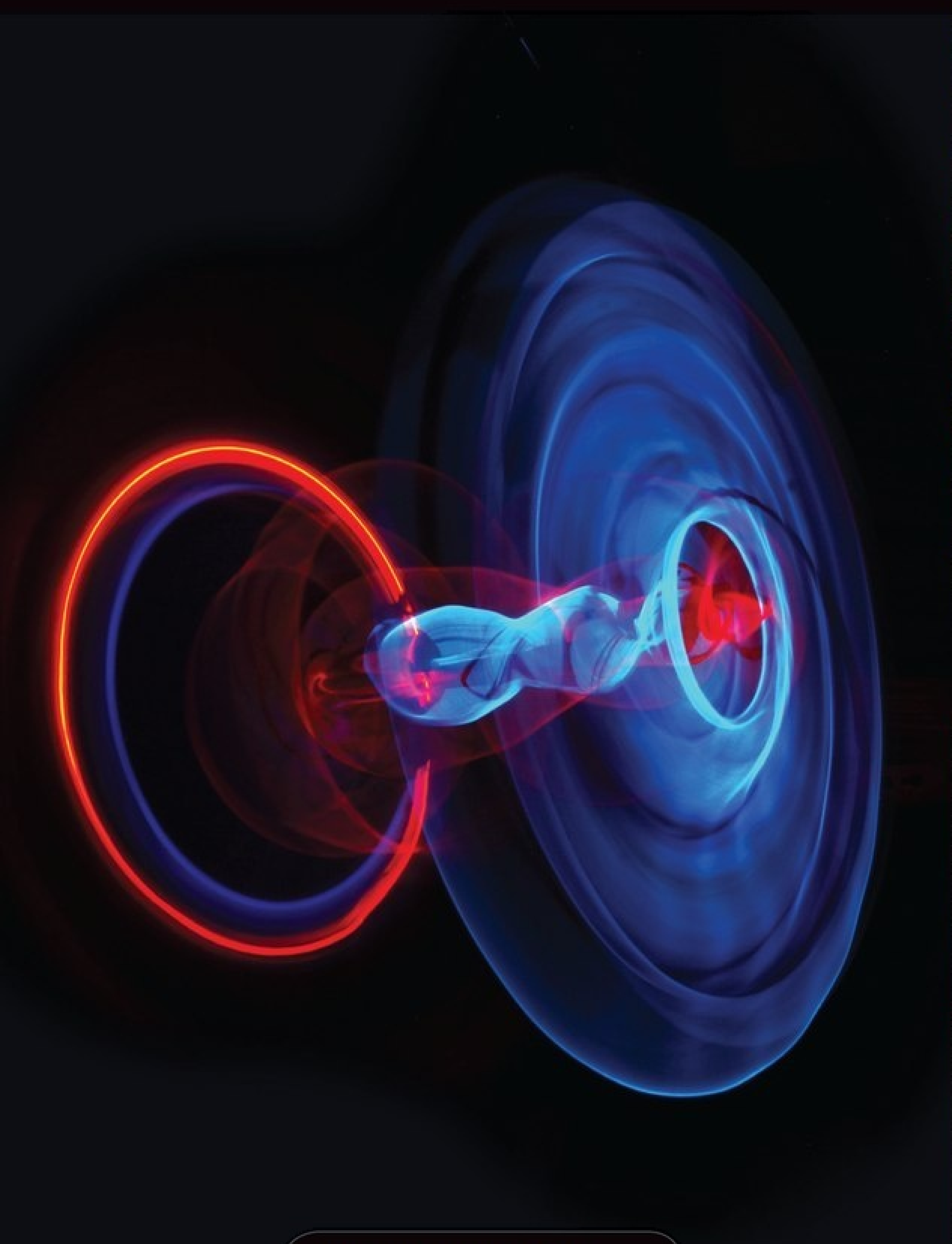
THE LIGHT PEN

Dana Maltby's light pens are made from holiday lights, batteries, lots of tape, and some simple on/off switches. Using one is as simple as pointing it at the camera lens and drawing in the air. Renowned light painter Darren Pearson has used Maltby's light pens to create everything from skateboarding skeletons to electric dinosaurs.

EL WIRE

Though artist Wes Whaley has so far been close-mouthed about the details of this tool (a tutorial is "in the works"), it's known that he uses carefully shaped pieces of electroluminescent (EL) wire to punctuate conventional spinning arcs with angular, highly geometric patterns.

Wes Whaley



THE LIGHT LATHE

Patrick Scherer uses a handheld electric drill to drive his rig, which consists of a photo light stand, a black emitter mount, and a generous serving of duct tape. Turn on the lights, open the shutter, and slowly spin up the drill. The lighting elements, whatever they are, should have some flex, so that centrifugal force will cause them to bend outward as the drill speed increases.

Patrick Scherer

THE LIGHT STENCIL

This hack by Trevor Williams works on the same principle as the flash projector (*see page 50*). Tape scrap cardboard into a pyramid, then mount the flash at the narrow end and your stencil at the wide end. Stand in-frame and fire the flash to project images directly into the camera, or stand out-of-frame and project onto a surface in your scene.

Trevor Williams

Barry Elder

THE FIRE WALL

Not for the careless or faint of heart, this method from Barry Elder yields stunning results. You'll need fuel, a rope or strap, a long fireproof pole, a lighter, a wet towel, and an assistant (or two). Be sure to have a fire extinguisher handy. Hang the rope from the pole, dip it in the fuel, ignite it, then open the shutter and walk along the path where you want the wall to appear. Then carefully extinguish the flame.

Dan Whitaker

THE DIGITAL WAND

Unlike the other "analog" tools on this page, this is a full-featured programmable RGB LED light wand, built around an Arduino with an SD card shield and a small LCD readout so you can load your images and go. Once you start your exposure, all you have to do is move the LED wand at a more-or-less even pace; the microcontroller takes care of the rest.

+ For tutorial links and more work from these amazing light painters, check out makezine.com/light-painting.

BROWNIE PAN LED LIGHT PANEL

Roll your own for a fraction of the cost of pro units.

Written and photographed by Tyler Winegarner

Time Required: 4-6 Hours
Cost: $70-$100

Hack LED strips with a better dimmer and save hundreds.

TYLER WINEGARNER is a filmmaker and photographer based in San Francisco. When he's not busy shooting, he's down in his shop grinding, soldering, or hacking at his next project. Follow him at @the_real_tylerw.

OPINIONS ARE MIXED ON LED LIGHTING UNITS, BUT ANYONE WHO HAS EVER DONE LOCATION WORK CAN'T DENY THEIR UTILITY — they're lightweight, they have very low power draw, and they generate very little heat. They're an excellent tool to have in a one-man band style of shooting. They're also expensive. But now, with the proliferation of LED lighting kits for home use, you can build a very good equivalent to $500 off-the-shelf products for under $100. It even looks good — and that might be handy, depending on who your clients are.

At the core of this project is the adhesive-mounted strand of LED lights. These are usually sold in kits with an external power supply and an inline dimmer. Unfortunately this dimmer operates at a relatively slow cycle — it looks steady to your eyes, but in camera you'll see the flicker. So we'll be using the guts of a better, external dimmer to get the results we need.

There's a lot of soldering in this build, but none of it is very tough, so it's a good project to help you build your skills.

1. CUT THE PANELS

Cut the plexiglass and corrugated plastic to size. Drill a ¼" mounting hole in each corner of the corrugated panel, ½" inward from the edges.

2. PREPARE THE HOUSING

Using the holes drilled in the corrugated panel as your guide, mark and drill four corresponding

¼" holes on the back of the baking tin, starting with the 1/16" bit for a pilot hole.

In the bottom of the long edge of the housing, drill 3 additional holes: one ¼" hole in the center for the mounting hardware, and about 2" away, 7/16" and 5/16" holes for the DC jack and the dimmer knob. Keeping the jack close to the mounting hardware will make cable management easier when using the light.

Use your grinding wheel to roughen the metal (and remove any teflon coating for better adhesion) around the inside of the ¼" center hole.

If your pan is teflon coated, also remove about a 1"×2½" patch of teflon roughly 2" above the holes for the DC jack and dimmer knob.

3. MOUNT THE INTERNAL THREADING

Use the grinding wheel to score one side of a ¼-20 nut. Use epoxy to bond the nut to the inside of the housing, centered on the ¼" center hole. Let the epoxy set.

4. CUT AND SOLDER THE LED SEGMENTS

You can only cut the LED strip at the marked areas, which appear every 3 lights. Starting with the end that has the loose wires, cut fourteen 10" segments.

Cut fourteen 2"–3" segments of speaker wire, and split and strip each end.

Now use the wire segments to solder all the LED segments back together. I find the best technique is to melt a small dot of solder onto each terminal of the LED segment, and then heat up that solder while poking the wire end into it. Connect all the LED segments end to end, making sure you don't cross up the positive and negative terminals.

Use a voltmeter to verify continuity.

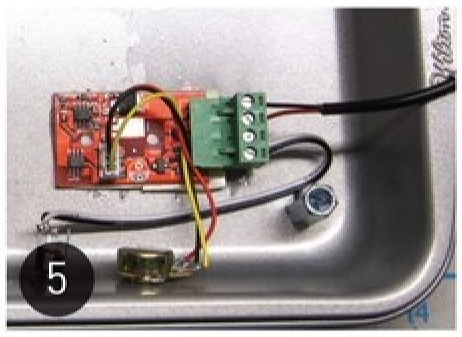
5. MOUNT THE DIMMER AND JACK

Disassemble the PWM dimmer and remove the PCB and potentiometer. Use double-sided foam tape to mount the PCB to the inside of the housing, on the patch you prepared.


3

TIP: To get a better bond, you can use the stud from the ballhead to hold the nut in place while the epoxy dries — but you may end up permanently fusing the ballhead to the housing.


4


5


6

Use a 3"–5" length of speaker wire to connect the DC jack to the input terminals on the dimmer PCB, following the manufacturer's instructions for both. Connect the positive and negative wires from the first LED segment into the output terminals of the dimmer PCB.

Mount the DC jack and dimmer potentiometer into their holes. Connect your DC jack to power and check your circuit to make sure everything lights up and dims when you twist the potentiometer.

6. MOUNT THE LED PANEL

Mount the corrugated plastic panel to the housing by fitting the Allen screws and washers into the coupling nuts.

Peel the adhesive backing from your first LED segment and mount it to the corrugated panel just above the washers. Mount each consecutive segment in the same way, zig-zagging your way up the panel.

Check your circuit again, and resolder as needed.

7. MOUNT THE COVER PANEL

Use the original holes at the ends of the baking pan to mark the plexiglass. Drill ¼" holes at your marks, then mount the plexiglass cover to the front of the housing using the remaining Allen screws, washers, and nuts.

If you have access to a bandsaw, you can cut the plexiglass to match the shape of the baking pan.

Use the grinding wheel to carefully clean up any rough edges. You're done!

USE IT

You can use the threaded hole on the ballhead to mount to any ¼" tripod stud, or use the shoe adapter included with the ballhead to mount to any shoe mount.

Because the LEDs generate little heat, you can use household items like baking parchment to diffuse the light. Binder clips can be used to attach diffusion material or gels to the outside of the housing.

There's a lot of variation you can do with this project, from panel size to color temp to lots of other configurations. Happy shooting!

Materials

- **Baking tin, 11"×7"** with holes in the rim, such as Wilton #2105-960
- **Clear plexiglass, 12½"×8"**
- **Corrugated plastic, white, 6"×10"** aka Coroplast
- **LED strip, 5 meters long, self-adhesive** I'm using a 600-LED, daylight balanced, non-weatherproof model, Amazon #B005ST2I9O.
- **PWM Dimming Controller, for LED lights** Amazon #B007V1B0W8
- **Power supply, 12V 3A DC, with size M plug** Amazon #B00BPCL0MY
- **Coaxial DC power jack, size M, panel mount** RadioShack #274-1563
- **Speaker wire, 2-conductor, 22 gauge, braided, 36"–48" length**
- **Tripod ball head** with ¼" threaded hole on the bottom and ¼" stud at the top
- **Nuts, ¼-20 (3)**
- **Nylon washers, ¼" ID (6)**
- **Cap head Allen screws, ¼-20, ½" long (6)**
- **Double-sided foam tape**
- **Coupling nuts, ¼-20, 1" long (4)**
- **Machine screws, ¼-20, ½" long (4)**

Tools

- **Electric drill with drill bits: 1/16", ¼", 5/16", and 7/16"**
- **Grinding wheel for drill** or Dremel with grinding wheel
- **Soldering iron**
- **Wire cutter / stripper**
- **Masking or painter's tape**
- **Utility knife**
- **Voltmeter / continuity tester**
- **Bandsaw (optional)**

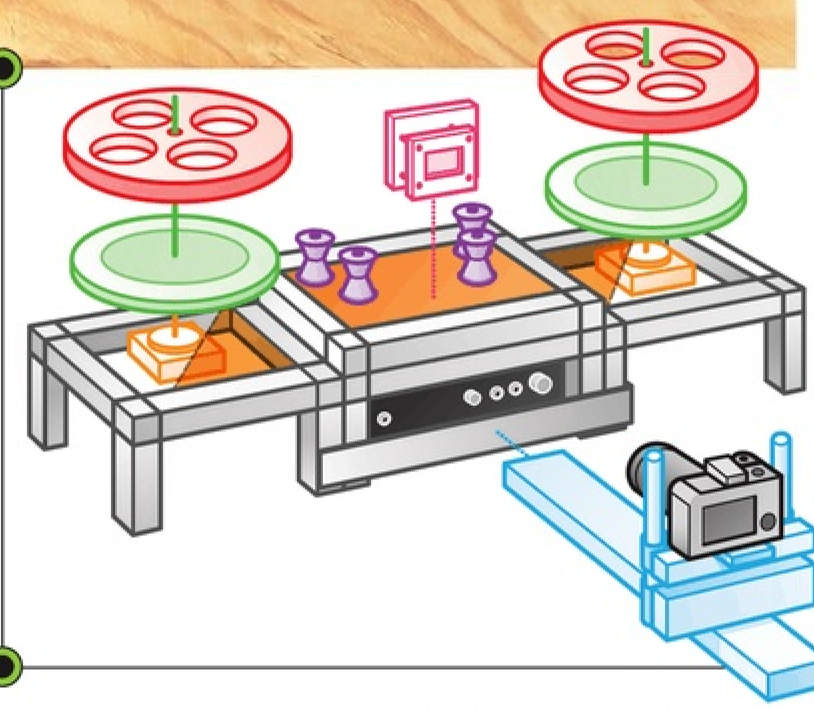
For full instructions and photos, go to makezine.com/brownie-pan-led-light-panel

Matthew Epler

THE KINOGRAPH

An open-source negative scanner for digitizing film.

Written by Matthew Epler



Damien Scogin

MATTHEW EPLER is a creative technologist in Brooklyn, NY. His work has been featured in the Milan Triennale Museum of Design and on *Wired, Huffington Post, Newsweek, Reuters, Boing Boing, Vice, The Creators Project, Creative Applications,* the Processing home site, the Raspberry Pi home site, and many more.

PRO TIP:

When negotiating with a king, always add a zero.

I WAS TEACHING FILM HISTORY IN JORDAN WHEN I FOUND A GARAGE FULL OF OLD FILM CANS HEADED FOR THE TRASH. There was some curiosity about what was on them, but not really time or resources to figure it out. This is how most films are lost forever. I photographed the label and the first few images of nearly 100 reels with a point-and-shoot and a hastily-built light box.

Then I waited.

Months later, HM King Abdullah II visited our school, and I showed him a frame from one of the prints featuring his late father, the highly respected HM King Hussein, deplaning in Moscow during a royal visit in the 1970s.

He looked at me and asked "How much?"

I asked for $10,000. He agreed without blinking and walked away.

I was able to digitize just 10 of the 850 reels with that money. To digitize the whole lot, at that rate, would take $750K. Commercial digitizers were proprietary machines the size of refrigerators, averaging $250K. I needed a fast, cheap, portable, digitizer built entirely from parts that could be purchased online and shipped internationally.

Enter the Kinograph. The prototype was developed as my thesis project at NYU's Interactive Telecommunications Program. It's controlled by Arduino and Processing, and uses a DSLR for capturing frames. The total cost, with camera, came to just over $3,000.

There are plenty of areas for improvement and I'm now working with the open-source community to make Kinograph, and the whole process of digitizing film, easier and more affordable. We are running out of time before the remaining films decay beyond repair. While we still can, it's important that we get all hands on deck to help conserve our shared visual heritage.

For plans, pictures, and more information about Kinograph and the Jordanian film project, check out makezine.com/kinograph.

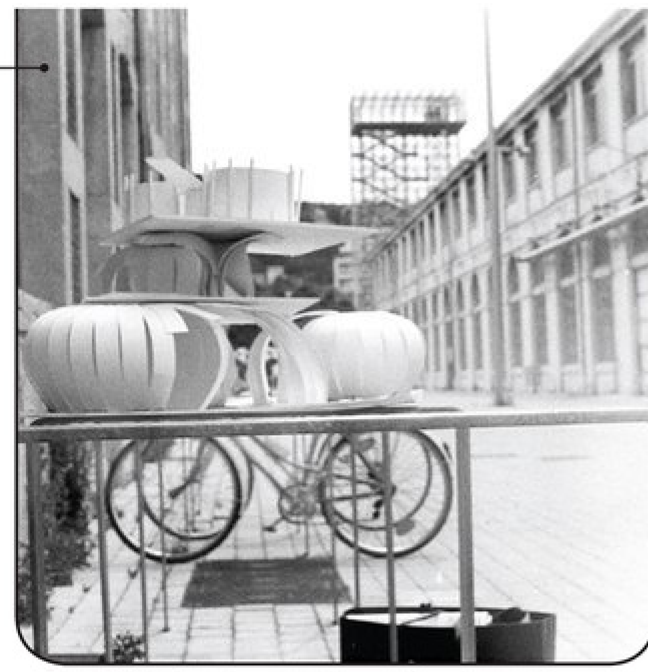
FIVE FULLY FUNCTIONAL 3D-PRINTED CAMERAS

Written by Anna Kaziunas France

Ranging from pinhole to digital, these cameras are all printable on desktop machines.

OPENREFLEX

Winner of numerous awards, the OpenReflex by Léo Marius is an analog camera with a mirror viewfinder and a finger-activated mechanical shutter that captures at approximately 1⁄60 of a second. Parts are separate files to simplify modifications, and print time is approximately 15 hours with under an hour of assembly. Download the files from Thingiverse (thingiverse.com/thing:113865) and find assembly instructions at makezine.com/openreflex.



Léo Marius

P6*6 120 PINHOLE CAMERA

Another design by Todd Schlemmer, the P6*6 120 pinhole camera has a 6×6cm frame, shoots medium-format 120 film and is well documented with a detailed assembly and usage guide. The body features a knurled film advancing knob. Community members have modified the camera to use neutral-density filters, allowing for the slower exposures that pinhole cameras like best. Download from Thingiverse (thing:157844) or purchase on Tindie (tindie.com/stores/schlem).

Todd Schlemmer

"sss860149"

PINHOLE135 CAMERA MINI

This small pinhole camera was the first 3D-printed design for Thingiverse user "sss860149." With a pinhole size of about 0.2–0.3mm, it has an 84° angle of view, a 24mm focal length, and shoots full-sized 4×6 "round image format" photos on standard 135mm film. The files are freely available for download from Thingiverse (thing:181764).

Todd Schlemmer

PINH5AD 4×5-INCH PINHOLE CAMERA

Todd Schlemmer created three different printable cameras and actively posts photos to his 3D Printed Cameras Flickr group. PINH5AD is designed around a 4×5 film holder and comes in both 90mm and 150mm focal lengths. It uses the "Pinhead shutter design" developed for Todd's first design, the PINHE4D. Files and instructions are on Thingiverse (thing:143882) or parts can be purchased from Shapeways (shpws.me/p7v5).

Randy Sarafan

3D-PRINTED DIGITAL CAMERA

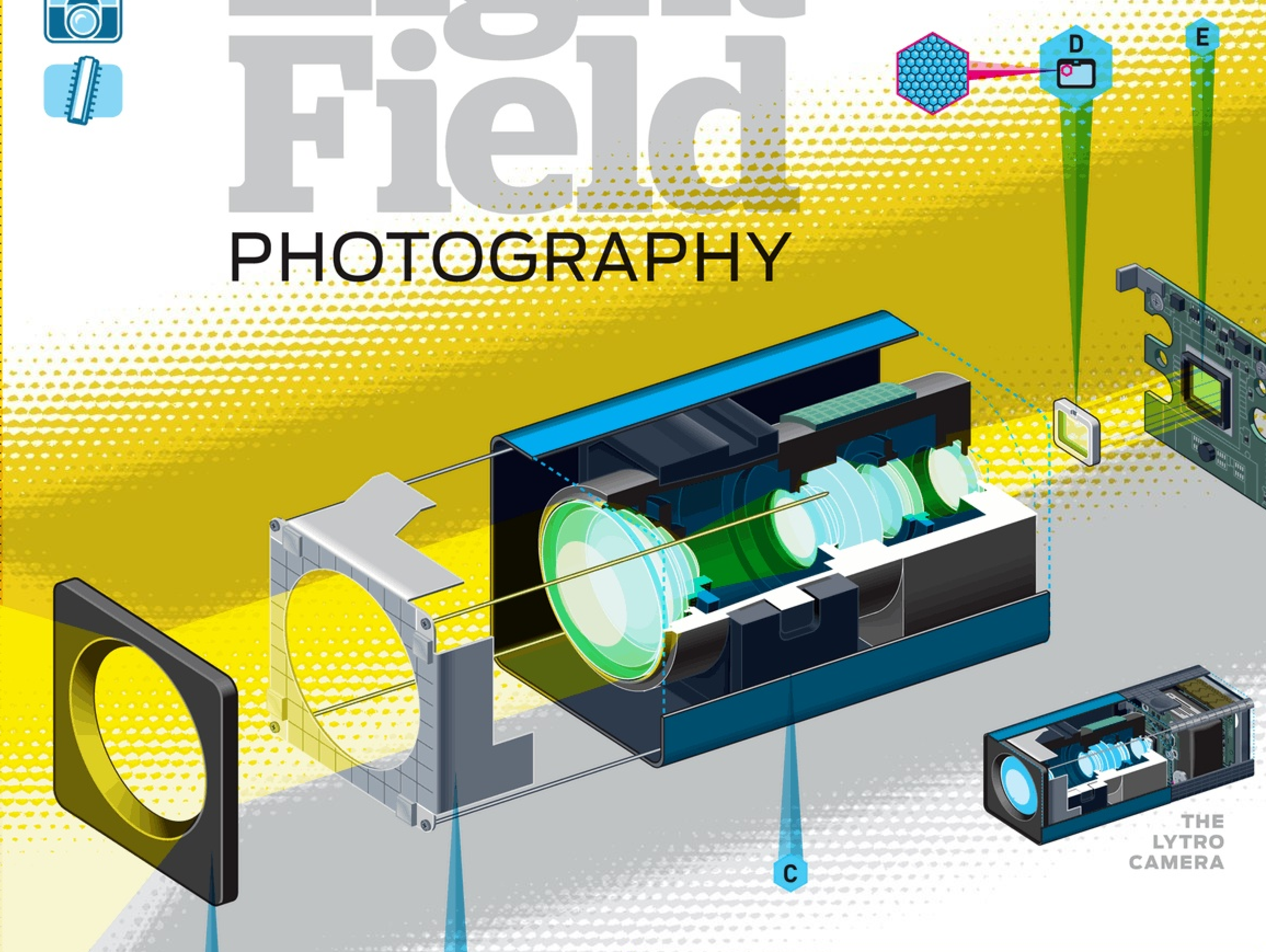
Randy Sarafan, author of *62 Projects to Make with a Dead Computer* and creator of *Simple Bots*, designed a digital camera with an Arduino, RadioShack JPEG Color Camera Board, Seeed Studio INT106D1P SD shield, and a few additional parts, all available from RadioShack. Pictures are easily transferred via SD card. Get the parts and instructions at makezine.com/3dpdigitalcamera.

SKILL BUILDER+

Learning new tricks every issue
Tell us what you want to learn about: *editor@makezine.com*

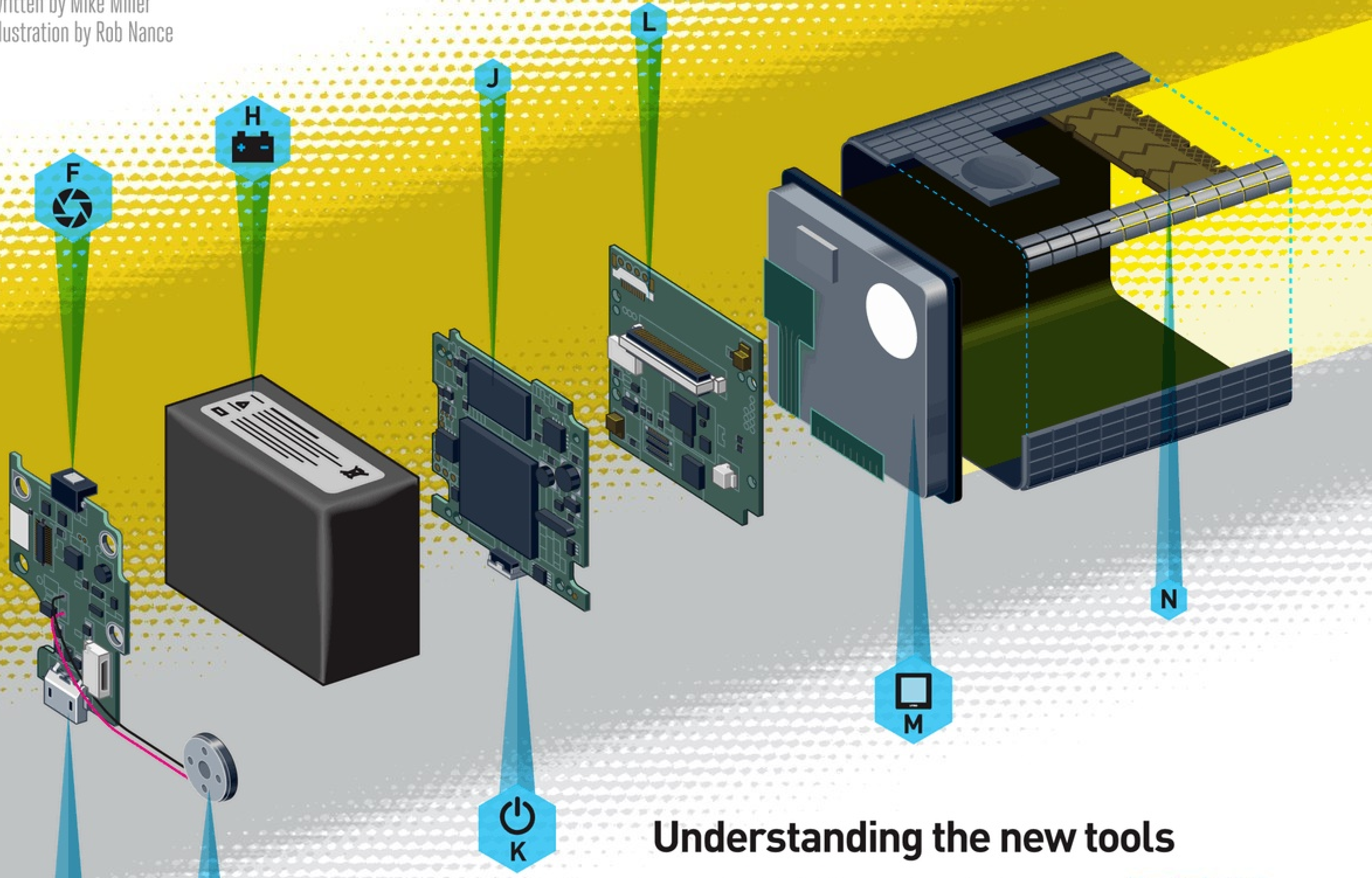
MODERATE

Light Field PHOTOGRAPHY



LYTRO IMAGES can be refocused in software at any depth, even infinity. It is also possible to shift perspective, and output stereographic 3D image pairs.

Written by Mike Miller
Illustration by Rob Nance



A FRONT BEZEL
With 1.1" lens opening.

B LENS RETAINER

C LENS ASSEMBLY
With 8x optical zoom and anodized aluminum housing. Because images can be focused in software, no focus adjustment is required. Aperture is fixed at f/2.

D MICRO-LENS ARRAY
Over 100,000 individual microlenses divide the underlying sensor into approximately 10×10 "pixel" regions. (In the context of light-field photography, "pixel" is not strictly accurate and "ray" is often substituted.) The microlenses have a very short focal length; the array is positioned a scant 0.001" above the sensor.

E CMOS IMAGE SENSOR
Light-sensing semiconductor device with 3,280 rows and 3,280 columns of active sensor elements. In a conventional camera, this would be an 11 megapixel sensor; here, the correct term is *megaray*. Because many rays are recorded for each microlens, the maximum output resolution is considerably lower (1,080×1,080 or about 1.2MP in conventional terms).

F SHUTTER BUTTON
The camera has no need to focus, so there's almost zero shutter delay.

G MICRO-USB PORT
For charging and image transfer.

H BATTERY
Lithium-ion chemistry, 3.7V, 2,100mAh, 7.77Wh.

I PIEZO BUZZER

J MAINBOARD/MEMORY
Zoran camera-on-a-chip processor with 8GB or 16GB Samsung NAND flash non-volatile image storage. The basic model costs $400 and stores 350 of Lytro's "living picture" LFP files. The 16GB model costs $100 more and stores 750 pictures.

K POWER SWITCH

L DISPLAY / WI-FI BOARD
A 2011 FCC Lytro teardown revealed a Marvell system-on-a-chip with onboard Bluetooth and wi-fi support, which was not implemented at the time. Lytro's firmware has since been upgraded to enable wireless picture transfer, firmware updates, and full-screen TV presentation via the Lytro Mobile iPhone app.

M DISPLAY
1.5" square backlit LCD with glass touchscreen overlay. Memory and settings are accessed via on-screen touch controls.

N ZOOM SLIDER

Understanding the new tools

The *light field* is a mathematical concept describing all the light rays in a region of space. Devices that capture some part of the light field exist in many forms. Pricey research-grade *plenoptic cameras* have been available to scientists for some time, but the Lytro, shown here, is the first consumer offering.

Conventional cameras capture a scene from just one point of view, and though software lets us do amazing things with these pictures, no amount of post-processing can increase the information captured by the hardware. The great promise of *light-field photography* is the ability to capture not just more information about a scene, but more kinds of information: color, intensity, direction, and distance. Access to these new data types opens up post-processing options that are impossible with traditional cameras: software refocusing, perspective shifting, and even 3D scanning.

Explore Lytro images and learn more about how light-field photos work at makezine.com/lytro

Share it: #lightfieldphoto

MIKE MILLER
is a writer and IT professional who lives in the San Francisco Bay Area with his wife. His eclectic interests include building and playing acoustic stringed instruments, running, business theory, and technology.

10 Tips for Making Great Build Videos

Written by Becky Stern

EASY

1. Your light is more important than your camera

Shoot near a window (but out of direct sunlight) during daylight hours. Fill from the complementary angle with a daylight-balanced softbox or clip lights diffused with tracing paper. If you're a night owl, you'll need a lot more lights.

2. Use a tripod

A cheap tripod is better than no tripod; for years I used a $15 Sunpak with no complaints. Some fancier models cantilever over your bench, or if your bench is sturdy you can use a clamp-on articulated arm, like my Manfrotto Magic Arm and Super Clamp.

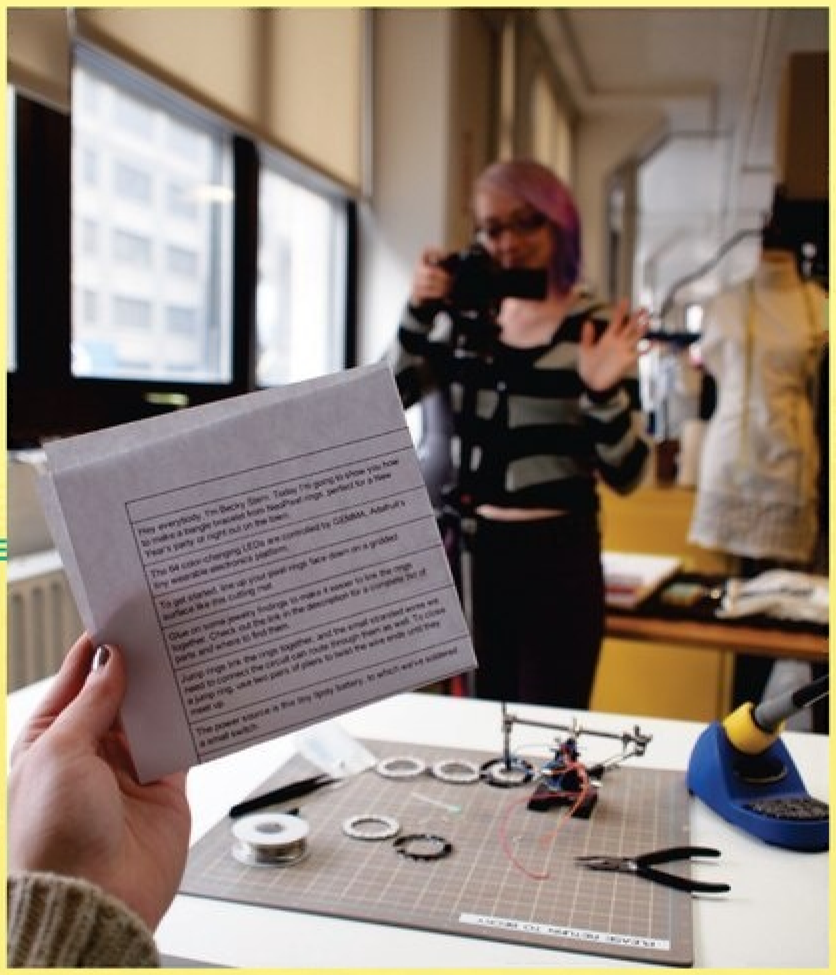
3. Shoot while building. Always

It's better to have too much footage than too little, and the more time you spend working in front of the camera, the more relaxed and natural your movements will be. I'm so used to working with my Magic Arm clamped in front of me that it feels weird to make stuff without it.

4. Clean your bench

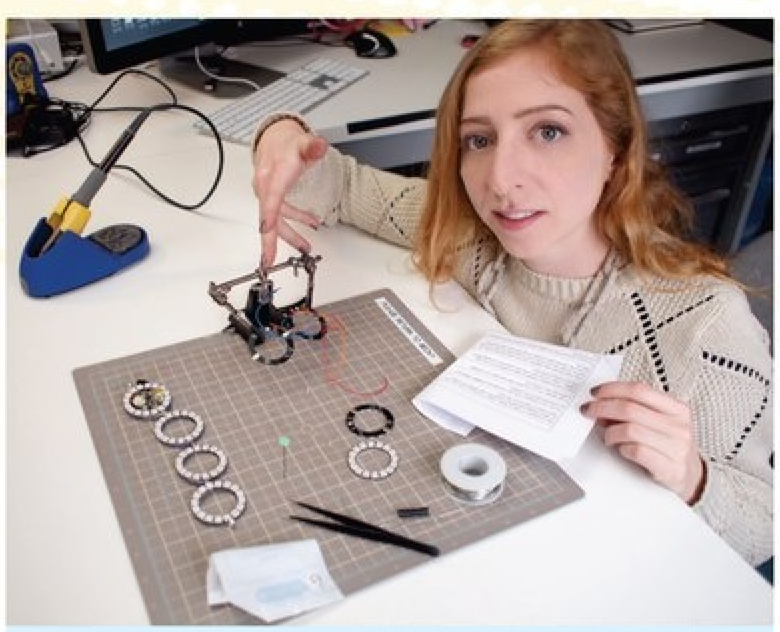
Clutter distracts viewers from the important details, so put away anything that's not necessary for the shoot.

BECKY STERN (sternlab.org) is a DIY guru and Director of Wearable Electronics at Adafruit. She publishes a new project video every week and hosts a live show on YouTube. She lives in Brooklyn, NY and belongs to art groups Free Art & Technology ("release early, often, and with rap music") and Madagascar Institute ("fear is never boring").



5. Write a script

Describe your project as if speaking to a knowledgeable friend. Write down everything you want to include, then prioritize and edit hard. Leave only the most important bits, and save the rest for the description or blog post. Show and/or tell the viewer what the video is about within the first 15 seconds. Read through your entire script at a natural pace. Under 5 minutes? Fabulous. Under 90 seconds? Even better.



6. Talk to the camera

Look directly into the lens, not at the screen. If you have a friend running the camera, ask her or him to look through the viewfinder and not make eye contact while shooting. It's OK to look at your project, but always come back to the camera lens to maintain an engaging connection with the viewer.

T Main for Adafruit

7. Record voice-overs

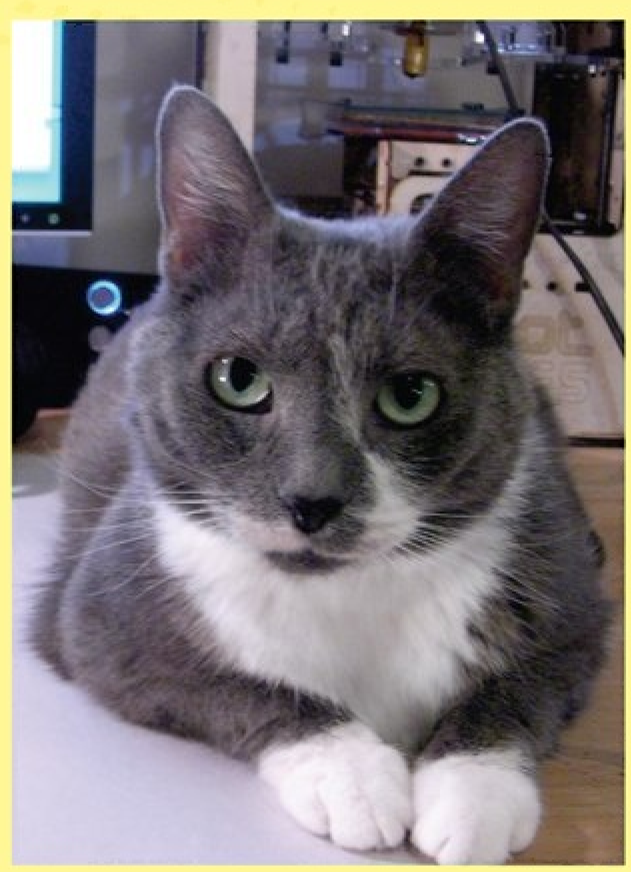
Find a comfortable and quiet place to record. A closet full of clothes makes a great sound-dampening mini-studio; even an iPhone in a parked car can record very clean sound. Drink plenty of water, sit up straight, smile like a complete buffoon, and project from your diaphragm. Keep smiling as you record — it makes the resulting audio much brighter and more engaging.

8. Edit obsessively

Get the video editing software that's easiest for you to learn and use. Go through your script and arrange the best takes of each line on your timeline, and sprinkle liberally with b-roll. Show some "hero shots" early on to entice your viewer to keep watching. Watch your video over and over; adjusting pacing, clip start/end points, audio levels, and color where applicable.

9. Publish relentlessly

Put your video on one or more of your favorite video sharing sites like YouTube and Vimeo. Don't slack off when it comes to title, tags, and descriptions. Share it with your followers on Twitter, Facebook, Google+, and Tumblr. Email it to your friends, then share it with topical forums and blogs. Look for submission forms or "tips@" email addresses to the editors. Write a polite and brief description of your project/video, paste the link, and suggest that his/her readers might like it. Check out the YouTube playbook (youtube.com/playbook) for more tips on engaging and growing your online video audience.



10. When in doubt, add a cat

Your videos, if you make them often enough, will improve over time. And remember: When in doubt, add footage of the project with a cat — everybody likes cat videos!

For more tips from Becky, and to check out some of her amazing projects (and amazing videos) visit makezine.com/beckystips.

Share it: #beckystips

PHOTOGRAPHING Small Objects

EASY

Get beautiful macro shots and easily crop out and adjust backgrounds using this inexpensive hardware and software setup. Written by Charles Platt

If you're selling something on eBay, or documenting a craft project, or photographing valuables for insurance purposes, you'll want it to look as good as possible. For my forthcoming book *Make: More Electronics* (the sequel to *Make: Electronics*), I wanted especially clean photos. This entails controlling two primary variables: lighting and background. In addition, you may want to include a grid that shows the scale.

I addressed the issue of lighting in "LED Photo Lights" back in MAKE Volume 34 (makezine.com/miniature-led-photo-lights), but controlling the background is trickier. With Photoshop you can select the object and remove it from the original background, but this is a time-consuming chore — even using plugins that claim to make it easy.

A workaround is very simple. Since you're dealing with an inanimate object, it will sit there while you make a second exposure, exactly aligned with the first, and optimized to make selection easier. In other words, you make a silhouette.

1. Dual Exposures

1.1 With your camera on a tripod, and a remote shutter release, make a couple of test exposures before fixing the exposure manually to take your final picture of your object and background.

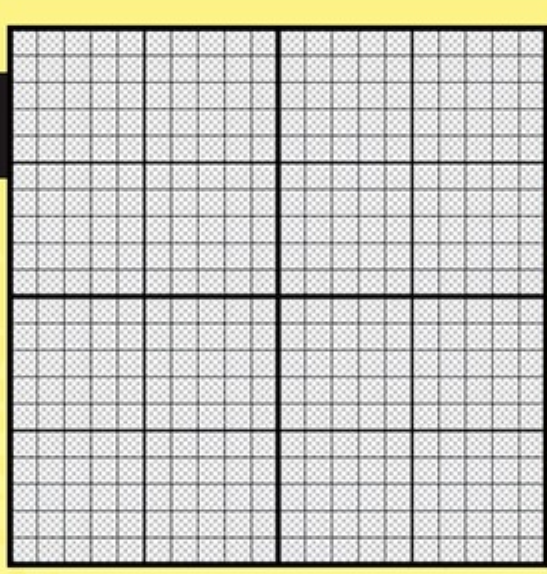
1.2 Substitute a sheet of white paper under the glass, ideally framed with black paper to suppress any white glare.

1.3 Switch off all your lights except one, and angle it down about 45° so that the white background is fully lit.

1.4 Shade the object with a piece of card to darken it while you take your second picture. Because the exposure was set manually, the camera won't try to compensate for the bright white background by dimming it.

1.5 If you want to add a grid, remove the object and substitute a sheet of graph paper on top of the glass. Take a picture of that, and the photography phase is complete.

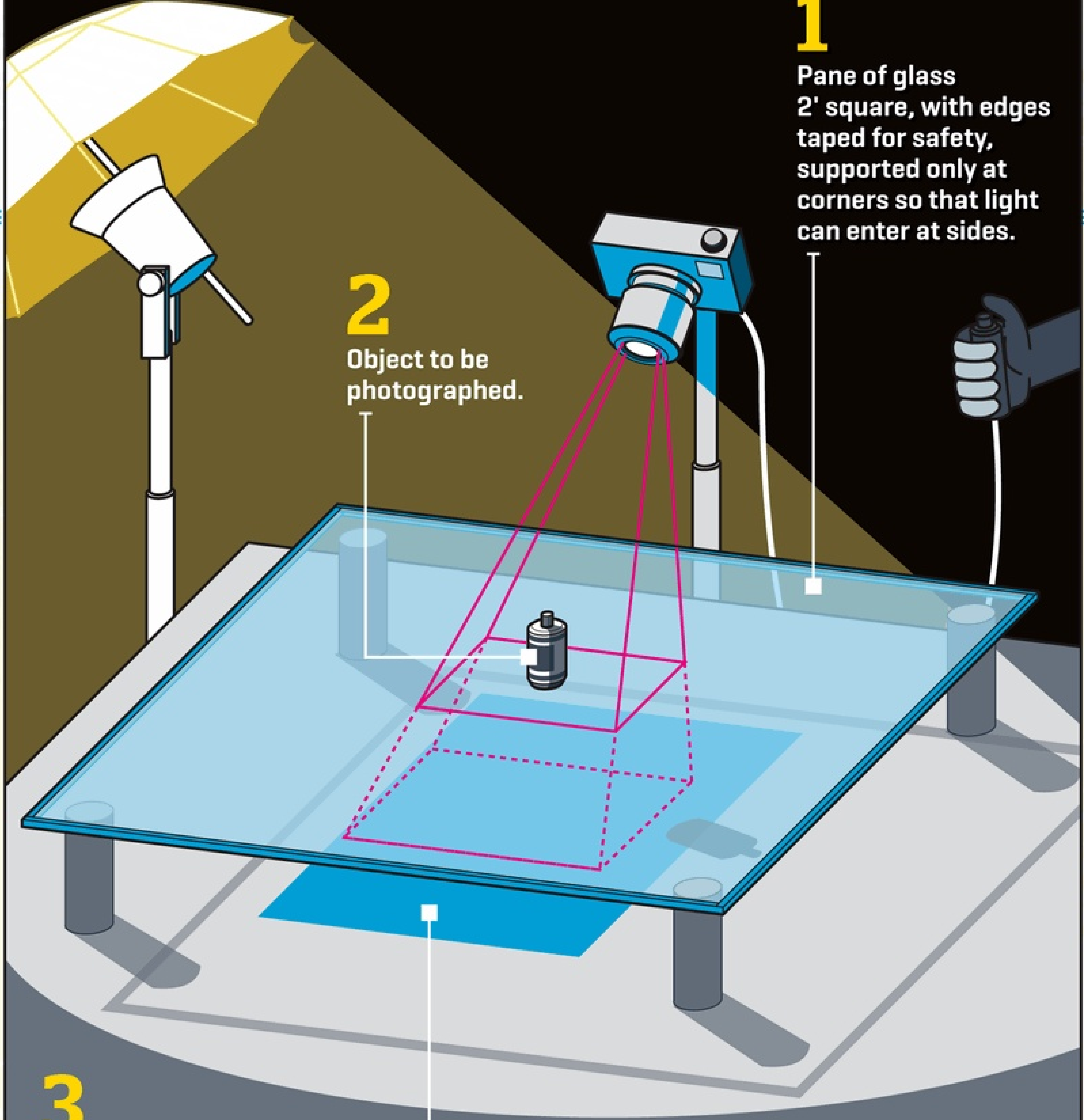
NOTE: AVOID TOUCHING THE CAMERA OR THE TABLE BETWEEN STEPS 1.2 AND 1.5. ANY MOVEMENT WILL PREVENT YOUR TWO PICTURES FROM ALIGNING PROPERLY.



THE VIRTUAL GRID

To get a really sharp, clean effect you need to make a "virtual" grid that is purely digital. I created mine with a drawing program and saved it with a transparent background. When I open it in Photoshop it looks like this, with a checkerboard pattern identifying the transparent areas. Incidentally, my version of Photoshop is ancient — version 6.0, cheaply available on eBay. You don't need the current version to perform the procedures here.

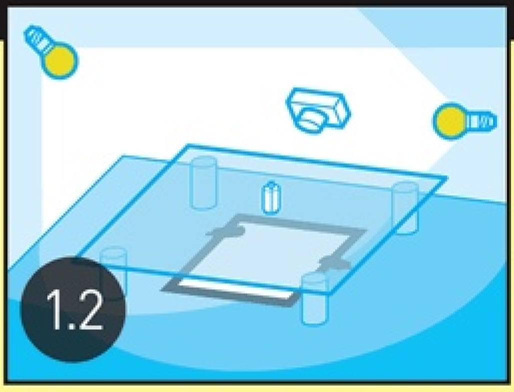
The Setup



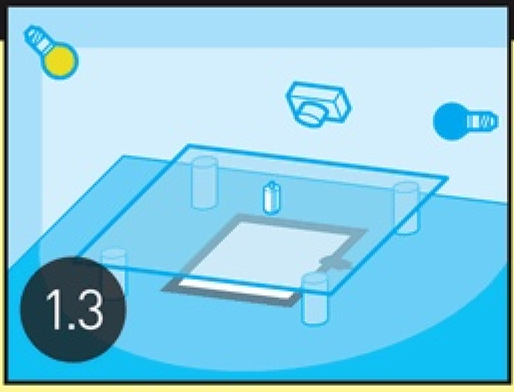
Color choice is important. You can change it later in Photoshop, but some of the original color will have reflected up onto the object, and if this cast doesn't match a subsequent background, it won't look right.

Elevating the object on a glass pane has the advantage that its shadow will be projected through the glass to one side, so that the camera won't see it. You can also swap background colors very easily.

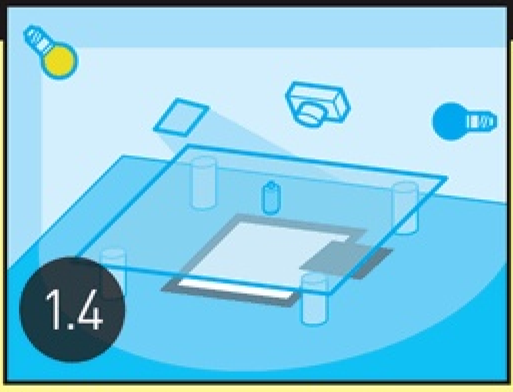
Rob Nance



White paper under glass, framed in black.



Just one light, at 45 degrees.

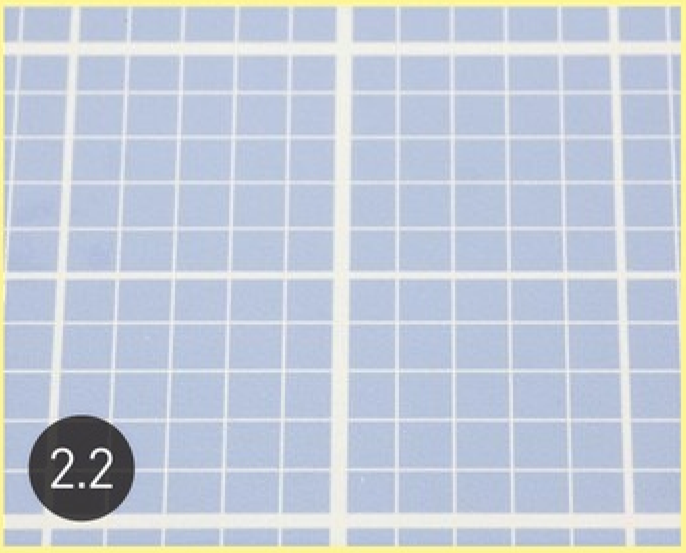


Shaded object appears in silhouette.

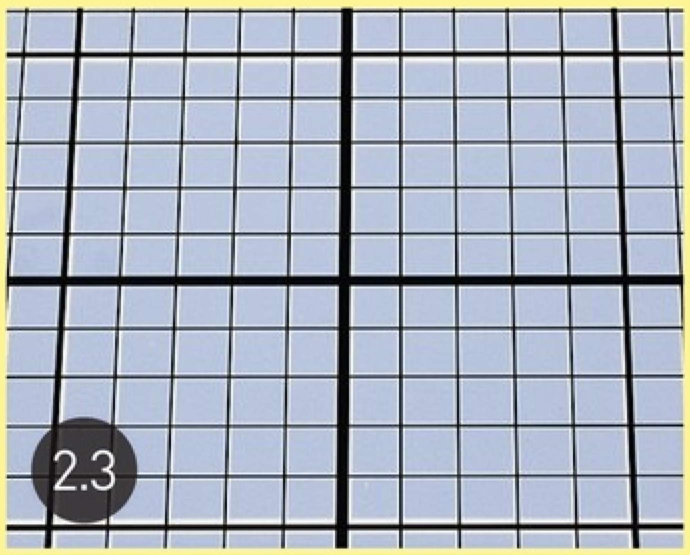
CHARLES PLATT is the author of *Make: Electronics*, an introductory guide for all ages, as well as Volume One of the *Encyclopedia of Electronic Components*. Look for *Make: More Electronics* in Spring 2014.

Tools

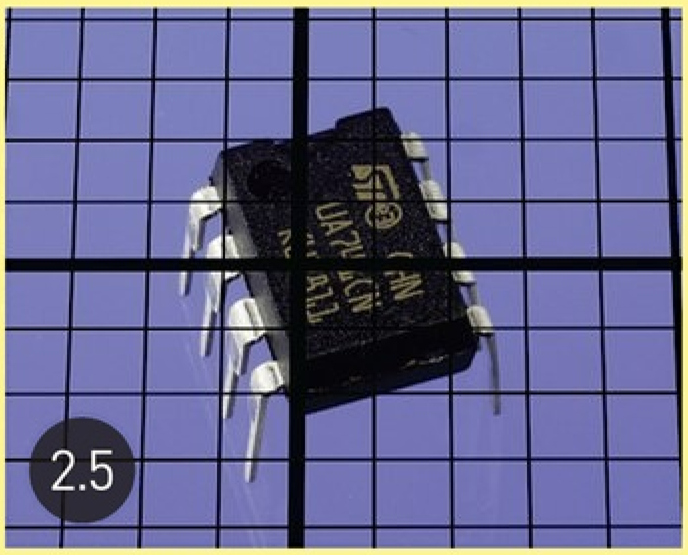
- **Digital camera**
- **Remote shutter release**
- **Photo lights**
- **Computer with Photoshop or similar imaging software**
- **Glass pane, 2'×2'** Tape the edges to reduce the risk of cutting yourself.
- **Plastic cups (4)** or other supports to elevate the corners of the glass
- **Colored paper** or other background material
- **White paper** for silhouette background. Ideally framed with black paper at the edges to suppress any white glare.
- **Graph paper** for adding a scale grid
- **Cardboard** for shading subject during silhouette photography



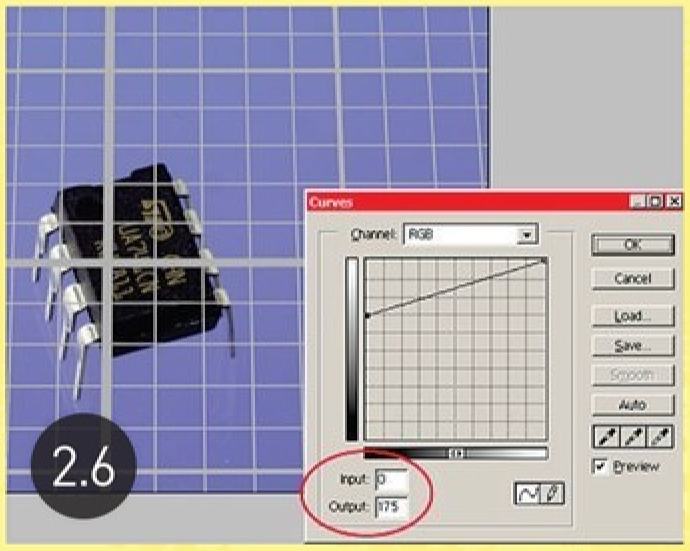
Graph paper photographed at the same angle as the object. Note the foreshortening and perspective.



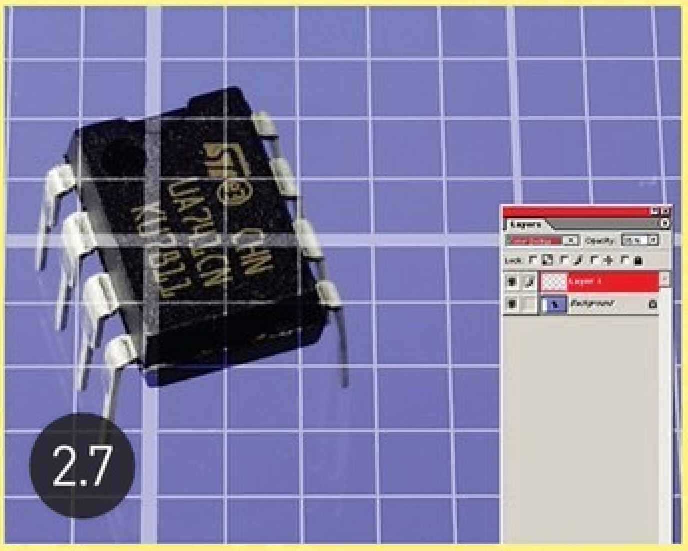
The virtual grid, on a Photoshop layer, distorted to match the graph paper.



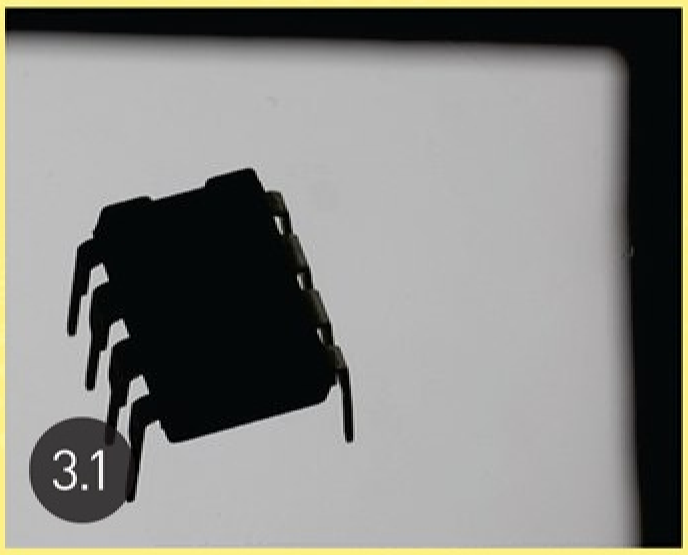
The virtual grid imported on a layer over the object.



Using the Curves palette to gray the grid.



Setting the opacity and the layer property of the virtual grid.



The silhouette photo.

2. Add the Grid

2.1 Make a "virtual" grid in the drawing program of your choice, or download ours from makezine.com/macroplatt.

2.2 Open the photograph that you took of the piece of graph paper.

2.3 Paste the virtual grid as a layer over the graph paper, and use Edit → Transform → Distort to make the grid match the perspective.

2.4 Copy the virtual grid layer and close both documents without saving.

2.5 Open the picture of your object, and paste the virtual grid. It becomes Layer 1.

2.6 Convert the grid to 30% gray by moving the dark end of the diagonal line in the Curves palette till the numbers show an input of 0 and an output of around 175.

2.7 Using the Layers palette, change Opacity to 35% and set the grid layer property to Color Dodge. This colorizes the gray lines.

That's it for the grid. You can hide that layer for the time being.

3. Natural Selection

Now you'll select the object in the photograph.

3.1 Open the silhouette picture, Select All, Copy, and Paste it into your main document as Layer 2.

3.2 To heighten the contrast, move the dark end of the diagonal line in the Curves palette horizontally till you see Input 100, Output 0. Now move the light end of the line horizontally so that the data for that point are Input 150, Output 255.

3.3 Using the Magic Wand tool in Contiguous mode, on one layer only, with a 30% tolerance, select the black silhouette of the object.

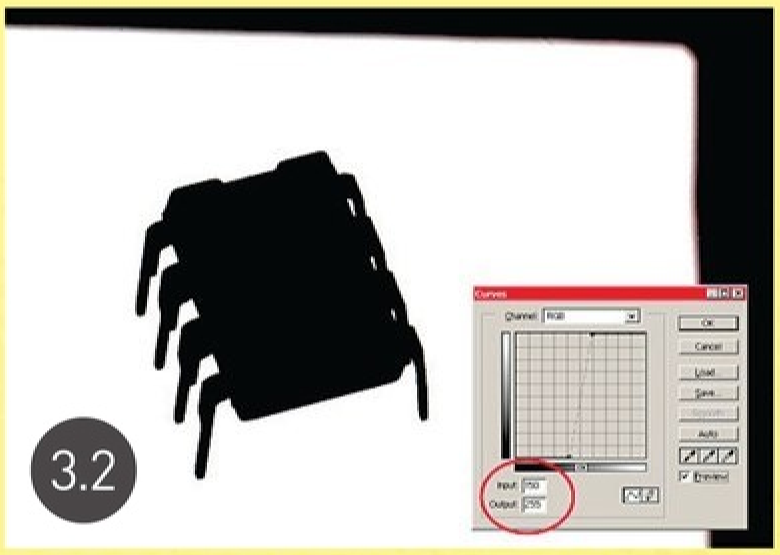
3.4 With the Lasso, include any lighter areas inside the object that escaped automatic selection.

3.5 Hide Layer 2, and you should see your selection exactly aligned with your object on the background layer. Simple!

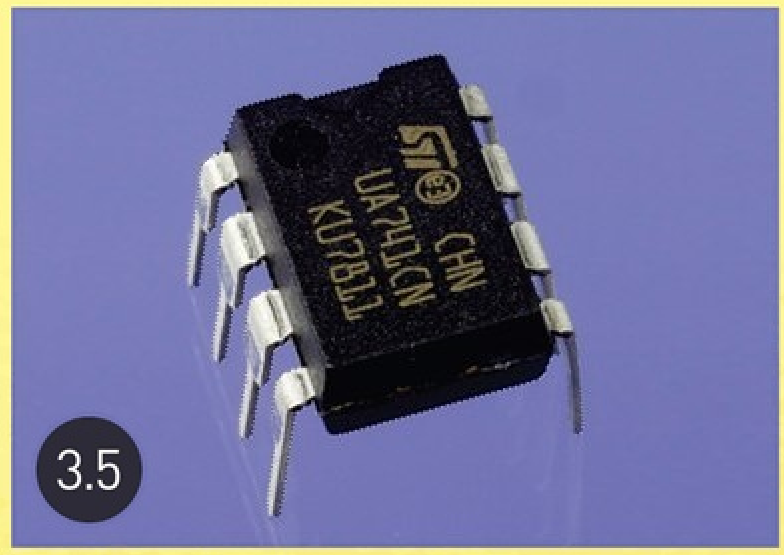
3.6 With the background layer active, copy and paste to duplicate the object on Layer 3. If you're happy with it, trash the silhouette on Layer 2.

4. Background Check

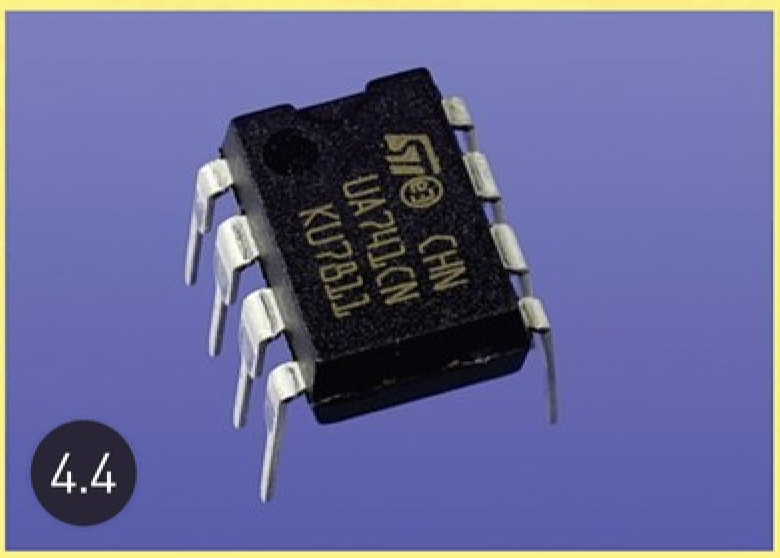
Now you can create a new, clean background.



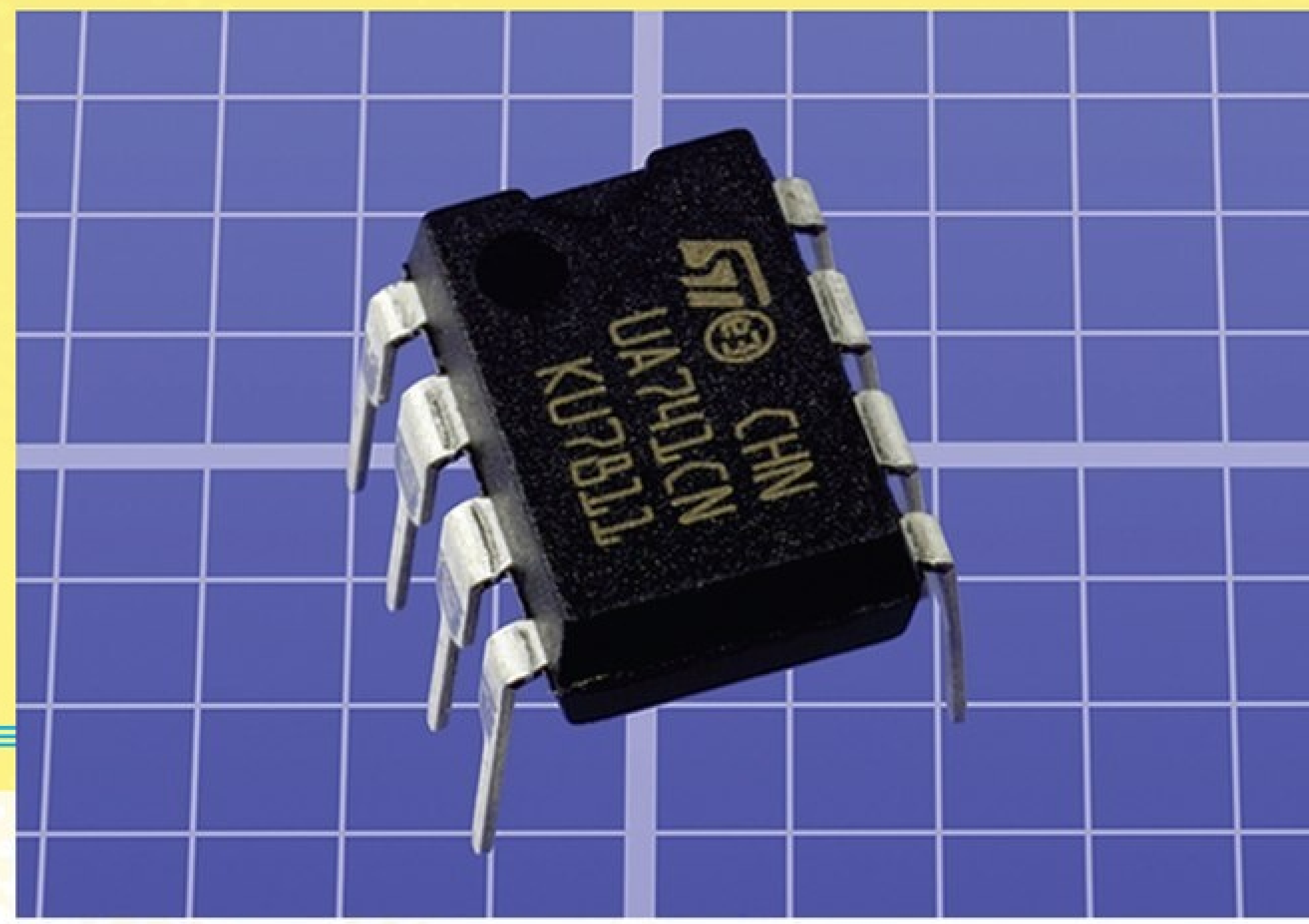
Extreme contrast applied to the silhouette with the Curves palette.



After selecting the silhouette with the Magic Wand, the selection outline fits the photograph of the object. It is copied from the background and pasted into a new layer.



Now that the object is free from the background, the background is improved with the Gradient tool.



The object can be centered on the grid. Color balance and tone range are tweaked to suit your taste. Job done!

4.1 Deselect your object, hide layers 1 and 3, and make the background active.
4.2 Choose the Gradient tool and edit the existing gradient. Sample the darkest part of the background color for one end of your gradient, and the lightest part for the other end. You can adjust these colors, but not too much.
4.3 Drag the cursor across the background, replacing the whole area with your gradient. This wipes out the picture of your object, but you already pasted it onto Layer 3, so you don't need the original anymore.
4.4 Resequence the layers so that your object, on Layer 3, is above the other layers. Make the object and the background visible.

Finishing Touches

The color balance and tonal range of your object can be adjusted in the usual way. You can adjust the opacity of the grid (or leave it out completely) and adjust Hue/Saturation/Lightness of your background, so long as it remains close to its original color. Matching the colors will help to hide any fringe of colored pixels around your object that were accidentally selected with it.

The end result is a clean photograph with no shadows. If you prefer some artificial shadow, use the Burn tool on the background or airbrush a shadow onto an extra layer immediately above the background. I think it's easier to get something the way you want it by creating it from scratch than by trying to fix a version that isn't right.

This system for photographing small objects satisfies the basic requirements and is so much quicker than selecting an object by other means. Also, if you don't show people this guide, they'll have a hard time guessing how you got that completely shadowless effect against a background of a curiously perfect grid.

Show us your shots at makezine.com/macroplatt
Share it: #macroplatt

GLOW Bike

Use EL wire to make your bike a sight at night.

Written by Emily Smith and Luke Closs ■ Illustration by Emily Smith

Emily Smith

Time Required:
1–2 Days
Cost:
$45–$75
Learn to splice EL wire for a customized light show.

Materials

- **EL Wire Starter Pack, 25'** Maker Shed item #MKE-ZL02, makershed.com
- **Batteries, AA (2)**
- **Adhesive tape, clear, high-strength** such as clear hockey tape. You can also use cable ties or glue.

TO SPLICE EL WIRE (optional):

- **Copper foil tape**
- **Heat-shrink tubing: 1mm, 3mm**
- **Wire, stranded insulated** or 2-conductor stranded wire, such as speaker wire
- **Shoe Goo adhesive**
- **2-pin connectors, male and female (optional)** Adafruit #319 and #318
- **1-to-4 splitter (optional)** Adafruit #402

TO FLASH TO THE BEAT (optional):

- **Sound-activated EL wire driver, long-length** from SeattleLumin (seattlelumin.com) or similar vendors
- **Battery, 9V** or 8 AAs in an 8xAA battery holder

Tools

- **Wire strippers**
- **Soldering iron and solder**
- **Heat gun**
- **Third hand tool (optional)**

TIPS ON BATTERIES AND DRIVERS

When you tackle bigger projects you'll use more powerful drivers. These accept 9V–12V, but your EL will be brighter with a full 12V.

- Alkaline batteries provide 1.5V, so 8 of them yield 12V.
- Rechargeable NiMH batteries provide 1.2V or 1.3V, so they won't be as bright, or you'll need 10 of the 1.2V type.
- Rechargeable alkaline batteries give 1.5V, are lighter than NiMH, and have no heavy metals.
- Lead-acid 12V batteries are heavy but have huge capacity and are very rechargeable.
- LiPo R/C helicopter batteries are very light, but expensive. Get a 14.4V LiPo pack and use a voltage regulator to knock it down to 12V.

BIKE LIGHTS AND REFLECTIVE TAPE ARE THE COMMON GO-TO'S FOR NIGHT RIDING, but why not go further and make your bicycle frame glow? About three years ago, Vancouver Hack Space member Luke Closs decided to put electroluminescent (EL) wire on his bike, mostly because he thought it would look cool — but also for the added benefit of bicycle visibility.

After making a few prototype kits, Luke decided he wanted to see hundreds of Glow Bikes in the city. I put together a kit and discovered it was a great introduction to soldering. So as Luke assembled kits, I took photos and compiled an instruction manual. These helped us simplify "build nights" and get large groups of people to mod their bicycles together. At the end of this project, we sold over 100 bike kits!

Back then, soldering your own inverter to the EL wire was the only way to make it glow. Now there are plug-and-play options, like the EL Wire Starter Pack we'll use here, and fancy splitters so you can have 4 wires powered from the same driver. Even though it takes a bit of time and effort to solder your own EL, it's a valuable skill — once you understand how to solder EL wire, you also know how to fix it. It's always good to "open up the box."

With the Starter Pack kit, you can wrap your bike in glowing EL wire in minutes. But what if you want the glow to cross over to your handlebars, front fork, a bike trailer, or any other part of the bike that flexes? EL wire doesn't like to flex, so we'll show you how to splice EL wire to ordinary wire, to make clean bends in your design. Want an even brighter show? We'll show you how to add a more powerful driver that also has the ability to respond to sound.

I encourage you to make your own Glow Bike and tell your friends as well. It's rewarding, and it's sure to turn a lot of heads.

1. Design your Glow Bike

Figure out the design you're going for and decide where you'd like to put the glowing EL wire on your bike frame, forks, handlebars, etc. You can always redo it (unless you glued it on). This kit gives you 25' of EL wire to work with. Some tips:

- Clean straight lines and smooth curves look great.
- Put the EL wire on the top/bottom (or front/rear) of your tubes rather than on the sides. That way, it'll be visible from both sides, making your bike brighter.
- Don't put EL wire in places where it will flex when riding or storing your bike. This can break it. Instead, use ordinary wire in places where you need flex — for example, to cross from the frame to the front fork — and connect it to your EL wire as described in Steps 2 and 3.

Decide where you'll mount the battery pack. Depending on your design, you might find it easier to use a 1-to-4 splitter near the battery pack, then run 4 lengths of EL wire in different directions.

2. Prepare your EL wire for splicing (optional)

If your design crosses over any part of the bike that flexes, you'll want to splice the EL wire to ordinary wire to bridge these places.

Disconnect the EL wire from the driver/battery pack and cut it to length. Using wire strippers or a knife, strip the vinyl sheath off the last 2cm of EL wire (about a thumb's width), taking care not to cut the core wire.

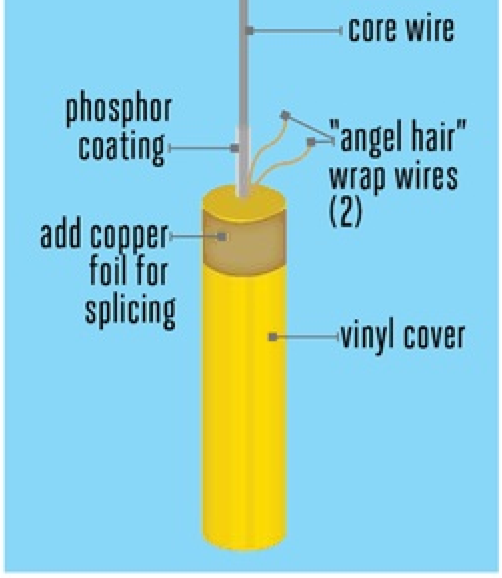
EMILY SMITH
(emilyesmith.net) is an avid textile artist, community organizer, maker, teacher, and communication designer. She is co-founder of Vancouver Mini Maker Faire (makerfaire.ca) and Vancouver Maker Foundation. She enjoys knitting, spinning, weaving, swimming, cycling, and learning to play the banjo.

LUKE CLOSS
is a Vancouver-based hacker and entrepreneur. He keeps busy with his local hackerspace VHS, biodiesel co-ops, and his civic startup Recollect.net, while learning circus skills and raising two young kids.

WHAT IS EL WIRE?

Electroluminescent wire consists of a core of copper wire coated in phosphor (a luminescent substance similar to what's in glow-in-the-dark toys), which glows when an alternating current is applied across it by outer wrap wires (aka "angel-hair" wires).

Anatomy of EL Wire

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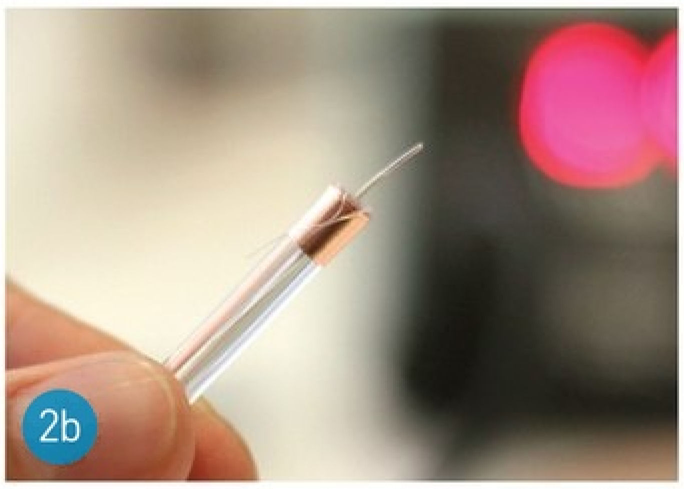
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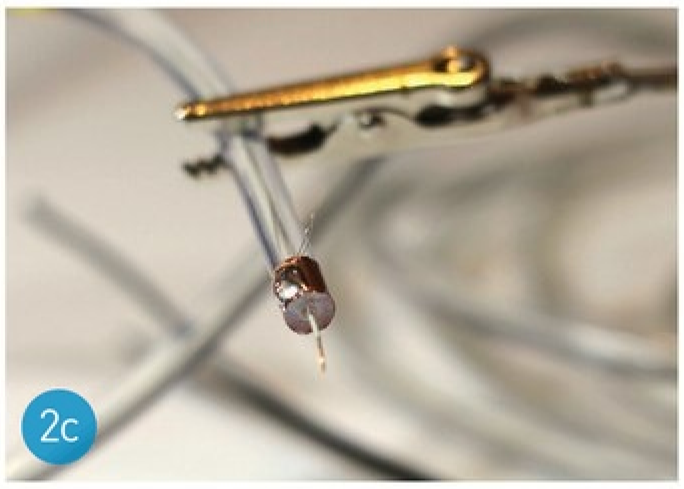
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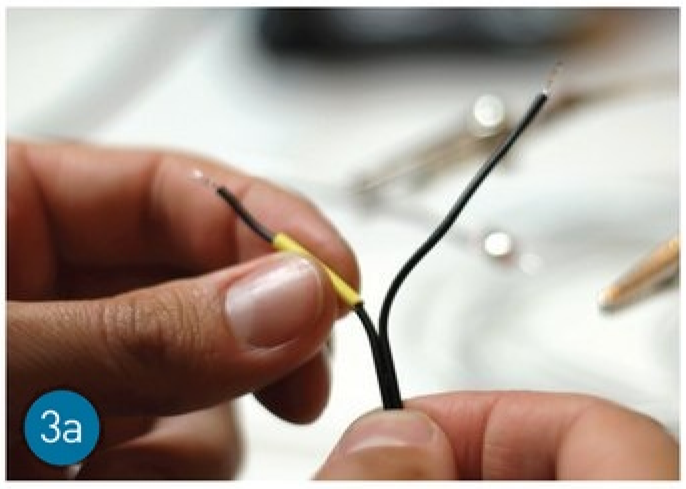
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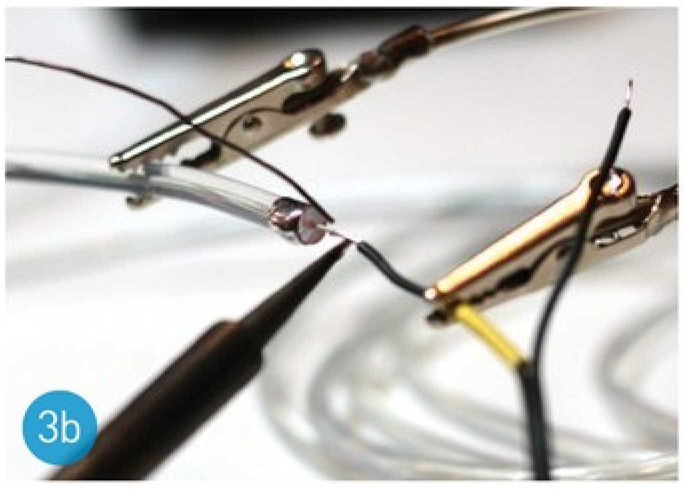
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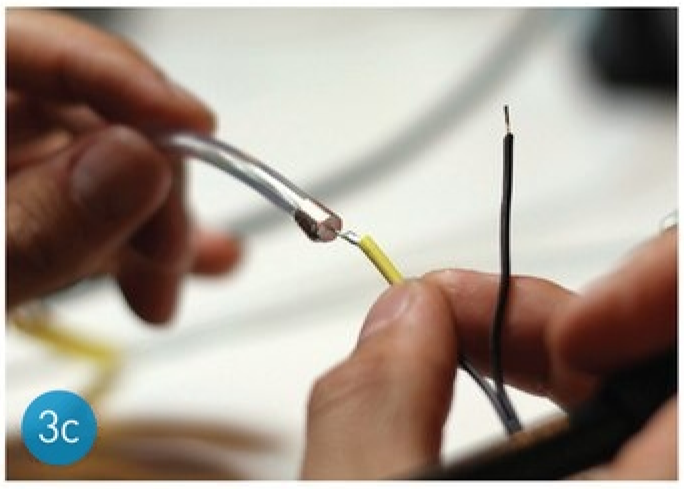
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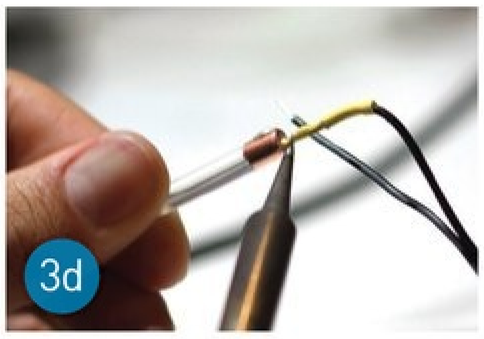
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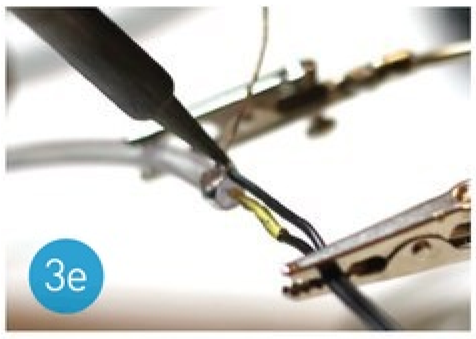
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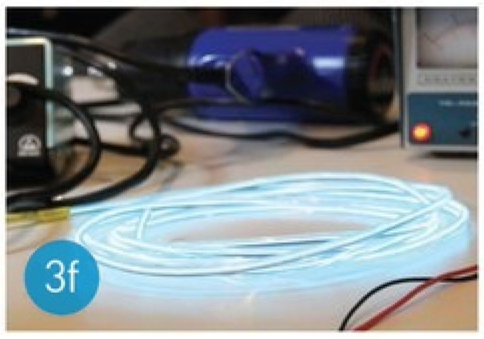
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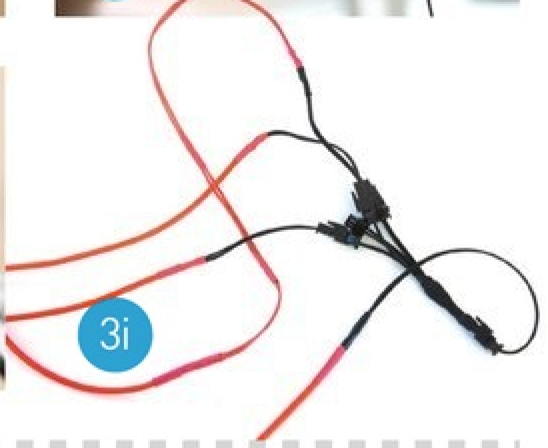
3g


3h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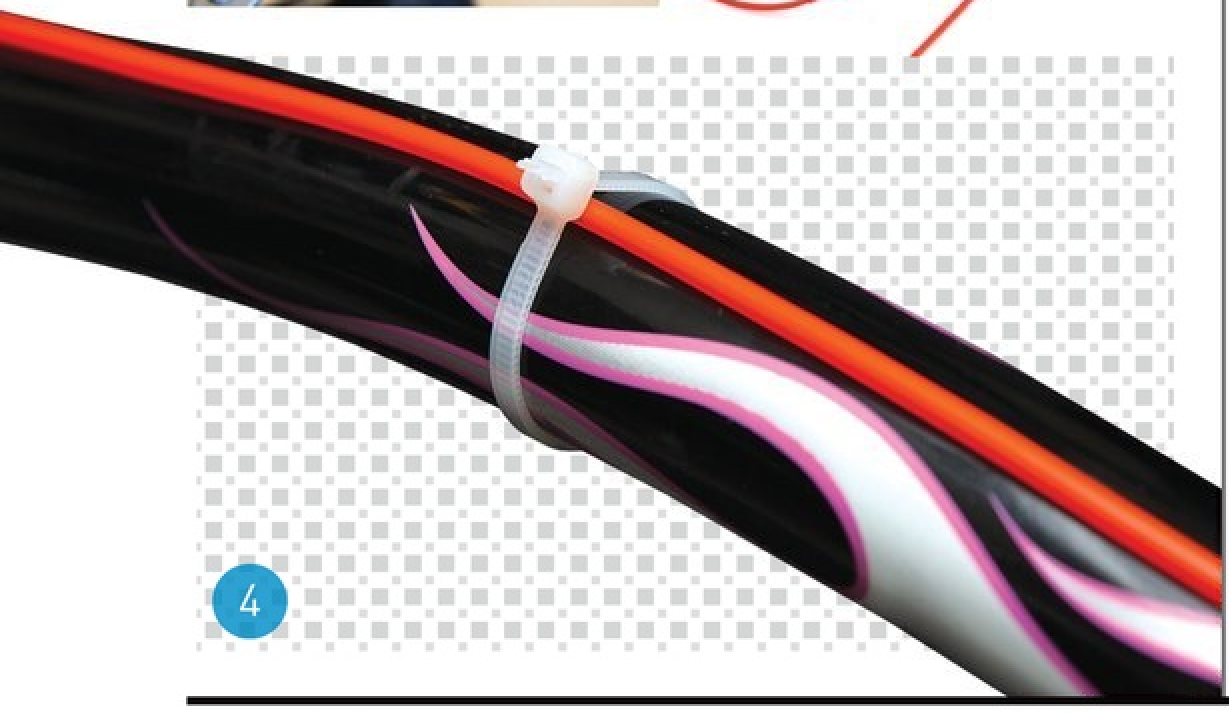

4

Slip a length of 3mm heat-shrink tubing over the EL wire (**Figure 2a**). This step is easy to forget but very important.

Wrap the top of your EL wire with copper foil tape (**Figure 2b**).

Separate the outer "angel hair" wires from the core wire and wrap them backward onto the copper foil. Be careful, they're fragile.

Solder the angel-hair wires to the copper foil. If you have a third hand tool, this will make the process much easier (**Figure 2c**).

Repeat this step to prepare the other cut end of the EL wire.

3. Solder EL wire to ordinary wire (optional)

Cut 2 leads of stranded insulated wire long enough to bridge the flexible part of the bike you're trying to cross. You'll have to attach one lead between the copper foil contacts, and the other between the core wires, so measure and cut them to fit.

Slip a length of 1mm heat-shrink tubing over the shorter of the 2 leads (**Figure 3a**), the one you'll attach to the core wire.

Pre-tin the core wire by first heating it with the tip of the soldering iron, then touching solder to the wire (not to the iron) so that it melts and covers the wire. Then solder the shorter wire lead to the core wire (**Figure 3b**).

Slide the heat-shrink over the joint, then apply heat to shrink it in place, protecting the connection. You can use your soldering iron or a heat gun (**Figures 3c** and **3d**).

Solder the longer wire lead to the copper foil, thereby connecting it to the angel-hairs (**Figure 3e**).

Repeat this step on the other cut end of the EL wire to complete the connection.

To test your work, attach the EL wire to the driver and switch it on to make sure it glows (**Figure 3f**). Disconnect the driver. Apply Shoe Goo to all connections for extra hold, and then shrink the bigger heat-shrink tube down over the connections (**Figure 3g**).

If you want your EL wire connections to be detachable, say for connecting and disconnecting a Glow Bike Trailer, you can follow these same steps to solder the EL wire to 2-pin male and female connectors (**Figure 3h**), just as you spliced the ordinary wire.

To use the Adafruit 1-to-4 splitter, follow these same instructions to solder connectors to as many as 5 segments of EL wire (**Figure 3i**).

4. Attach your EL wire to your bike

Route your EL wires according to your design, and use clear hockey tape or zap straps (aka zip ties) to secure the EL wire to the bike (**Figure 4**). If you prefer, you can glue it on with Shoe Goo, but it will be harder to change or remove.

5. Look cool and tell your friends!

Click the EL wire's (or splitter's) male connector into the driver's female connector, and switch on the glow (**Figure 5**). The driver has 3 modes: continuous glow, flash (about every 1 sec.), and strobe (about every ¼ sec.). Time for a night ride!

Going Further

Alex Cheker

» **FLASH TO THE BEAT.** To drive more EL wire or to make it flash in response to music, substitute the Sound Activated Driver (Long-Length version). It will drive 20'–50' of EL wire from a 9V battery or an 8xAA battery cage (take care not to run it without at least 20' or you'll burn it up), and it's got a slider to adjust the sound sensitivity. Bring a boombox and watch your bike flash to the beat!

» **MULTIPLE COLORS.** Splice different colors of EL wire together, or patch them into splitters, to create new multicolored designs.

See complete step-by-step photos and share your Glow Bike ideas at makezine.com/glow-bike

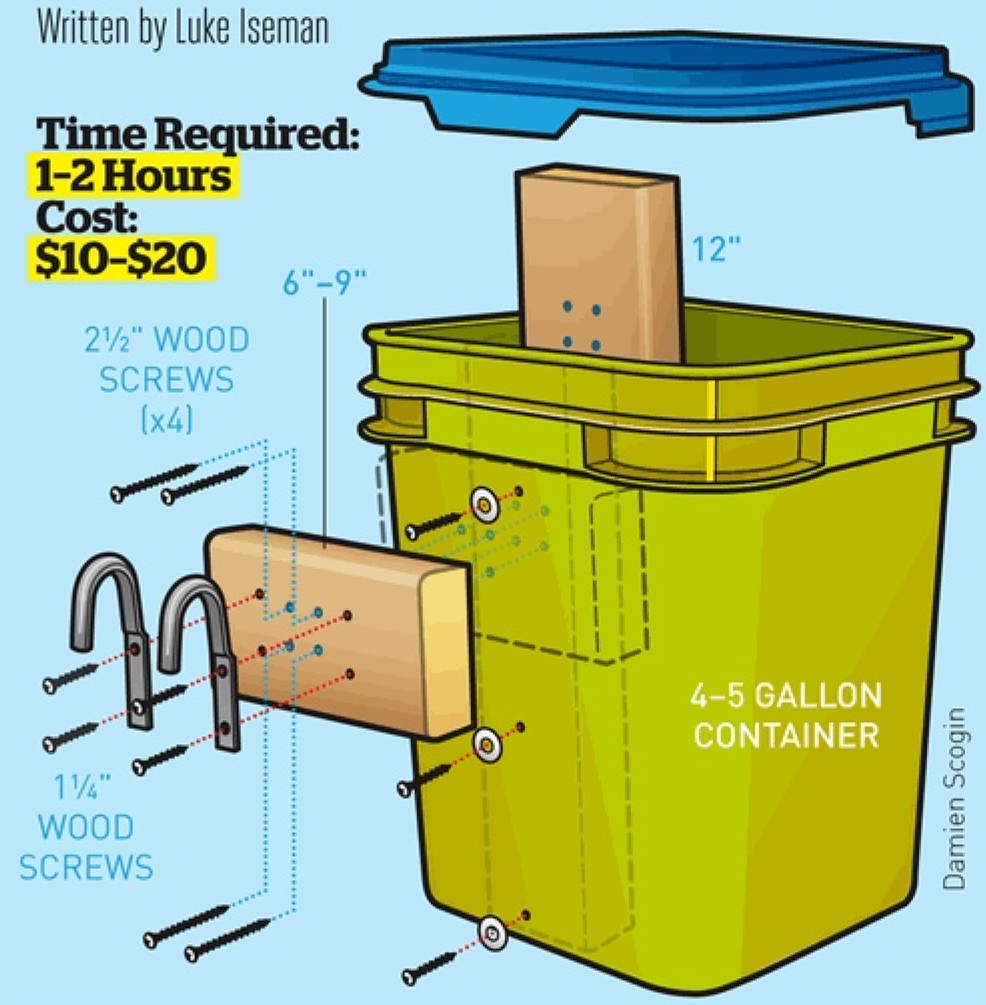
Share it: ***#glowbike***

Hippie Bike Panniers

Build $10 saddlebags from 5-gallon buckets.

Written by Luke Iseman

Time Required:
1–2 Hours
Cost:
$10–$20



Damien Scogin

LUKE ISEMAN
makes stuff, some of which works. He invites you to drive a bike for a living (dirtnailpedicab.com), stop killing your garden (growerbot.com), and live in an off-grid shipping container (boxouse.com).

FOR ABOUT 10 BUCKS YOU CAN BUILD YOUR OWN BIKE PANNIER OUT OF A BIG PLASTIC BUCKET. Of course, you'll need a bike with a rack to mount these.

1. Cut an inner board slightly shorter than your bucket, and an outer board to fit your rack where you want to mount the bucket.

2. Attach the bucket to the inner board using short wood screws.

3. Attach the inner and outer boards, through the bucket, with long wood screws.

4. Mount 2 tarp/rope hooks upside down on the outer board. You want these to rest flush against the cross-braces on your rack, so your pannier won't slide. Align the pannier carefully — too far forward and your feet will hit it as you pedal; too far backward and a bike at rest with full panniers will want to do a wheelie!

5. Optionally, paint your pannier in a shade that's highly visible.

6. Use an old bike tube to strap the pannier down on the rack.

7. Enjoy your newfound cargo-hauling abilities!

Thanks to Brian Huntley (crazyguyonabike.com) and Bikes Across Borders for sharing their kitty litter panniers, and check out Star Simpson's 5-Gallon Panniers at Instructables for an even lower-cost take. Happy riding, and heavy hauling!

For the complete parts list and instructions, go to makezine.com/hippie-bike-panniers

Share it: ***#hippiepanniers***

DIY Video Game Plushies from 3D Models

Written by Jenny Cheng

Make stuffed animals of your favorite video game heroes and monsters.

Jeffrey Braverman

JENNY CHENG is a software engineer who loves video games, 3D printing, and e-textiles. She blogs about her adventures, her explorations in DIY, and her favorite knick-knacks at caretdashcaret.wordpress.com.

I'VE PLAYED A LOT OF VIDEO GAMES, IN PARTICULAR THE MULTIPLAYER ONLINE BATTLE ARENA (MOBA) CALLED *DOTA 2.* In *Dota 2*, there was a monster that I loved. I wanted a plushie of that monster, but to my dismay, the game's makers didn't sell any. So, I rolled up my sleeves and made my own, using the in-game 3D model to create the sewing pattern.

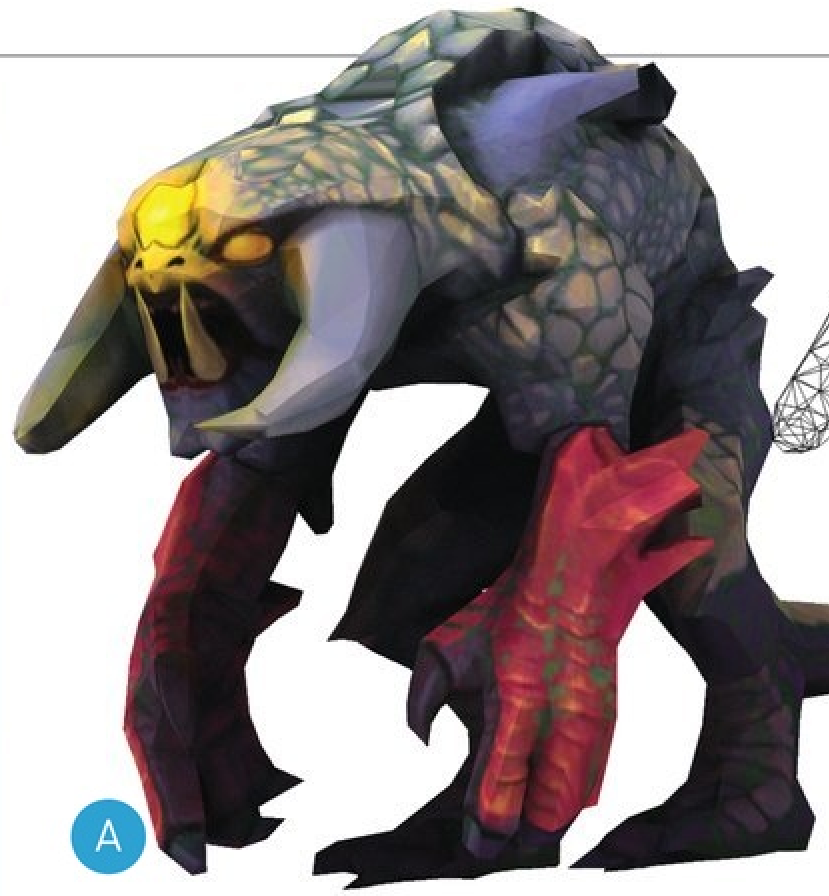
You too can make your own plushies of 3D characters exported from video games. In this guide, you'll learn everything from the fundamentals of 3D models to running Python code to drafting a sewing pattern. This ambitious project will give you the experience to pattern-draft from any 3D model to create anything from car seat covers to custom-fitted clothing.

1. Obtain your 3D model

There are a number of ways to obtain the 3D model of your video game character. You can download them from authorized websites, fan sites, or 3D repositories. You can also extract them yourself with tools such as GCFScape and StudioDecompiler. And for vintage games, Mikola Lysenko posted an ingenious method for making 3D models from 8-bit sprites (makezine.com/3d-8-bit).

The final model needs to be in an OBJ format (**Figures A and B**) with the texture in a PNG format (**Figure C**).

TIP: CHARACTERS THAT ARE "WIRY," WITH LONG, THIN FEATURES, WILL BE HARDER TO SEW.



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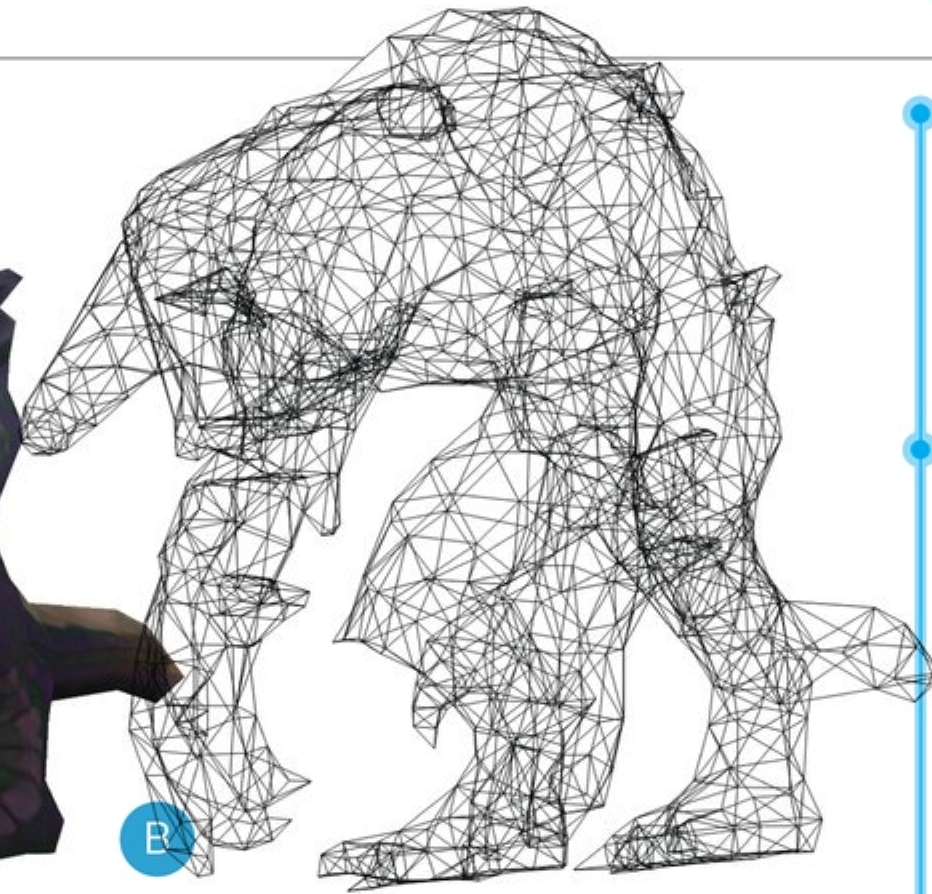


B

Jenny Cheng

Time Required:
Design: A Few Hours
Sewing: A Weekend
Cost:
$20–$30

Materials

- **Custom printed fabric, 1yd** You'll design it in this project. We got ours from Spoonflower (spoonflower.com) for about $18; similar vendors include DPI (dpi-sf.com) and Fabric On Demand (fabricondemand.com).
- **Stuffing** I used 1 bag of Fairfield Poly-Fil Premium Polyester Fiber.

Tools

- **Needle and thread, and/or sewing machine**
- **Computer with software:**
  - **3D modeling program** such as 3ds Max or Maya (free for students) or Blender (always free at blender.org/download)
  - **Headus UVLayout (optional)** from uvlayout.com. It's powerful but costs $100—$400; you can use Blender to lay out UVs instead.
  - **Blender Source Tools (optional)** if you use Blender to lay out UVs, free from steamreview.org/BlenderSourceTools
  - **Python 2.7, Python Imaging Library, and NumPy** free downloads from python.org, pythonware.com/products/pil, and numpy.org
  - **Patternfy script** at github.com/caretdashcaret/Patternfy
  - **Image editing software** such as GIMP or Adobe Photoshop, for touch-ups and rescaling

1a. GCFScape and StudioDecompiler are good for extracting assets from 3D games available on the Steam platform, such as *Dota 2, Left 4 Dead, Portal, Team Fortress, HalfLife*, and *CounterStrike*. I extracted the Baby Roshan monster from *Dota 2*.

Install GCFScape and locate the game folder. Unpack the file named *pak01_dir.vpk*. This will unpack all the assets of the game.

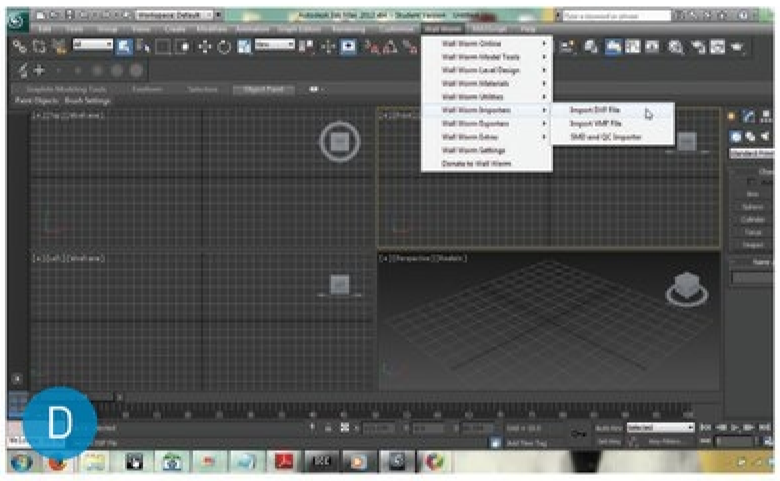
All the unpacked 3D models are MDL files, which you'll need to decompile to SMD files using StudioDecompiler. A tutorial on decompiling MDL files can be found at wyksblog.com/getting-started-dota-2-cosmetics.

1b. In your 3D modeling software, convert the SMD files to 3D mesh files in the OBJ format. This could require custom plugins such as Blender Source Tools for Blender or Wall Worm for 3ds Max (**Figure D**).

1c. All the unpacked texture files are VMT files. Use StudioDecompiler to decompile your character's VMT files to TGA files.

Then you can easily convert TGAs to PNG files. Just open the file in an image editor program like Photoshop or GIMP, click Save As, and select the PNG format.

C



D

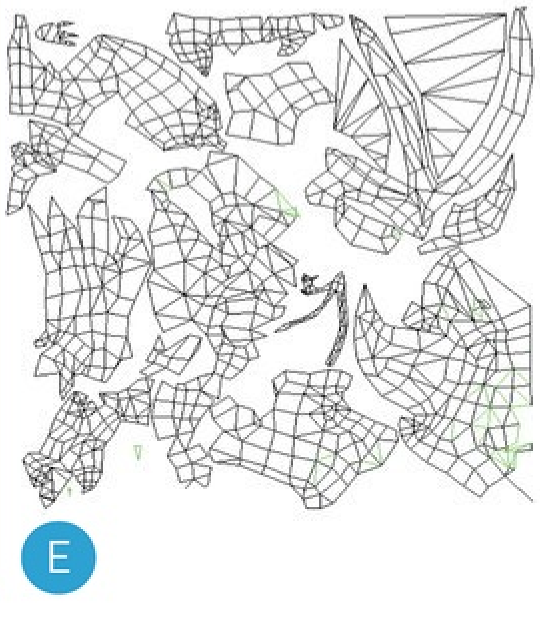
2. Create seams for your model

In the OBJ file format, a 3D model is represented as points in space, with faces connecting them. The OBJ format also includes *UV maps*. UVs are 2D projections of the 3D model onto a flat plane (**Figure E**). They're used to define how texture is applied to the 3D model (**Figure C**).

In this project, the UVs will become the shapes that define your sewing pattern. Currently, they're optimized for texture density, with several *shells* that are stacked on top of one another. So you need to create a new UV set to serve as the basis for your sewing pattern. I did mine in UVLayout, but if you want to do it in Blender, see Step 2b.

2a. In UVLayout, open the OBJ. Create a set of new UVs by creating seams (**Figure F**, following page), and then flattening them (**Figure H**).

These seams will represent the final seams on the plushie — and as you can see in **Figure G**, the more seams your mesh has, the better its 3D contours will be preserved in the plushie.



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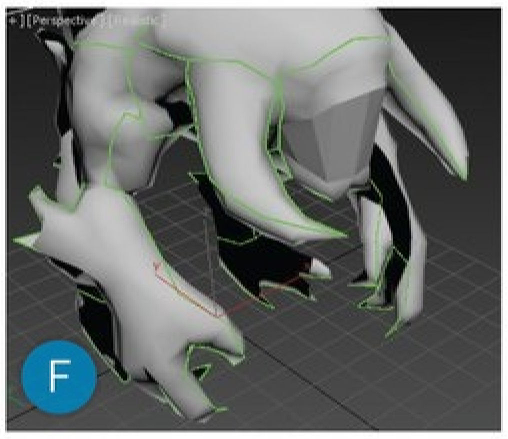
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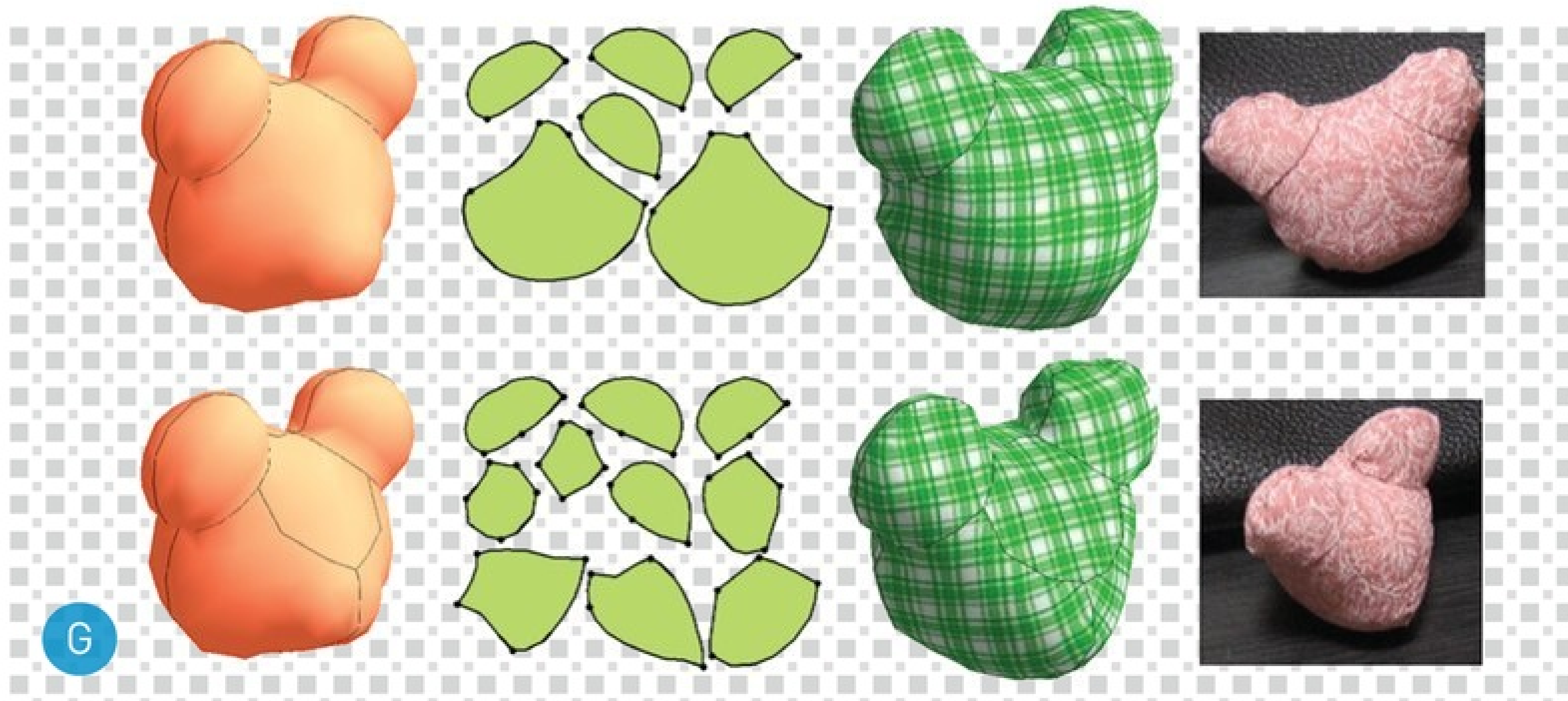

G

On the layout, drag the UV shells slightly apart so that there's no possibility that they would overlap if the scales were changed slightly.

Export the new OBJ, with the same 3D mesh as the original, but with your new UVs instead of the old ones.

2b. To do the same process in Blender, first download Blender Source Tools, then open Blender, select File → User Preferences, and in the Addons tab, click Install from File and choose the file you just downloaded. Once installed, it needs to be enabled: Type "source" in the search box to find it, then hit the checkbox and Save User Settings.

In the Outliner panel at top right, right-click and Delete the default Cube, Lamp, and Camera from the Scene.

Go to File → Import → Source Engine and import the *mdldecompiler.qc* file that you output from Studio Decompiler. You'll see your model in the 3D View panel (**Figure K**). Here we're making a cuddly "headcrab" parasite extracted from *Half-Life 2*.

Grab the panel's top right corner and drag it toward the center to split the panel in two. In the bottom left corner, use the Editor drop-down menu (the little cube) to switch the second panel to UV/Image Editor view.

Use the Mode drop-down to change from Object Mode to Edit Mode. This mode allows you to manipulate the vertices of the model, as well as set UV seams.

To mark a seam, right-click to select a vertex, and hold down the Shift key to add more vertices (**Figure L**). You want fairly straight seams, to minimize the cinching around curved parts when you sew them later. Once you have a seam completely selected, use the Mark Seam button in the Mesh Tools at the left of the 3D View.

Repeat this process until you've marked all your seams, cutting the model up nicely.

Move the cursor to the 3D View panel and press the A key twice to select the entire model. Now click the Unwrap drop-down and select Unwrap. Blender will map the UV shells onto the grid in the UV/Image Editor panel (**Figure M**).

You may end up with some tiny shells made up of just a few small triangles. You want to avoid stitching more pieces than necessary, so you may have to clear and mark seams a few times to get them just right.

Blender likes to unwrap the UV shells close together on the texture map. You need to create at least 1" of space between pieces to have adequate material to sew together. To move a piece, select all its vertices then press the G key to grab and move it. Left-click to put it back down.

Once the pieces are nicely spaced, hit File → Export → Wavefront (.obj) to save the modified model as an OBJ with a new name.

3. Create the sewing pattern

3a. Download my Python script, Patternfy, from github.com/caretdashcaret/Patternfy.

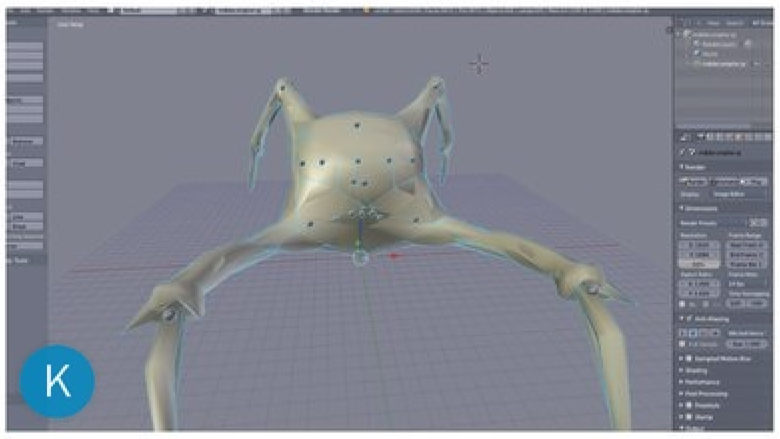
3b. Put your original OBJ, original texture PNG, and your modified OBJ into the same directory as the script.

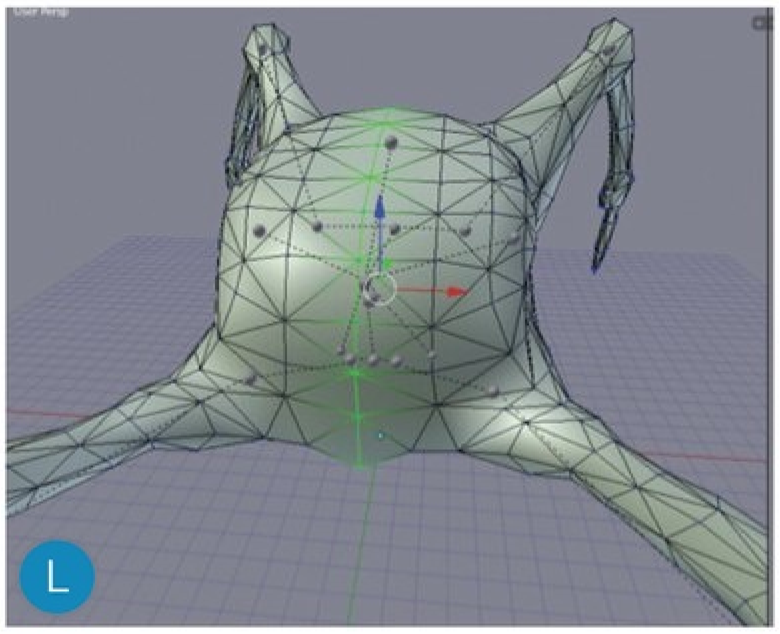
3c. Open up Python and run the script. The output image is your final sewing pattern (**Figure I**).

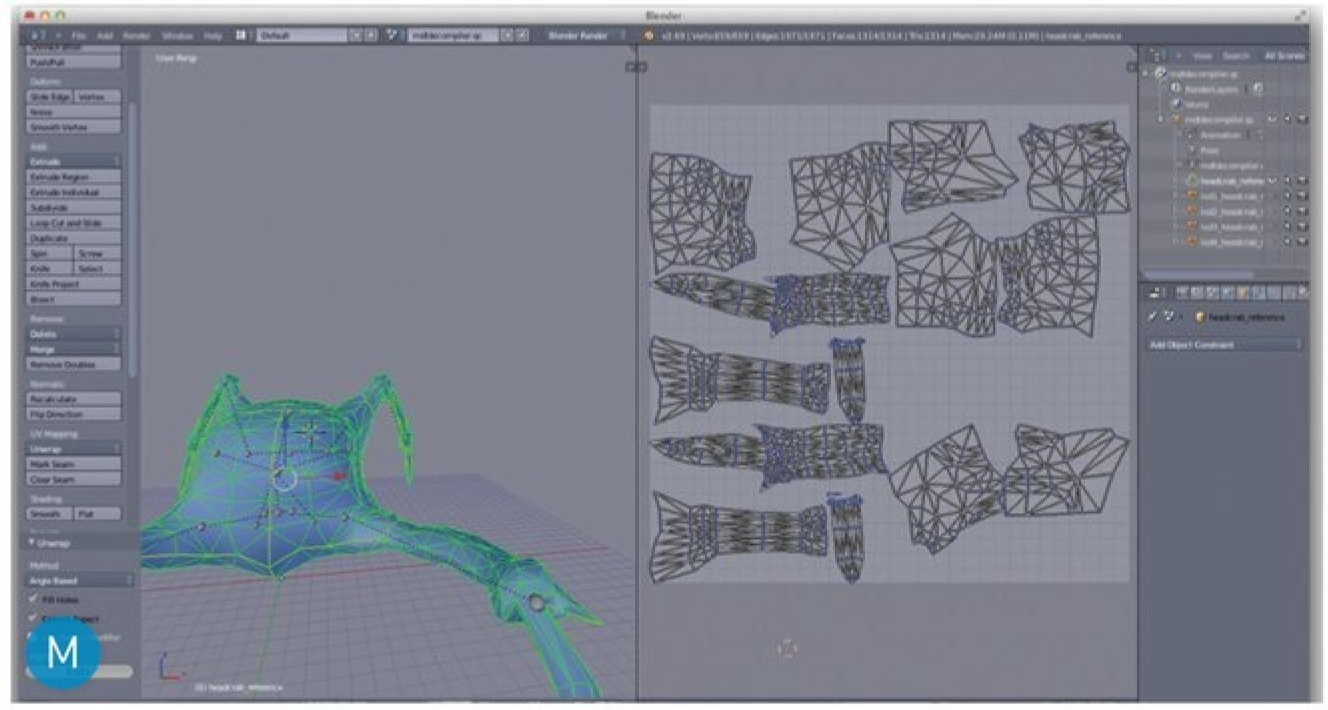
`Factorh` and `factorw` are the relative height and width of the new UV compared to the old UV. Try different factors to scale your UVs to approximately the size you want for sewing.

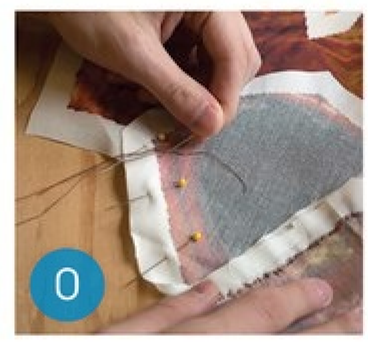
```
texture = "babyroshtext.png"
original = "babyrosh.obj"
modified = "modrosh.obj"
save_as = "output.png"
factorw = 3
factorh = 2

run(texture, original, modified, save_as, factorw, factorh)
```
J

Y. Igarashi and T. Igarashi (top right)









4. Print the sewing pattern

4a. Use your image editing software, such as GIMP or Photoshop, to clean up any unwanted artifacts on the image and rescale it for printing (**Figure I**). The image should be scaled as large as possible to fill a yard of fabric, which requires 6,300×5,400 pixels.

Test-print the pattern on paper to check colors, and adjust the saturation if needed, for deeper blacks and richer colors.

Then upload the image to your custom fabric printer's site and order 1yd of fabric (**Figure J**). We used Basic Combed Cotton from Spoonflower.

5. Sew your plushie

5a. Once your fabric is delivered, cut each piece out with approximately a ½" border (**Figure N**). This will be the seam allowance.

5b. When sewing, face the printed side of the pieces toward the inside, and sew along the pattern edge (**Figure O**). When done, turn the sewn piece inside out. This will hide the seams.

5c. To figure out which pieces are connected, open the new OBJ file in your 3D modeling software. Open up a UV viewer as well, and select an edge or a shell. It should be highlighted on the 3D model. If two UV shells share the same edge in 3D, then sew them together.

» In 3ds Max, bring up the UV viewer by selecting the 3D object and Modifiers --> Unwrap UVW modifier from the Modifiers drop-down menu.

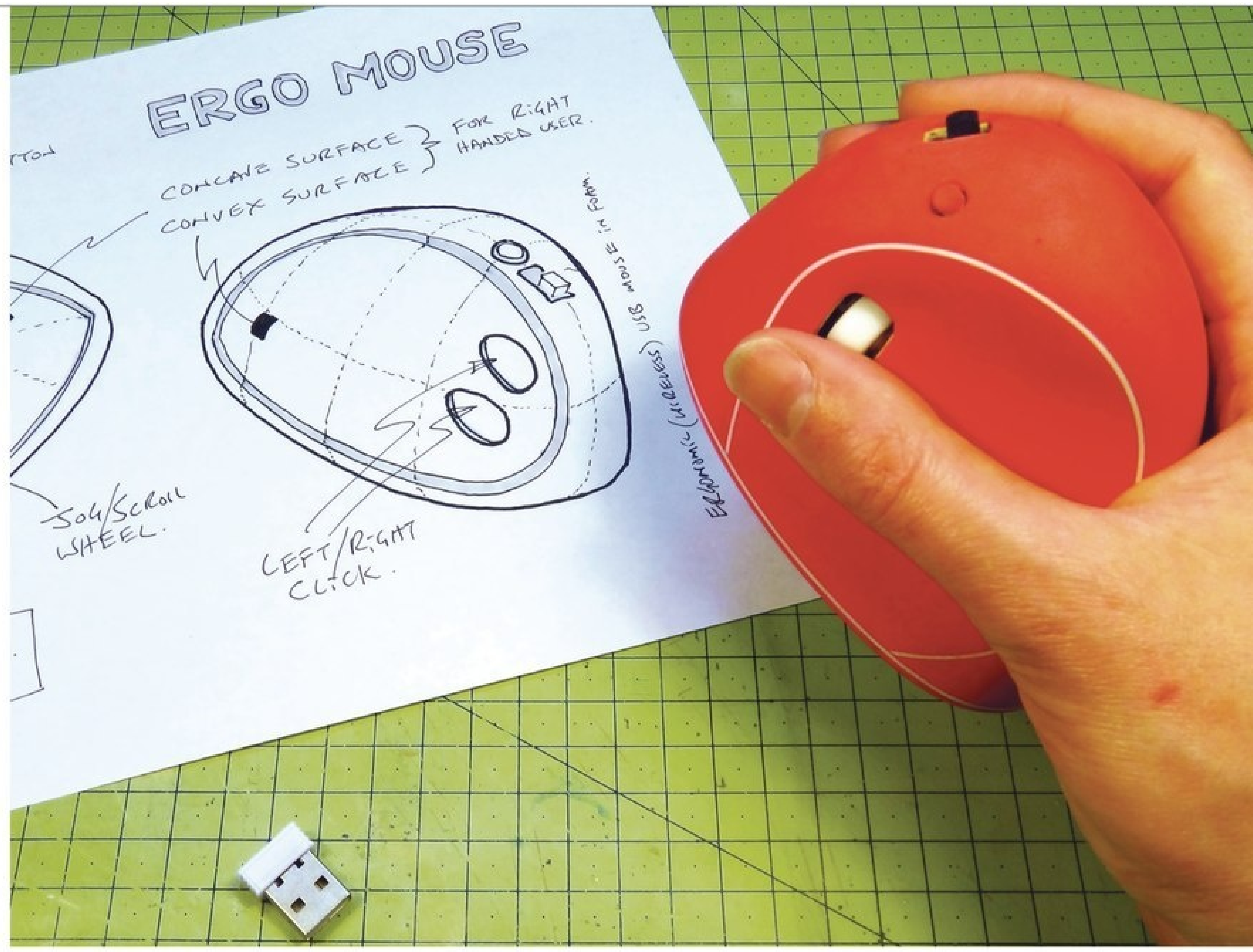
» In Blender, use the UV Select Sync tool.

5d. Stuff the plushie and close it up (**Figure P**).

There you have it — your very own video game plushie. For my Baby Roshan, I didn't create UVs for the wings, but free-formed them from a piece of purple fabric. The possibilities are endless!

See more step-by-step photos and share your plushies at makezine.com/video-game-plushies

Share it: ***#videogameplushies***



Time Required:
5 Hours over a Weekend

Cost:
$15–$25

MATERIALS:

- **Wireless USB mouse**
- **Extruded polystyrene (XPS) foam, about 2"×4"×4"** aka styrofoam or blue foam — *not* expanded polystyrene (EPS)
- **Sugru, 4–5 packs** Maker Shed item #MKSU1, makershed.com
- **ABS/styrene plastic rod, ~1mm square, about 30" total length** such as Plastruct #MS-40
- **Glue, PVA**
- **Water-based filler** such as spackle or Polyfilla. Get a fast-dry grade if possible.
- **Chemical-based filler** such as U-Pol or car body filler. Get "smooth" or extra-fine grade.
- **Craft sticks, jumbo** or tongue depressors
- **Plastic cling-film wrap**
- **Super glue**
- **Electrical tape**
- **Toothpicks or cocktail sticks**

TOOLS:

- **X-Acto knife** with straight No. 11 and curved No. 22 blades
- **Rasps**
- **Files**
- **Sandpaper, wet/dry: 400, 800, and 1,000–1,200 grit**
- **Scrap board** Glue sandpaper onto it for a flat sanding surface (rough on one side, fine on the other).
- **Toothbrush, old**
- **Hot glue gun** Don't overheat the glue or it will melt the styrofoam dramatically!
- **Soldering station**
- **Multimeter**
- **Wire cutter / stripper**
- **Flux pen**
- **Nonstick surface (optional)** for working with fillers. Or just use a scrap of cardboard.
- **Rolling pin, dowel, or rod** to roll the Sugru thin
- **Razor saw** such as a Zona saw. Or use an old hacksaw blade with tape around one end for a grip; ensure that the "cutting stroke" is toward you for a better result.
- **Goggles**
- **Gloves**
- **Respirator or particle mask**

Build a Wireless Ergo Mouse

Written and photographed by Jude Pullen

Adventures in ergonomic foam sculpting and "Sugru skinning."

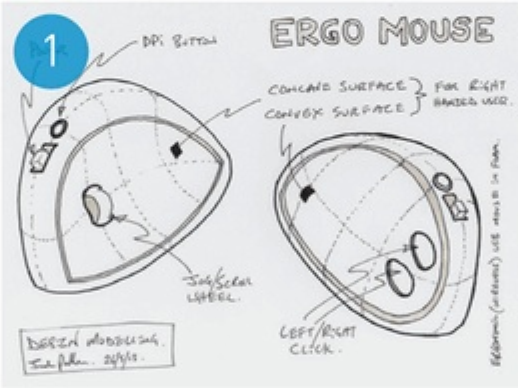
JUDE PULLEN is an award-winning product design engineer with creative experience in California (Speck Design), England (Dyson), and Scotland. He's fascinated by solving unconventional problems — both mechanical and human. Since writing this article, he has joined Sugru as chief engineer. Get in touch via judepullen.com.

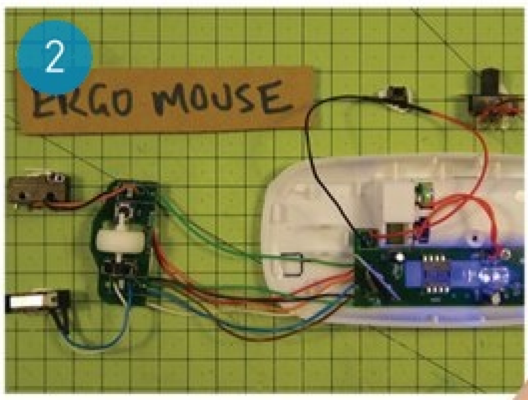
THE ERGO(NOMIC) MOUSE WAS ORIGINALLY DEVELOPED AS PART OF MY DESIGN MODELLING ONLINE TUTORIALS to demonstrate ways to work with styrofoam modeling foam. However, it quickly evolved into a more complex project detailing how to "Frankenstein" a wireless mouse PCB to put the controls where the user wants them, and how to finish the foam with various surfaces, including a first: creating "Sugru skin." Instead of spray-painting, this

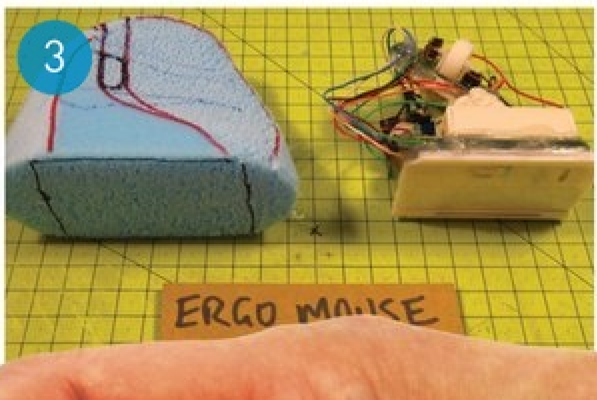
HEALTH AND SAFETY

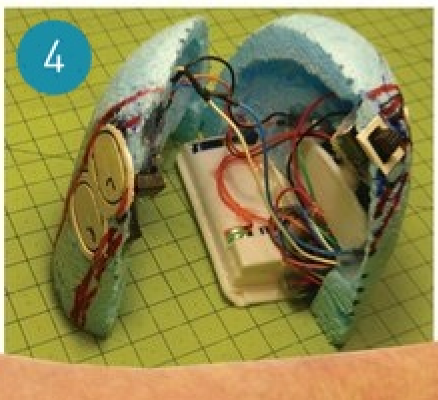
When sawing and sanding foam or fillers, use a particle mask or respirator for protection from dangerous airborne particles. When working with wet fillers, use good ventilation and a mask that protects against fumes. A good all-around respiratory filter is 3M's 7500 series multi-purpose "half-mask," with cartridges such as 6059 (ABEK1 rated) or 60926 (NIOSH approved), which protect against particles and against organic and inorganic solvents. Read the warnings on whichever products you intend to use.

Gloves are recommended when working with fillers and Sugru, and close-fitting goggles are a good idea to protect your eyes from particles, fumes, chemical splashes, glues, or even shattered knife blades.









technique gives your models a novel, tactile finish using the popular air-curable, moldable silicone rubber.

Here are some of the steps involved in creating the Ergo Mouse. Read the complete Skill Builder online and use these techniques on any project you can think up!

1. Plan the concept. A sketch helps to define the needs of a product, but the model-making process will usually yield new ideas and insights of its own.

2. Frankenstein the PCB. The wireless mouse PCB is cut in half, and features like the jog wheel are put on extended leads to allow repositioning within the foam.

3. Form the foam for function. The foam is worked to fit the hand, while roughly positioning the PCB components to check wire length, etc.

4. Assemble. The foam model is cut in half and hollowed out, the components are fitted inside, then it's sealed shut with hot glue.

5. Apply fillers. Water-based (white) and chemical (yellow) fillers are applied in a detailed process to finish and strengthen the model form.

6. Apply styrene strip for definition. Once the fillers have been sanded back, a typical industrial design model would be ready for spray painting. For the Ergo Mouse, this is when the white plastic strip is applied.

7. Cover with Sugru skin! The "Sugru skin" technique I developed is detailed in the complete Skill Builder online. Roll the Sugru flat between sheets of plastic wrap to create consistent, 1mm-thick sheets that can be applied to the model. Sanding back the Sugru gives a tactile finish and exposes the white lines.

Although your Ergo Mouse will not be officially certified to help prevent or reduce repetitive strain injury (RSI), it will most likely be a good fit in your hand, and you may look at your personal possessions in a new light — how to make them better.

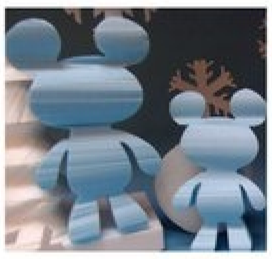
This project is as much about becoming confident with modeling techniques as how to communicate ideas using physical prototypes.

For more Design Modelling projects, please visit judepullen.com/designmodelling
Share it: ***#ergomouse, @judepullen***

+SKILL BUILDER
FOAM SCULPTING, SURFACING, AND SKINNING

The modeling technique shown here has 3 main steps: sculpting, surfacing, and Sugru skinning. I'm demonstrating it with the Ergo Mouse, but you can apply it to any creative process requiring models to explore interactions and aesthetics, quickly and at low cost. Read the complete Skill Builder online at makezine.com/foam-sculpting-surfacing-skinning.

More Fantastically Plastic Projects from makezine.com/projects



5-Minute Foam Factory
Make this easy hot-wire foam cutter and reuse leftover EPS foam to create new treasures from trash.

SKILL BUILDER: Industrial Design for Makers
Discover how to make your project even better through smart design.

SKILL BUILDER: Working with ABS Plastic
The pleasures (and quirks) of ABS, the plastic of Legos and 3D-printer filament.

Dremel Devil Flying Ring

3D-print it, spin it up to 30,000 RPM, and watch it take off like a rocket! Written by Dan Spangler

Time Required:
1–2 Hours
Cost:
$1–$2

DAN SPANGLER
is the fabricator for MAKE Labs, and our in-house dastardly moonlight tinkerer.

Tools

- **3D printer with ABS filament** ABS is tougher and more durable than other filaments.
- **High-speed rotary tool with auto-braking** We use a 12v cordless Dremel 8200

THIS SURPRISING DEVICE, LIKE A NUMBER OF MY PROJECTS, started out with me working in the lab alone late at night and goofing off with slightly dangerous tools!

As some of you may recall, in MAKE Volume 31, we did a project called the Mendocino Motor (makezine.com/mendocino-motor-2), a funny little electric motor powered by solar panels mounted to its rotor, which floats on magnetic bearings. To test the project, we used powerful incandescent bulbs, but soon discovered that the intense heat was melting the glue that held the motor together. So I was asked to design a 3D-printed fan to be mounted on the end of the rotor shaft.

Late one night, the print finished and I tested the new fan. The Mendocino Motor is not highly energetic, so the spinning fan was underwhelming at 100 rpm. Bored and slightly sleep deprived, I figured I'd see what happened if I mounted the fan to a cordless Dremel tool. I grabbed an empty arbor for the Dremel and wrapped electrical tape around it till the fan fit snugly.

You can imagine what happened next: I turned on the tool and the fan spun up to 15,000 rpm, generating a torrent of wind behind it. I was pushing the slider switch all the way to 30,000 when suddenly the fan took off like a rocket and crashed into the whiteboard at the end of the room, shattering into a dozen pieces and leaving a fresh dent. I sat there stunned, until the proverbial light bulb in my head went on.

I dove into the model in Inventor and modified the fan to have 5 blades instead of 4, and I added a ring with an airfoil profile to support the ends of the blades. This time I decided to test it outside, and when I spun it up to 30,000 rpm the fan flew off like a little missile in a line-drive straight trajectory. Not until the very end of its flight, some 200 feet away, did it start to arc and fall back to earth.

So here it is — the Dremel Devil, a 3D-printed fan that you launch from your high-speed rotary tool to soar up to 200 feet. Grab the file and get printing!

CAUTION: NEVER PUT FINGERS OR OTHER PRECIOUS OBJECTS NEAR THE SPINNING FLYER. ALWAYS AIM THE ROTARY TOOL AND FLYER AWAY FROM PEOPLE AND PROPERTY, AND STAND CLEAR OF THE SIDES OF THE TOOL SINCE SOME 3D PRINTS COULD FAIL WHEN SPUN AT HIGH SPEEDS, FLINGING DEBRIS TO THE SIDES.

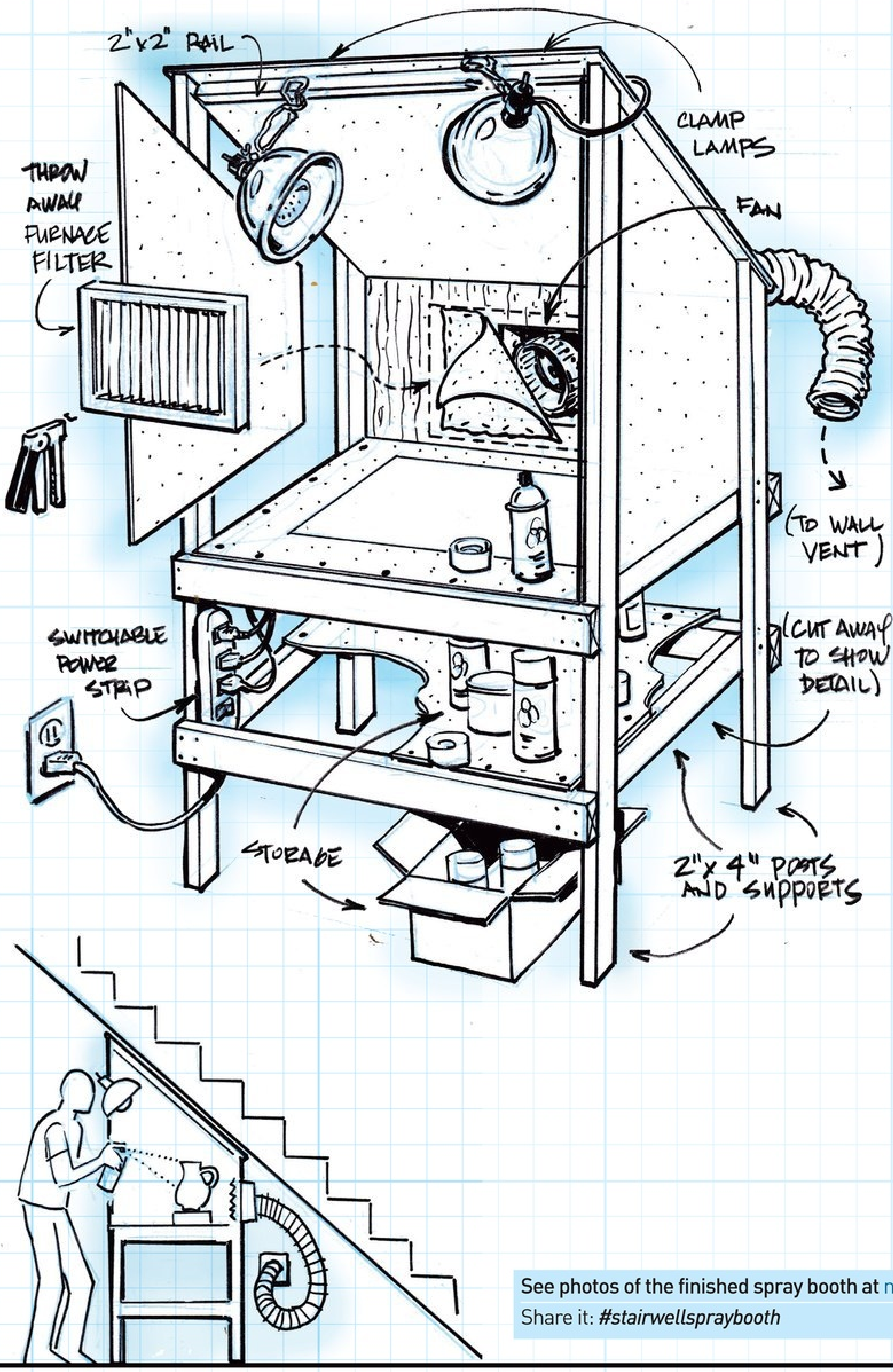
Download the 3D file for printing and share your Dremel Devil tales at makezine.com/dremel-devil

Share it: ***#dremeldevil***

Toy Inventor's Notebook

STAIRWELL SPRAY BOOTH

Invented and drawn by Bob Knetzger



WHEN I WAS SETTING UP MY NEW GARAGE SHOP, I WAS WONDERING WHAT TO DO WITH THE TRIANGULAR SPACE UNDERNEATH A FLIGHT OF STAIRS. The odd shape didn't lend itself to efficient storage, so what else would be good? I was tired of makeshift spray painting and had outgrown my desktop mini spray booth, so this upgrade was timely.

I measured the space and assembled a frame using 2×4s and wood screws. Its slanted top fits the stairwell space snugly so everything else is mounted inboard. The panels are ⅛" tempered hardboard screwed to the frame. The back panel is ¾" plywood with a hole cut out to accept a bathroom ceiling fan. I vented the fan to an outside wall with a flexible clothes dryer hose and vent. There are two stages of filtration: I stapled an inexpensive paper furnace filter over a sheet of fine filter paper (when they're loaded with paint, just tear them both off and replace). Clamp-on spots provide plenty of light and a little bit of heat for drying paint. The lights and fan plug into a switchable power strip for instant on/off action.

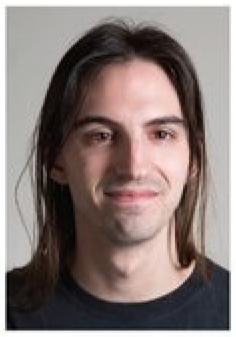
This rig has worked out great for painting, adding filler putty, spray mounting, or any other stinky project. It's tucked out of the way and offers plenty of storage on the shelf and underneath, too. What's under your stairway?

See photos of the finished spray booth at makezine.com/stairwell-spray-booth
Share it: ***#stairwellspraybooth***

Jeffrey Braverman

Raspberry Pirate Radio

Broadcast your own go-anywhere FM station with this amazingly simple Pi hack. Written by Sam Freeman and Wynter Woods



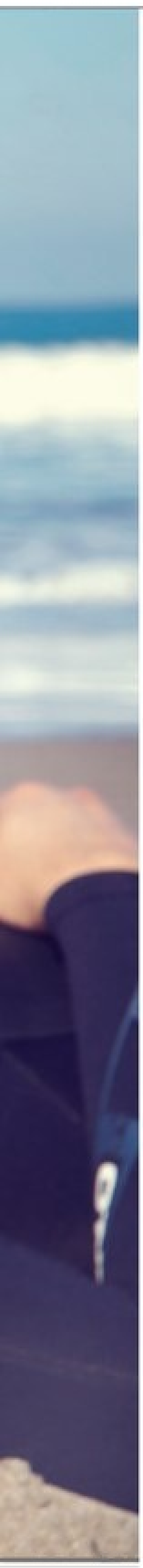
SAM FREEMAN Raised in the galactic capital of Earth, Sam was destined to work as the MAKE Labs manager — testing, designing, and breaking projects for MAKE.

WYNTER WOODS is a MAKE engineering intern and a programmer with one too many interests, ranging from hardware hacks to audio processing to 3D visualization of chemical sample data.

THIS SIMPLE HACK TURNS YOUR RASPBERRY PI INTO A POWERFUL FM TRANSMITTER with enough range to cover your home or dorm, a DIY drive-in movie, a high school ball game, or even a bike parade (depending on the stragglers). It's the coolest Pi device we've ever seen with so few materials.

You'll start with the absolute minimum you need to run a Raspberry Pi — an SD card, a power source, and the board itself — and add a single piece of wire. The PiFM software cleverly uses hardware that's meant to generate spread-spectrum clock signals on the GPIO pins to output FM radio energy instead.

PiFM was originally created by Oliver Mattos and Oskar Weigl, and revised by Ryan Grassel. MAKE's contribution, the *PirateRadio.py* Python script, now enables automatic playback without using the command line and handles all the most common music file formats. It was written here in the MAKE Labs by engineering intern Wynter Woods.



1. Make the antenna

Stick a wire into GPIO pin 4 of your Raspberry Pi. That's it! We used 40cm of fat 12 AWG solid copper wire, soldered to a female jumper. We covered the connection with heat-shrink tubing and reinforced it with a gob of hot glue.

2. Flash the SD card and add music

MAKE Labs created a disk image that runs the *PirateRadio.py* script on startup, so your music starts broadcasting immediately. It handles MP3, WAV, FLAC, AAC, M4A, and WMA files automatically. Download it from the online project page and flash it to the SD card. It's easy; check the project page for more advice.

Then just drag any music files, or artist or album folders, to the root of the Pirate Radio partition. Your music files can be nested within these folders, so there's no need to dump all your music into one mess on the root directory.

3. Edit the *config* file

Set `frequency` to the station you want to broadcast on. Useable FM frequencies are typically from 87.5MHz to 108.0MHz.

Set `shuffle` to `True` to shuffle files, or `False` to play them alphabetically. Set `repeat_all` to `True` if you want to loop forever through your playlist.

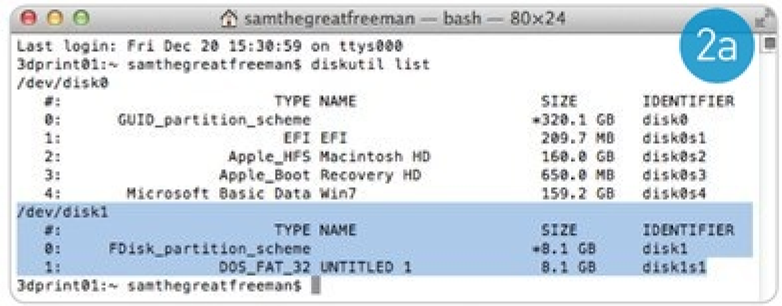
4. Start it up!

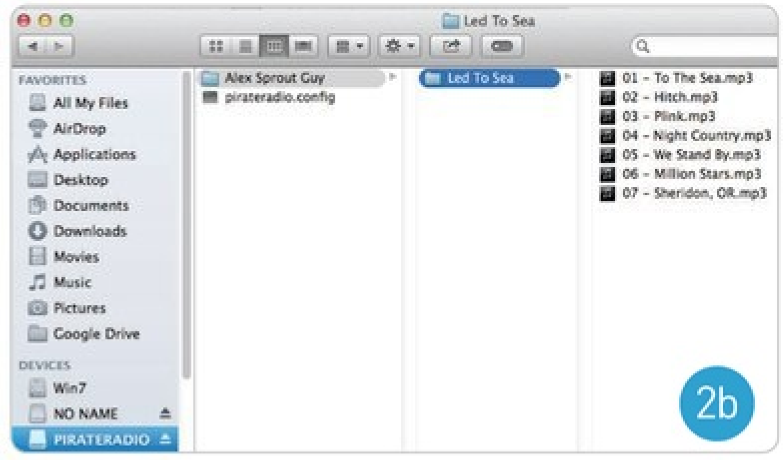
Tune an FM radio to your frequency and plug in the Raspberry Pi. In about 15 seconds you'll hear your music loud and clear!

How It Works

The PiFM software manipulates the frequency of the Raspberry Pi's internal PLLD clock (500MHz) using a fractional divider. For a target broadcast frequency of 100MHz, for example, the frequency is modulated between 100.025Mhz and 99.975Mhz. That's how FM radio transmits an audio signal.

The Python code defaults to 87.9 FM with shuffle and repeat turned off. It scans the SD card for music files and builds a playlist based on the options in the *config* file. It then passes each file along to a decoder based on the file type. Each file is then re-encoded into a format the PiFM radio can handle.





NOTE: THE PI'S BROADCAST FREQUENCY CAN RANGE FROM 1MHZ TO 250MHZ, WHICH MAY INTERFERE WITH GOVERNMENT BANDS. LIMIT YOUR TRANSMISSIONS TO UNOCCUPIED PORTIONS OF THE FM BAND OF 87.5MHZ–108.0MHZ.

Going Further

Tuck everything into the plastic case from the Raspberry Pi Starter Kit, or 3D-print this awesome radio tower enclosure, drawn up by MAKE Labs manager Sam Freeman. Download it at thingiverse.com/make.

Then add a USB battery pack so you can carry your station wherever you need to take over the airwaves. (It fits in the radio tower, too.)

Get complete step-by-step instructions and download the Pirate Radio code at makezine.com/raspberry-pirate-radio

Share it: ***#rasppirateradio***

Time Required: **30 Minutes**

Cost: **$30–$50**

This is the coolest Pi device we've ever seen using so few materials.

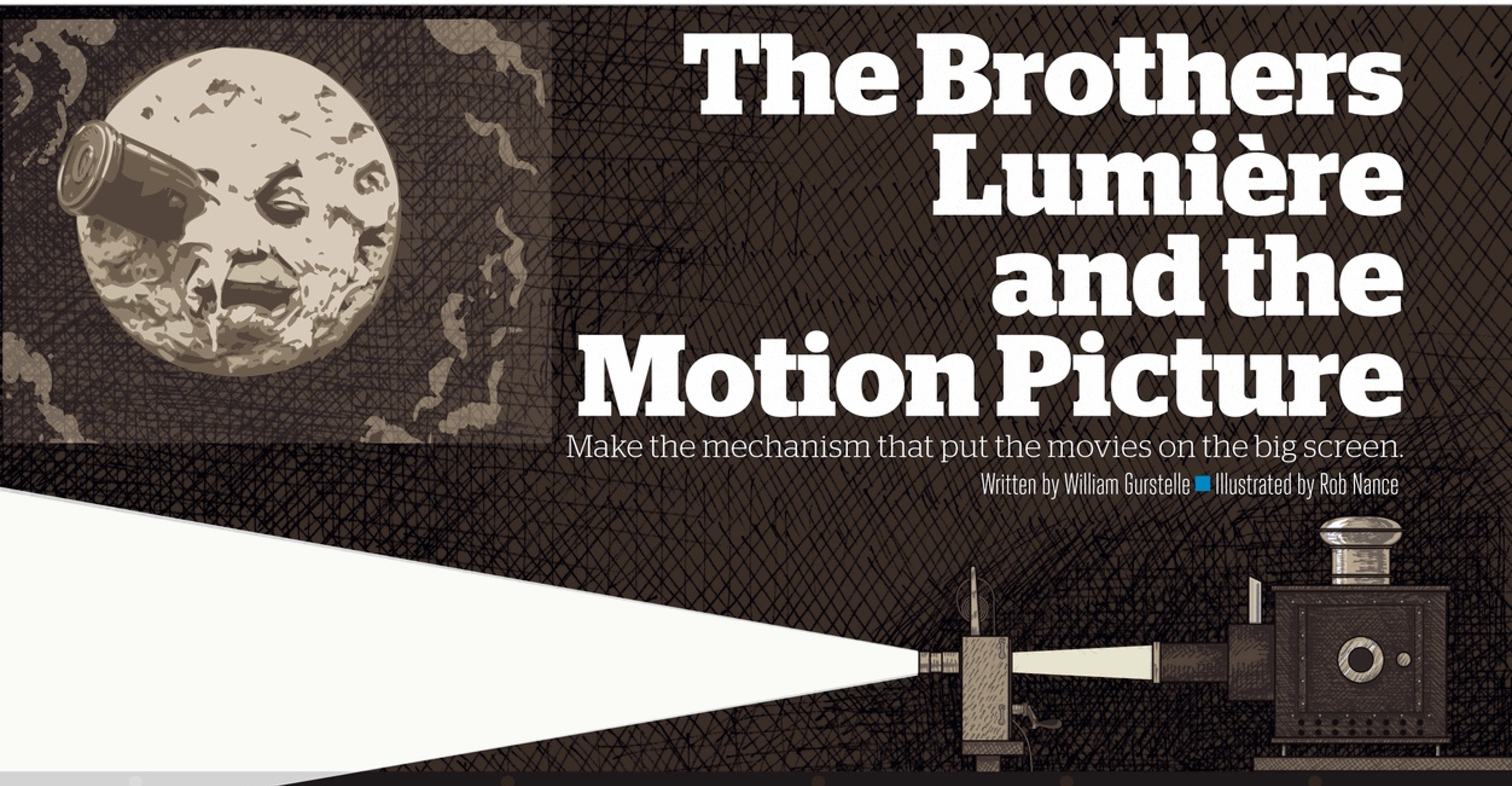
MATERIALS:

- **Raspberry Pi single-board computer** Maker Shed #MKRPI2, or get the Raspberry Pi Starter Kit, #MSRPIK, at makershed.com
- **SD Card, 4GB or more** An 8GB card is in the Starter Kit, and in our Pi/SD bundle, #MKRPI4.
- **USB wall charger, 2A, with USB cable** also in the Starter Kit
- **Hookup wire, solid-core, 12 AWG, 40cm length**
- **Female jumper wire**
- **Heat-shrink tubing**
- **FM radio**
- **Battery pack with USB socket (optional)** for portable operation, such as RadioShack #270-087 (4xAA) or the Smart Power Base, Maker Shed #MKMTS01, a rechargeable 5V 1A lithium-ion power pack that works with many popular development boards.

TOOLS

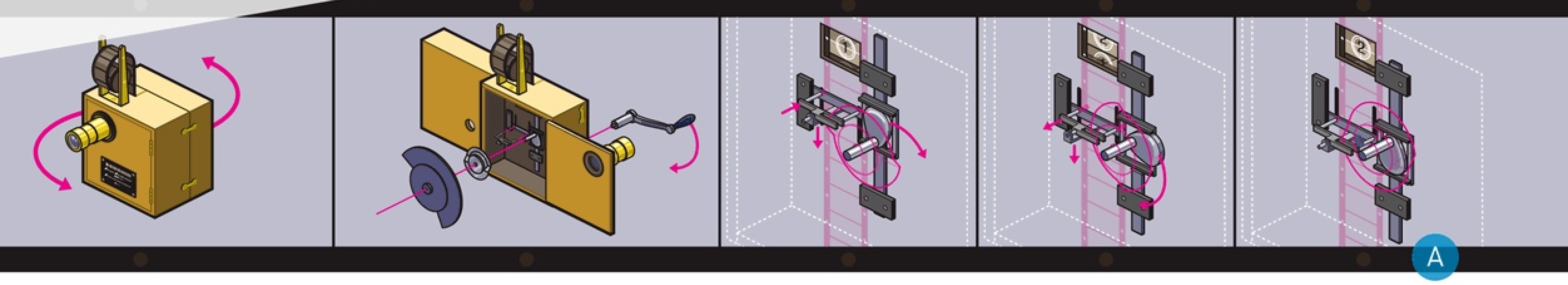
- **Computer**
- **Wire cutters / strippers**
- **Soldering iron**
- **Hot glue gun**

The Brothers Lumière and the Motion Picture



Make the mechanism that put the movies on the big screen.

Written by William Gurstelle ■ Illustrated by Rob Nance



Time Required: A Few Hours
Cost: $10–$20

WILLIAM GURSTELLE is a contributing editor of MAKE. The new and expanded edition of his book *Backyard Ballistics* is available in the Maker Shed (makershed.com).

Materials

- **Plywood or hardboard, ¾": 5½"×8" (1) and 5½"×5" (1)** for stand (1) and prop (2)
- **Plywood or hardboard, ⅜": 3½"×3½" (1) and 2"×2" (1)** for follower (3) and cam (4)
- **Wood dowels, ¼" diameter, 2½" long (2)** for follower's pin (5) and claw (6)
- **Wood dowels, ⅜" diameter: 1½" long (4)** for axle (7), cam crank (8), and pin guides (9)
- **Wood glue**
- **Clamps**
- **Paint** (optional)

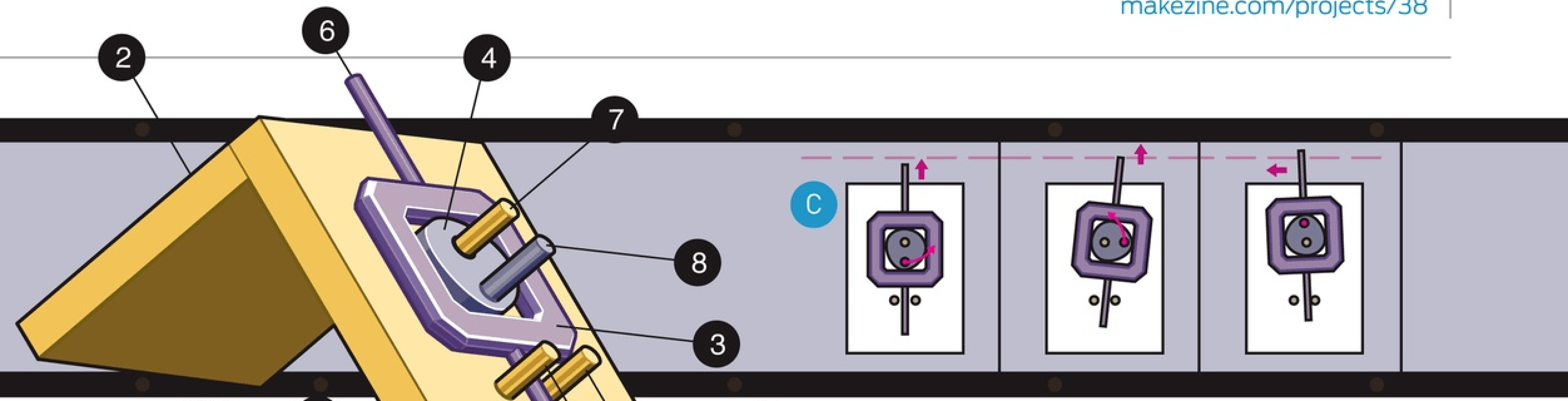
Tools

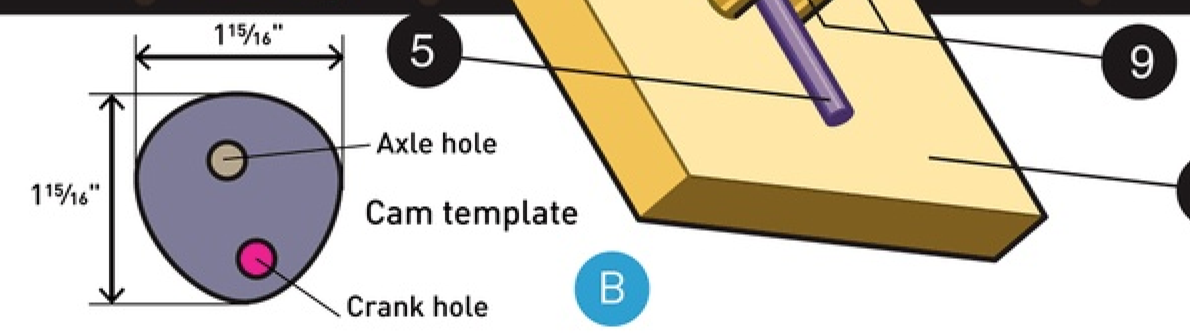
- **Jigsaw**
- **Drill with ¼" and ⅜" bits**
- **Sandpaper or file**
- **Safety glasses**

CONTROVERSY SWIRLS ABOUT WHO MOST DESERVES CREDIT FOR INVENTING MOTION PICTURES — Thomas Edison, Eadweard Muybridge, Étienne-Jules Marey — but a good case can be made that French brothers Auguste and Louis Lumière were the fathers of the modern movie. The experience we get at the local multiplex is due, in large part, to this brilliant pair.

The Lumières were born in Besancon, France, in the 1860s. Their father, Antoine, was a well-known portrait painter and manufacturer of photographic equipment. In 1894, Antoine saw a demonstration of Edison's kinetoscope, an early motion-picture player. He was impressed; not so much by the technology, but by the potential for an entirely new entertainment-based business.

Excited by their father's vision, the brothers took up the challenge of building something that would provide a better, more immersive experience than Edison's peephole. If moving pictures were to become popular, they believed, the image had to be projected on a large





screen. Not only could many people watch (and pay for) the movie at one time, but the experience would be bigger, grander, and more exciting.

They moved with astounding speed, designing and patenting their device in 1895. The Lumières' *cinématographe* was compact and lightweight, a mere 16 pounds. It used a simple hand crank instead of the kinetoscope's heavy, noisy, and expensive DC electric motor. And most importantly, it was a bona fide projector, able to throw a moving image onto a large screen. In March 1895, the brothers screened a 47-second film for a Parisian audience. *The Godfather* it isn't, but it was a world changer.

The Cam-Controlled Movie Projector

The cinematograph did a lot of things much better than the praxinoscope, the kinetoscope, the mutoscope, and the other motion-picture machines that preceded it. Its most important technological advance was the use of a sophisticated mechanism called an *eccentric cam* to position a single frame of the film stock in front of the projector lens, hold it there for 1/16 second, and then quickly advance the film to the next frame (**Figure A**). By cranking at 2 revolutions per second, the projectionist moved the film at 16 frames per second, providing a smooth, realistic depiction of motion, perfect for films of factory employees leaving work, babies eating crackers, and other popular turn-of-the-century storylines.

Rotary cams are among the most important mechanical mechanisms. They're in cars and trucks, machine tools, sewing machines, and myriad other technologies. Their main purpose is to translate rotating motion into linear motion. Typically a spring is used to keep a part called a *follower* in sliding contact with a rotating disk called a *cam*. As the cam turns, the follower traces out a programmable up-and-down motion based on the shape of the cam.

In their projector, the Lumière brothers designed the cam follower to completely enclose the cam. No spring is necessary to maintain sliding contact; the mechanism works in any direction or orientation. The follower is connected to claws or pins that grab the movie film by its perforations, advance it, then release it. This method provides a smooth and dependable method of moving, pausing, and advancing film. See it in action at makezine.com/go/lumierecam.

Make a Lumière Cam and Follower Mechanism

This project is fun to make, and you'll get an interesting desk toy out of it. When you turn the crank, the claw moves with a peculiar motion that you can adjust by making small changes in the profile of the cam.

1. Cut the cam follower

Don safety glasses and use a jigsaw to cut the 2"×2" square opening centered in the 3½"×3½"×⅜" follower piece. Sand the interior surfaces; they must be smooth and free from nicks in order for the cam to slide easily inside the follower.

2. Attach the pin and claw

Drill a ¼" hole ½" deep in the exact centers of the upper and lower ends of the cam follower. Add a drop of glue to each hole and insert the pin and claw dowels. Let dry.

3. Cut the cam

Using **Figure B** as a guide, use a jigsaw to cut the cam. Sand it smooth, then test-fit it inside the follower — the cam should rotate completely, without any binding or interference. If binding occurs, note where it takes place and use sandpaper or a file to trim the cam until it turns smoothly.

4. Drill the cam

Drill ⅜" holes through the cam as shown, for the axle and the crank. Enlarge the axle hole to 7/16" so the cam can spin freely.

5. Make the base

Drill a ⅜" hole through the base, centered 2¾" from the top, and another pair 2¾" below it, centered 1" apart. Glue the axle and the pin guides into the holes. Glue the prop to the back of the base. Clamp and let dry.

6. Attach the crank

Glue the crank into the cam's crank hole, making sure it doesn't protrude out the back. Wipe up any excess glue and let dry.

7. Sand and paint

Sand all contact surfaces. The smoother the cam and follower, the better they work. Paint (if desired) and let dry completely.

8. Assemble the mechanism

Place the cam over the axle, and the follower over the cam, its pin between the guides.

9. Turn the crank and try it out!

As you turn the crank counterclockwise, the cam follower traces out a repeating motion (**Figure C**) where the claw rises (engages the perforations in the film), moves to the left (advances the film), remains stationary a moment ("dwells" in engineering lingo), dips and returns, and then starts over.

Get build photos and more on the Lumières at makezine.com/lumiere-cam

Share it: ***#lumierecam***

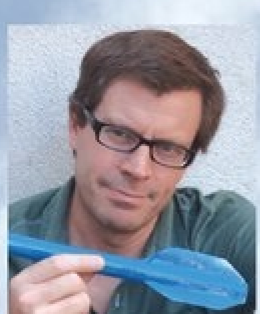
Time Required: 1-2 Hours

Cost: $10–$15

R/C Remote Drop Mechanism

Carry a toy (or pizza) high in the air and drop it from your R/C plane or copter!

Written by Rick Schertle



RICK SCHERTLE teaches middle school in San Jose, Calif., and designed the Compressed Air Rockets for MAKE Volume 15 and the Rocket Glider for MAKE Volume 31. With his wife and kids, he loves all things that fly.

Materials

- **Wooden craft stick, small** aka popsicle stick
- **Velcro tape, self-adhesive**
- **Zip ties, super thin: 8" (2) and 4" (3)**
- **Old bike inner tube, road bike size** You only need a 1½" "slice."
- **Pencil cap eraser**
- **Servomotor, 9g** such as Hobby King HXT900
- **Servo extension cable, 12"–18" (optional)** depending on your R/C aircraft
- **Aluminum angle, 1½" legs, 1½" length**

Tools

- **Scissors**
- **Wire cutters**
- **Hot glue gun**
- **Drill and 7/64" bit**
- **Hacksaw**
- **File**

I'VE ALWAYS BEEN FASCINATED BY THINGS THAT FLY, and when Breck Baldwin showed how to build the "Towel" R/C Flying Wing in MAKE Volume 30, I was bitten by the flying bug again. We struck up a friendship at Maker Faire, and the flying wing, now known as the Flack (*flying* + *hack*), has been an absolute blast to fly. (Build it at makezine.com/projects or get the kit, Maker Shed item #MSFW1, makershed.com).

In MAKE Volume 31, I showed how to build a small but super fun balsa wood Folding-Wing Glider that's rocketed into the air using a hand-held rubber band catapult. At its apex, the wings pop open for a long and gentle glide down. (Build it at makezine.com/projects or get the Rocket Glider kit, Maker Shed #MKRS2).

Then I thought: How cool would it be to combine these two projects? With a drop mechanism, the toy could be carried high in the air and then released from the bottom of the powered plane!

Make the Drop

My drop mechanism is mounted to aluminum "angle iron" that's attached to the bottom of the R/C plane with velcro. (This allows the drop mechanism to be harmlessly "torn" off in rough landings.) Attached to the angle iron is a servomotor with a lengthened servo arm, capped with a rubber pencil eraser that pinches the payload against the other side of the angle. The servo is connected to the R/C receiver, to a channel that typically controls retractable landing gear, so it moves its full range with the flip of a switch on my transmitter.

This mechanism can easily be modified for different planes and quadcopters to drop different things. We've dropped the Rocket Glider, a foam "delta dart" glider, plastic paratroopers, and bunches of brightly colored roto-copters made of cardstock (www.cambriansd.org/Page/1574).

If you're dropping gliders, have a friend act as a spotter because once you release the glider, you need to keep flying the plane!

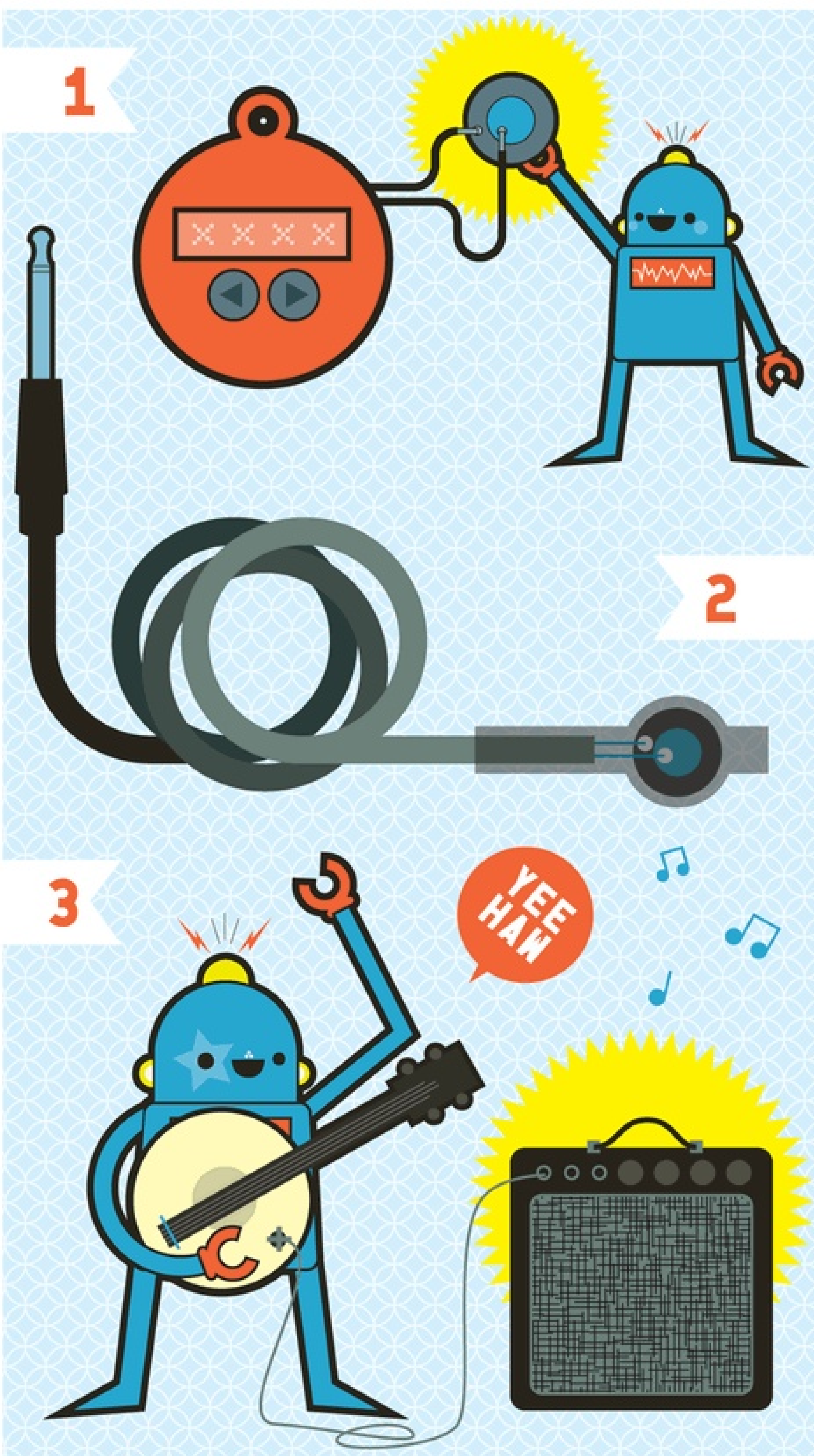
Once you get good at dropping, set up hula hoops as targets and come up with your own contests. Better yet, set up an autopilot system to drop your cargo at exact coordinates (think futuristic pizza delivery).

Get step-by-step instructions, photos, and video at makezine.com/rc-remote-drop-mechanism

Share it: ***#remotedrop***

1 2 3 Piezo Contact Mic

Written and photographed by Justin Emerson ■ Illustrations by Julie West



Ready to rock? See and hear the Piezo Contact Mic: makezine.com/piezo-contact-mic

Share it: ***#piezomic***

A CONTACT MICROPHONE IS A SMALL DEVICE THAT CAN BE USED TO AMPLIFY ACOUSTIC INSTRUMENTS. You don't sing or talk into a contact mic. As the name implies, it makes contact with a solid object and turns mechanical vibrations into electricity. Because a contact mic doesn't pick up ambient sounds in the room, it focuses in on one instrument without interference or feedback.

1. Aquire parts

Gather old toys from the attic or the thrift store and pull out the blippity bleepy ones. Open them up to see if they have a piezoelectric disc or a normal speaker. Hopefully you'll find some piezos. You will need to break apart some plastic bits to get at them — just be careful not to damage the discs.

2. Wire it up

Cut the audio cable in half. Now you have enough cable and connectors for two contact mics! Strip off a bit of outer insulation from the cut end of the audio cable. Strip and tin the signal and ground wires. Desolder the two piezo wires where they connect to the piezo. Now solder the signal and ground wires from your audio cable to those same points on the piezo. Dab some hot glue on the back of the piezo, for strength. Test it by plugging the cable into a low-powered amp and tapping on the piezo. You should hear the sound of the amplified tapping.

3. Finish it up

Use heat-shrink tubing, electrical tape, Plasti Dip, or epoxy to insulate the wires, the solder connections, and the piezo itself. Use gaffer's tape to attach the mic to different objects like cardboard boxes and paper cups, and acoustic instruments like guitars and kalimbas. You may get a feedback loop if the mic is too close to the amp; not necessarily a bad thing if you're a noise artist. Effects pedals can be used to flavor the sound to your taste.

+ Superpower your project by building a preamplifier circuit for your piezo: makezine.com/micpreamp.

JUSTIN EMERSON makes experimental electronic music with hand-built and modified instruments. His band, Burnkit2600 (burnkit2600.com), performs and gives workshops and presentations on the topics of circuit bending, chiptune, and DIY electronics.

You will need:

- **Piezo disc**
- **Audio cable** such as a ¼" guitar cable
- **Low-powered practice amp**
- **Heat-shrink tubing** wide enough to fit over the piezo
- **Gaffer's tape**
- **Soldering iron and solder**
- **Wire cutter / stipper**
- **Screwdriver, small**
- **Heat gun or hair dryer**
- **Hot glue gun and glue**

Wiimote Whiteboard IR Saber

Create an awesome IR pen from a toy light sword and control your computer with gestures.

Written by James McLain

Time Required:
1 Hour

Cost:
$10–$15

Command your "smartboard" with an elegant weapon for a civilized age.

Materials

- **Toy laser sword** such as Amazon #B00345MQ8W. I love the style and length of this one.
- **Speaker wire, 2-conductor, 24 gauge, 31"**
- **Resistor, 33Ω, ¼W**
- **LED, infrared, 940nm** such as Vishay Electronics #TSAL 6400
- **Electrical tape, white, 12"**
- **Push button, momentary**
- **Wire, solid**

Tools

- **Wire cutters/strippers**
- **Pliers, needlenose**
- **Screwdriver**
- **Utility knife**
- **Drill and 13/64" or 3/16" bit**
- **Soldering iron and solder**
- **Hot glue gun and glue**
- **Small organizer box** to store parts while you work

MINORITY REPORT AND IRON MAN-TYPE INTERFACES ARE ALREADY HERE. With an easy hack, you can interact with a projection of your computer's display just by waving a wand in midair. The setup is amazingly affordable, just needing a Wii Remote and an infrared (IR) light pen. How do you get an IR pen? You make it!

In 2007, Johnny Chung Lee invented the Wiimote whiteboard. As Lee explained in his runaway YouTube video (makezine.com/wiimotewhiteboard), every Wiimote has a high-resolution IR camera. To turn it into a mouse or an interactive whiteboard, we connect it to a computer, fix it in one place, and use movable IR pens within view of its camera.

An IR pen is a simple device — basically a flashlight with a momentary push button and a high-power IR LED like you find in TV remote controls. Most people use a dried-up dry-erase marker as the body, but performance is spotty because the LED points out the end of the pen, not straight at the Wiimote camera.

So I designed a big IR pen with the LED pointing out the side, and turned it into a small business. It's the longest IR pen in the world!

Build Your IR Saber

1. Wire the IR LED. Split and strip both ends of the 2-conductor speaker wire. Trim the LED leads evenly and solder them to one end, taking note of which conductor goes to the positive lead, and which to negative. Insulate all connections with electrical tape or heat-shrink tubing.

2. Tear down the toy saber. Remove all screws, then take out the batteries, battery connectors, internal switch, and external button, and separate the handle shells from the "blade."

3. Install the IR LED. Drill a 13/64" hole in the *side* of the blade, near the tip. Cut a small flap to open up the hole, then feed the speaker wire down the hole until it emerges from the far end. Mount the IR LED in the hole with hot glue, then push the flap back down.

4. Replace the internal switch. Desolder the saber's original toggle switch and positive battery connector (save the original string of LEDs for another project). Solder your momentary push button to the positive battery connector and the positive wire from the IR LED, wiring it in the "normally off" mode.

Depending on your saber, you might need to support your push button with a little wire bridge or hot glue so that it fits right. I also add a small gob of hot glue to extend the original external button so it will reach the new push button inside.

5. Add the resistor. Solder the 33Ω resistor between the negative battery connector (the one with the spring) and the negative wire from the IR LED.

6. Reassemble and test. Insert the batteries and close up the halves of the handle, snipping off any bits of hot glue or plastic that interfere with the new switch arrangement.

Press the button. You can't see infrared light with the naked eye, so look at it through a digital camera, like the one in your cellphone. You should see the LED glow a bluish color in your camera!

7. Finishing touch. Neatly cover the slit in the top of the saber with white electrical tape. You can use a paper hole punch to make a hole in the tape to fit the LED.

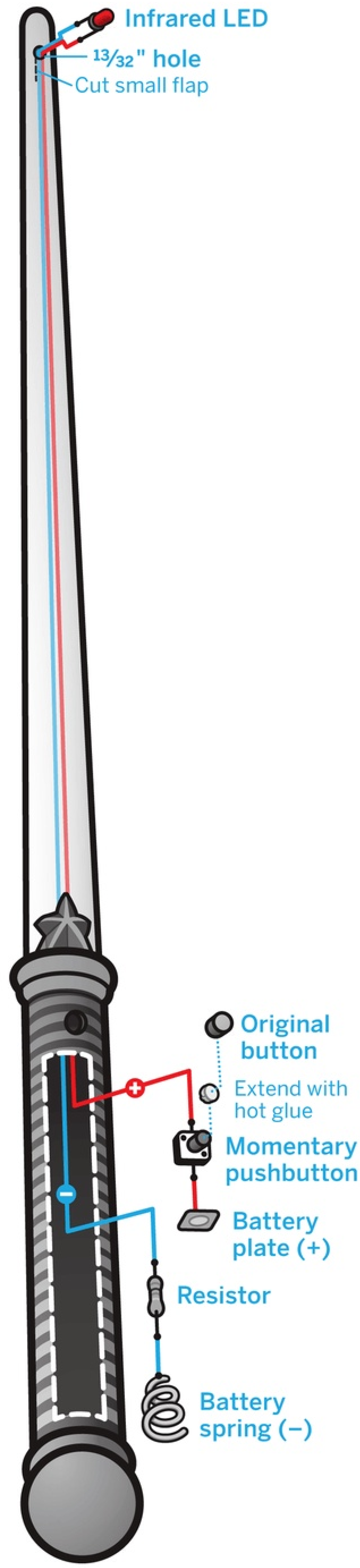
Going Further

What can you do with your IR saber? Anything your computer can do, except bigger, better, and more badass. Create a free PC theremin, play chess or solitaire on your wall, or browse family photos and internet videos. Have a fake laser battle with your kids, teach a class, or give a presentation. You can even build two IR sabers and do multipoint whiteboard control.

I show how to set up my Smoothboard system in my videos at youtube.com/user/Shakespeare1612, and there are lots of tutorials and software online for similar "Wiimote whiteboard" setups. Enjoy!

JAMES MCLAIN
was born and raised a good Catholic boy in the San Fernando Valley. He has a theater B.A. from Cal State Northridge and an electronics A.A.S. from ITT Tech. He loves video games, unicycle riding, juggling, biking, and road trips, and he lives in Santa Monica, Calif., where he runs Whalebone IR and Software (whaleboneir.com) out of his spare bedroom.

See build photos and show us your sabers at makezine.com/wiimote-whiteboard-ir-saber
Share it: ***#wiimotewhiteboardirsaber***



Vintage Bulb Lamp

Switch on the nostalgic glow with this dimmable, modern table lamp.

Written by Larry Cotton ■ Photography by Phil Bowie and Larry Cotton

LARRY COTTON is a semi-retired power-tool designer and part-time math instructor who loves music, computers, electronics, furniture design, birds, and his wife — not necessarily in that order.

HAVE YOU NOTICED A GROWING PLETHORA OF VINTAGE LIGHT BULB COPIES HANGING IN RESTAURANTS AND OTHER HIP VENUES? Let's add to that nostalgic glow this table lamp that's dimmable from a very bright reading lamp to a warm mood light.

It's made mostly of wood. I like walnut, and I happened to have a couple chunks, but any attractive hardwood will do. Electrical supply houses have the sockets and dimmer switch, and bulbs are readily available on the web.

My configuration uses three vintage bulbs — a 60-watt bulb in the center with 30-watters at each end, in porcelain sockets. Of course, feel free to alter the design and dimensions to your preference.

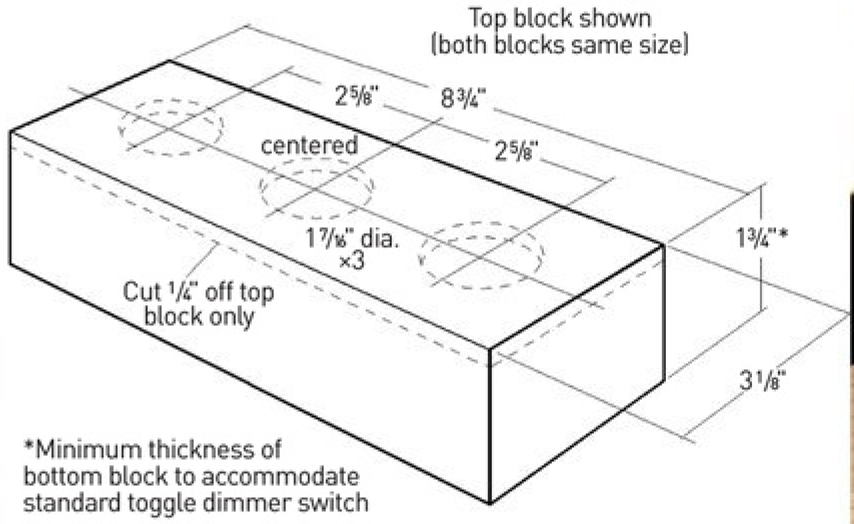
1. Make the parts.

1a. Before cutting anything, ensure the bandsaw blade is sharp and perpendicular to the table surface. Cut 2 hardwood blocks as shown in the diagram, then plane or sand them to the same size, and label each lightly with a pencil.

CAUTION: WEAR A NEW, QUALITY MASK WHEN WORKING WITH WOOD. SINCE SAWDUST, ESPECIALLY FROM HARDWOODS, CAN BE IRRITATING, KEEP THE MASK ON WHILE ANY DUST IS IN THE AIR. TO LEARN MORE, SEE MAKEZINE.COM/GO/WOOD-ALLERGIES.

1b. In one pass with the bandsaw, cut about ¼" off

Block Layout



one of the larger faces of the top block. This piece will be the top of the lamp, so make sure you like its appearance.

Don't sand the cut surfaces; later you'll glue them together in the same relative positions, leaving an almost invisible joint.

1c. Next you'll drill the socket holes in the top. If you're deviating from my configuration, space the holes to accommodate your bulbs and sockets; bulbs should clear each other by at least ¼" at their widest points.

Drill the socket holes with a circle cutter about 1 7/16" diameter to clear the 1⅜" diameter sockets. Grip the lamp top tightly and lower the bit slowly, for safety and clean appearance. Beware the circle cutter arm!

1d. Make the socket mounting platform, following the diagram. I used an old scrap of ⅜"-thick painted board.

Trace its shape onto the top block.

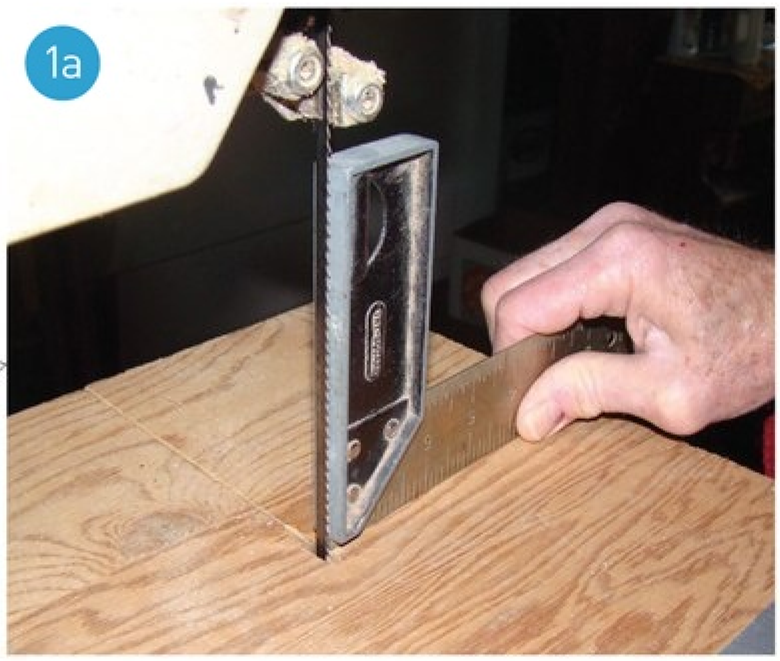
1e. Bandsaw a slot in one end of the top block, and cut out the inside to your traced outline. You'll fill the slot later.

Check that the platform fits into the cutout. You should now have the parts shown in **Figure 1e** (on following page).

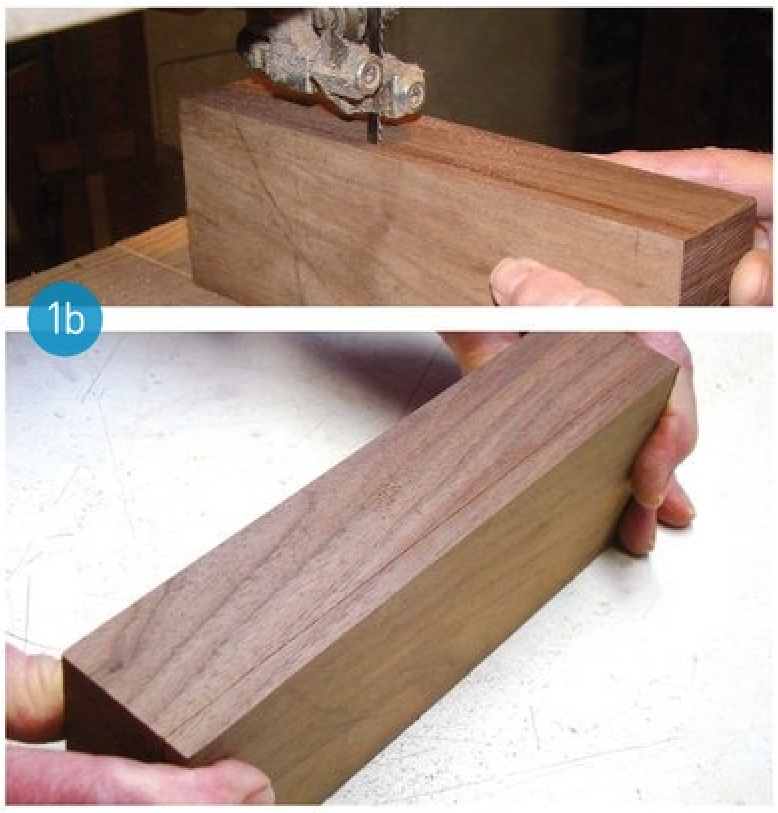
1f. Position the top block and its top together, in the same way you cut them. Glue them together, using lots of clamps to ensure a virtually invisible joint. When the glue is dry, unclamp and sand (**Figure 1f**).

1g. Chuck a ¼" rounding-over bit in your router and clamp it upside down in a vise, or use a router table if you have access to one. Round the outside edges and corners of both blocks, but not the surfaces that meet in the middle, which must stay flat (**Figure 1g**).

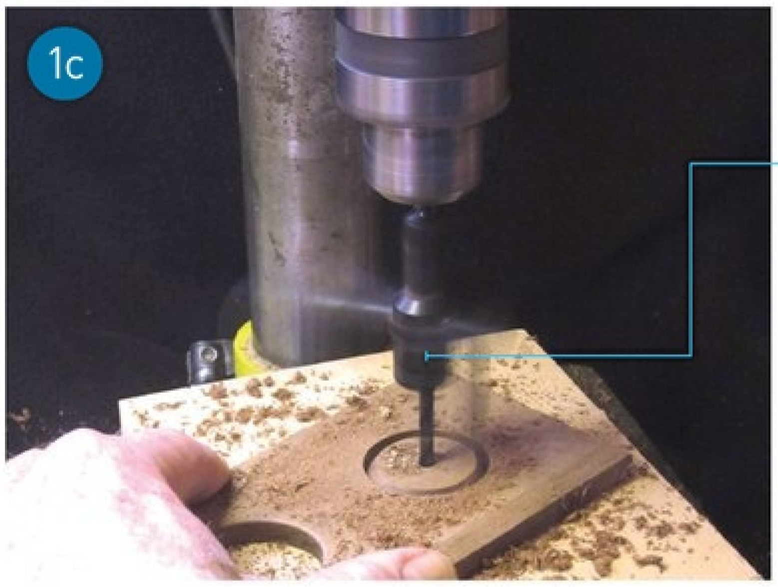
1a



1b

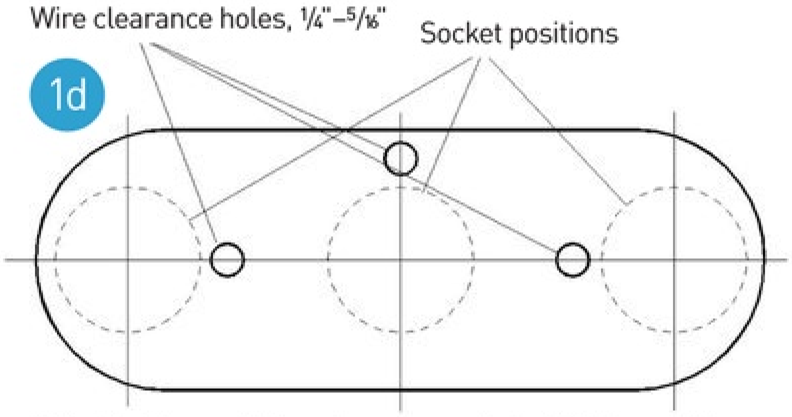


1c



Socket Mounting Platform

1d



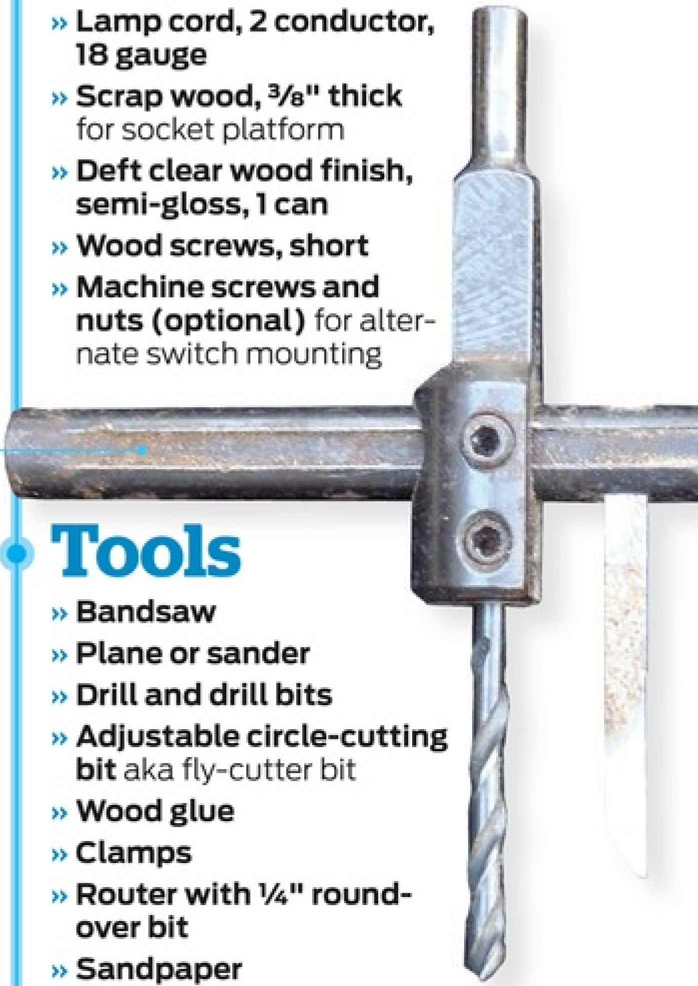
2½"×7" with rounded ends accommodates 3 vintage bulbs. Thickness can vary depending on socket length; we used ⅜ but you can laminate ⅛" pieces to achieve your desired socket protrusion.

Time Required:
A Day
Cost:
$50–$75

Make a beautiful and practical monument to that endangered species, the incandescent bulb.

Materials

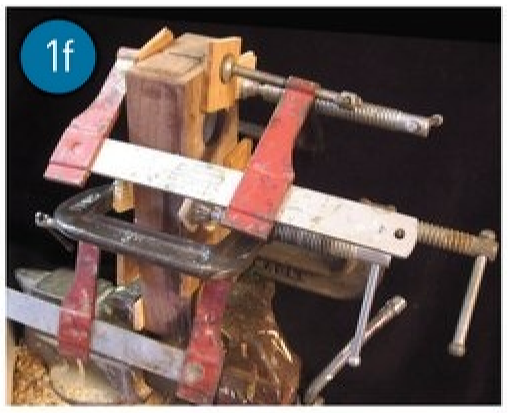
- **Hardwood block, at least 8¾"×3⅛"×3½" thick**
- **Lamp sockets, porcelain, switchless (3)** such as Lowe's #34550
- **Lamp bulbs, vintage style: 60W (1) and 30W (2)** such as #IN-L4099 and IN-L2780 from 1000bulbs.com. For a list of other suitable bulbs and online vendors, see the project page at makezine.com/vintage-bulb-lamp.
- **Dimmer switch, toggle, 600W incandescent** such as Lowe's #315352
- **Wire connectors, ⅞" long × ½" OD (3)**
- **Self-adhesive foam sheet, 9"×12"×0.083"** I used Cre-atology foam from Michaels.
- **Lamp cord, 2 conductor, 18 gauge**
- **Scrap wood, ⅜" thick** for socket platform
- **Deft clear wood finish, semi-gloss, 1 can**
- **Wood screws, short**
- **Machine screws and nuts (optional)** for alternate switch mounting



Tools

- **Bandsaw**
- **Plane or sander**
- **Drill and drill bits**
- **Adjustable circle-cutting bit** aka fly-cutter bit
- **Wood glue**
- **Clamps**
- **Router with ¼" round-over bit**
- **Sandpaper**
- **Paintbrushes**
- **Jigsaw**
- **File**
- **Screwdrivers**
- **Particle mask for wood dust**
- **Masking tape**

CAUTION: SET THE BANDSAW'S TOP BLADE GUIDE TO JUST CLEAR THE WOOD (SOME PHOTOS SHOW IT HIGHER FOR CLARITY).



1h. Glue a thin, slightly protruding wedge into the slot in the top block. Let the glue dry, and then sand it flush.

1i. On the bottom block, bandsaw a slot in the middle of one of the longer sides. Continue cutting a cavity to clear the switch and wiring in approximately the shape shown here. Ensure you have good surfaces to mount the switch plate.

1j. Drill a 7/32" hole in the middle of the side slot, then enlarge it to 1/4". With a jigsaw and file, enlarge the hole to a 7/8"×1/4" cutout to clear the switch toggle.

Carefully bandsaw a recess on the inside wall to bring the toggle farther out, keeping the wall 1/8" thick for about 1". Check that the switch fits, with its wires nearer the top of the opening.

1k. Drill a 1/4" or 5/16" cord hole into the wiring cavity, missing the switch plate, as shown.

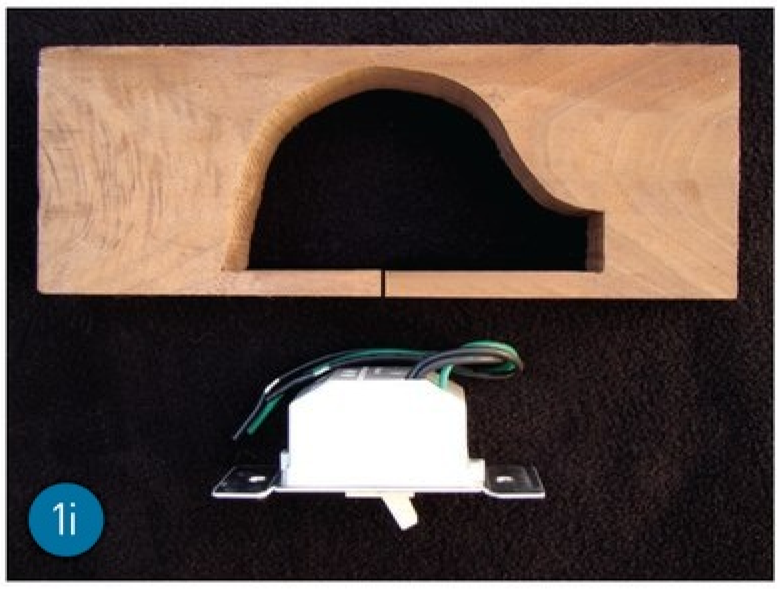
1l. Bandsaw 4 small slots in the switch mounting plate as shown.

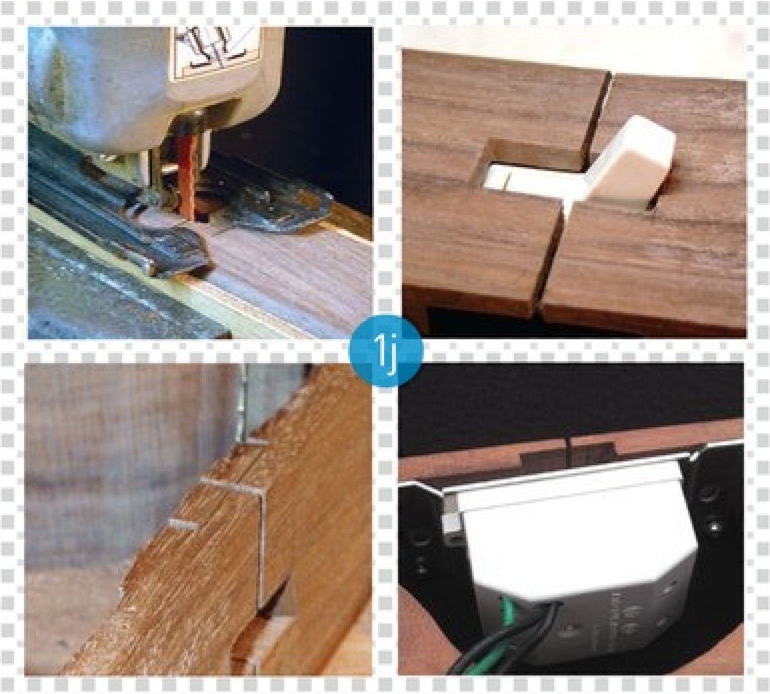
1m. Fine-sand both blocks and finish with Deft clear wood finish, lightly sanding between coats.

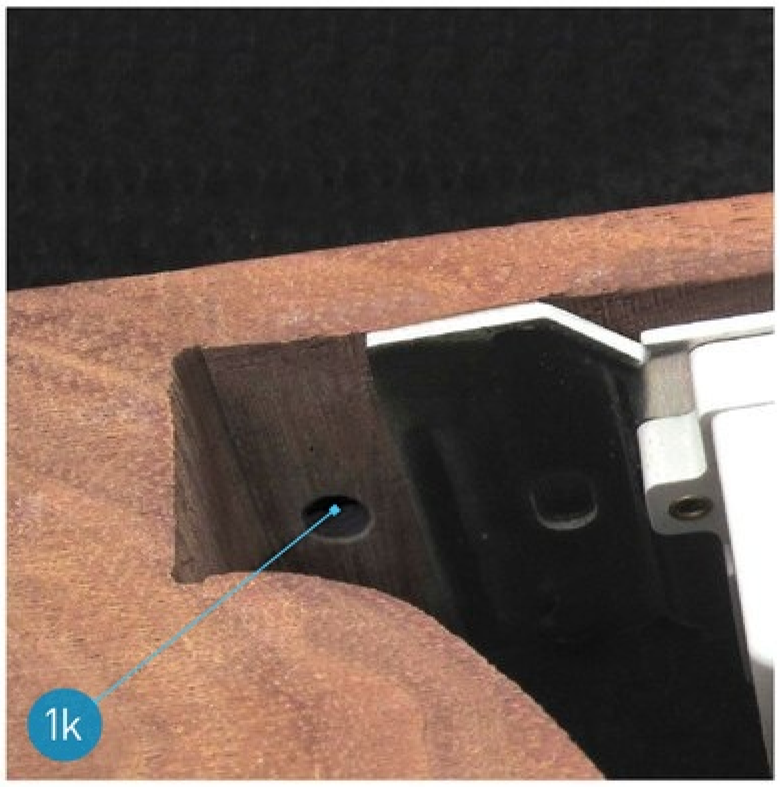
2. Assembly.

2a. Mount the switch in the bottom block using 4 small wood screws from the inside, aligned with the slots you cut in the plate. Don't allow the screw heads or switch plate to protrude from the block. (Alternately, if you don't mind screw heads showing, you can mount the switch with 2 machine screws and nuts using its original mounting holes.)

2b. Set the socket-mounting platform on the flat, top face of the bottom block. Remove the brackets (they're known as hickeys) from the







sockets as shown here and set the sockets on top of the platform.

Drop the top block in place to help locate everything. Mount the platform with 2 diagonal screws.

2c. Locate the sockets' positions on the platform and drill wire-clearance holes so that wires can pass into the cutout without hitting the switch below. Pass the socket wires through the holes.

2d. With both wood blocks taped together to keep them in alignment, attach the sockets with wood screws through the hickey mounting holes. The middle screw must not protrude through the mounting platform; it could hit the switch.

CAUTION: FOLLOW SAFE ELECTRICAL PROCEDURES FOR WIRING.

2e. From the bottom, wire the lamp following the diagram here. Some wires may need to be cut shorter. Tie a knot in the cord inside the wall for strain relief. Use wire connectors on all wire splices.

2f. Add 2 thin strips of self-adhesive foam to the bottom as feet.

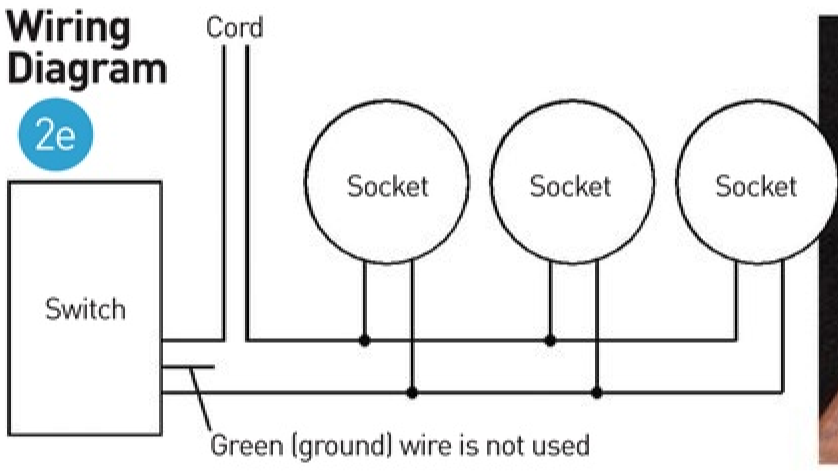
2g. Add 4 more strips around the top edge of the bottom block as a spacer.

2h. Drop the top block onto the bottom one. It isn't fastened in place, but the sockets and mounting platform will align it.

2i. Screw the bulbs in and you're done!

For more build photos, and sources for vintage bulbs, go to makezine.com/vintage-bulb-lamp

Share it: ***#vintagebulblamp***



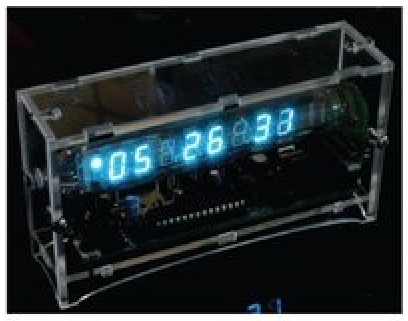
More Illuminating Projects at makezine.com/projects

Little Big Lamp

Build a bright, energy-efficient lamp with LEDs and PVC, in this popular project from MAKE contributing editor Charles Platt.

Pop Top Lamp Shade

Make "chain mail" from soda can tabs, using this technique invented by MAKE technical editor Sean Michael Ragan.



Ice Tube Clock Kit

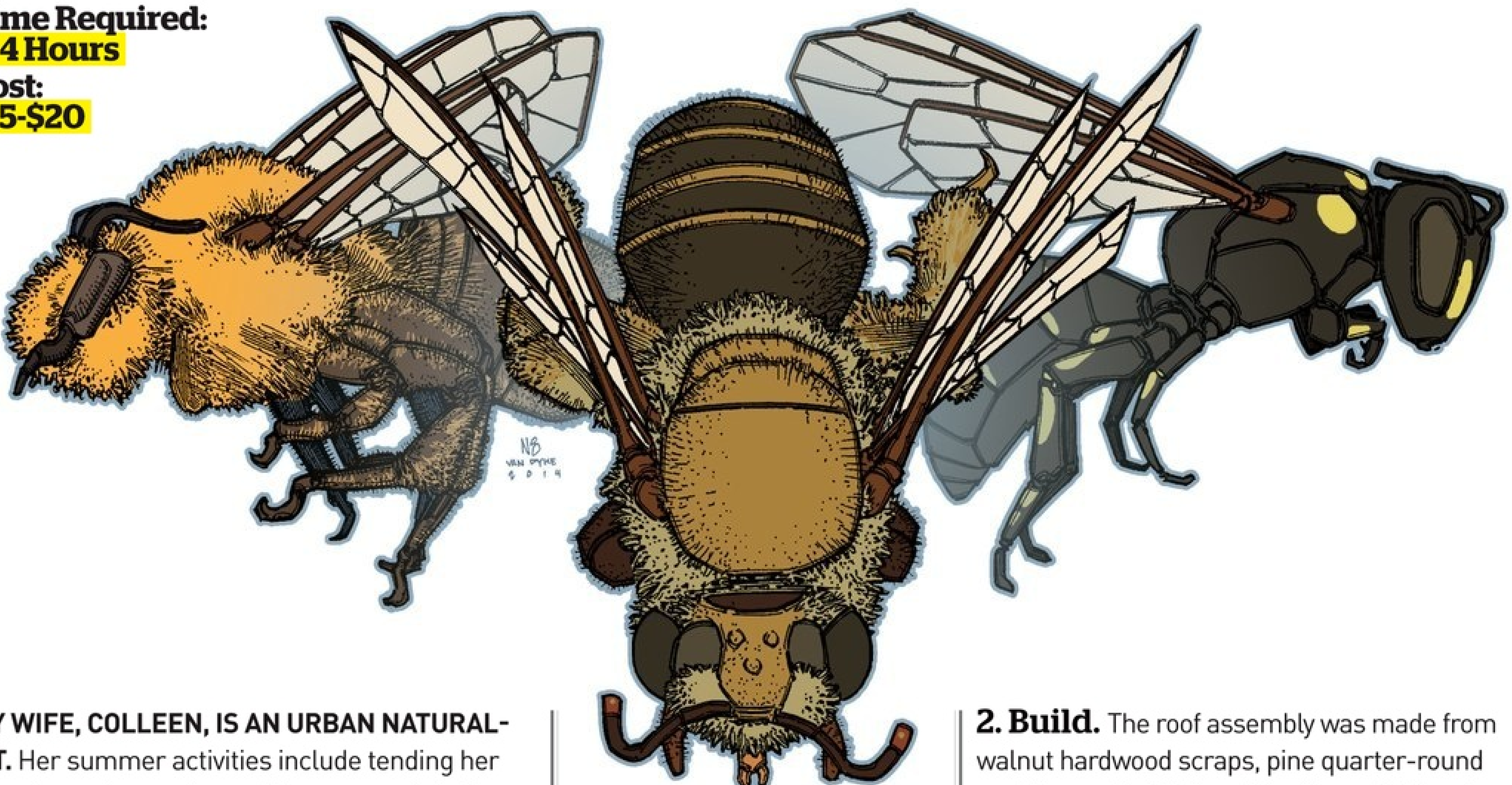
Nixie tubes are so 1963. This retro clock kit shows off a cool blue Russian-made, 9-digit vacuum fluorescent display (VFD) from the 1970s and 80s. Maker Shed item #MKAD16, makershed.com

Solitary Bee Condos

Build a passive-solar, backyard habitat for native solitary bees.

Written by Ken Vickerson

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



Nate Van Dyke

MY WIFE, COLLEEN, IS AN URBAN NATURALIST. Her summer activities include tending her amazing native garden, raising monarch butterflies, and lately, building condos for solitary bees — bees that nest independent of a colony. Of the 4,000 species of bees native to North America, over 1,000 are tunnel-nesting bees — they lay their eggs, provision them, and seal the entrance inside natural tunnels such as hollow plant stems and insect bore holes. Not every native bee is a solitary bee, and not every solitary bee is a tunnel nester.

Native bees are important pollinators and make a significant contribution to agriculture. Non-native species, such as the European honeybee, have been employed commercially to pollinate crops but have, in recent years, been subject to devastating diseases. The type of native bees attracted to your bee condo depends largely on where you live. In Toronto, our condos attract mainly cellophane, masked, mason, and leafcutter bees.

1. Design. The most popular styles of solitary bee homes are nesting blocks and stem bundles. A nesting block is a wooden block with a series of blind holes drilled parallel to the grain with a sharp drill bit. (Bees like smooth holes and won't lay eggs in an open-ended tunnel.) A stem bundle is just what it sounds like: a series of tubes sealed on one end, either lashed together or held in a container. I've chosen the latter for this project.

KEN VICKERSON
is an associate professor in the Faculty of Design, and chair of the Material Arts & Design program at OCAD University in Toronto.

2. Build. The roof assembly was made from walnut hardwood scraps, pine quarter-round molding, and a ⅜" dowel for the roof ridge, then treated with 3 coats of tung oil to weatherproof it. The roof keeps the stem bundle dry, discouraging fungal growth that can kill the bees.

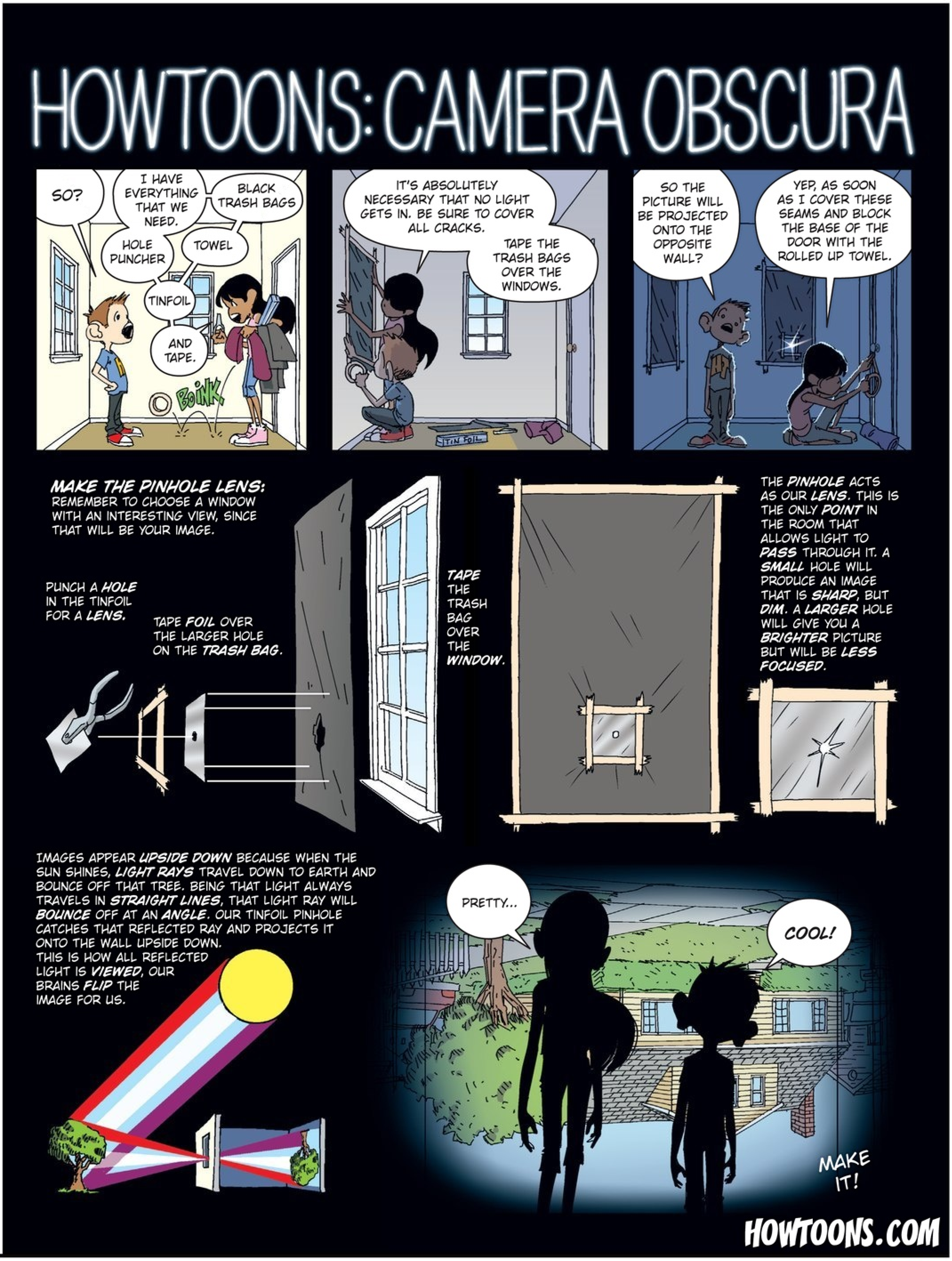
The bundle container is a discarded nut can (a plastic bulk CD container also works well) spray-painted black to warm up more quickly in the morning and retain heat during the day (this is the passive-solar aspect). Bees are cold-blooded, and the morning sun gets them up to operating temperature.

Inside, I'm using untreated bamboo garden stakes, but most any small-diameter tubes can be used. Cut the bamboo just behind the node (the swollen part that the leaf grows from), as there is a dividing wall at this point that will form the closed back end of the stem. Pack the bamboo stems into the container for a friction fit.

3. Mount and maintain. Bee houses should be located on the east side of the house and sheltered from the rain. (In hot climates, a north-facing location might be better.) After a couple of seasons, disinfect your bee house to prevent the spread of parasites and fungal disease.

For step-by-step photos, more build details, and pollinator resources, visit makezine.com/solitary-bee-condos.
Share it: ***#solitarybeecondos***

Ken Vickerson


HOWTOONS: CAMERA OBSCURA
SO?
I HAVE EVERYTHING THAT WE NEED.
BLACK TRASH BAGS
HOLE PUNCHER
TOWEL
TINFOIL
AND TAPE.
BOINK
IT'S ABSOLUTELY NECESSARY THAT NO LIGHT GETS IN. BE SURE TO COVER ALL CRACKS.
TAPE THE TRASH BAGS OVER THE WINDOWS.
TIN FOIL
SO THE PICTURE WILL BE PROJECTED ONTO THE OPPOSITE WALL?
YEP, AS SOON AS I COVER THESE SEAMS AND BLOCK THE BASE OF THE DOOR WITH THE ROLLED UP TOWEL.
MAKE THE PINHOLE LENS: REMEMBER TO CHOOSE A WINDOW WITH AN INTERESTING VIEW, SINCE THAT WILL BE YOUR IMAGE.
PUNCH A HOLE IN THE TINFOIL FOR A LENS.
TAPE FOIL OVER THE LARGER HOLE ON THE TRASH BAG.
TAPE THE TRASH BAG OVER THE WINDOW.
THE PINHOLE ACTS AS OUR LENS. THIS IS THE ONLY POINT IN THE ROOM THAT ALLOWS LIGHT TO PASS THROUGH IT. A SMALL HOLE WILL PRODUCE AN IMAGE THAT IS SHARP, BUT DIM. A LARGER HOLE WILL GIVE YOU A BRIGHTER PICTURE BUT WILL BE LESS FOCUSED.
IMAGES APPEAR UPSIDE DOWN BECAUSE WHEN THE SUN SHINES, LIGHT RAYS TRAVEL DOWN TO EARTH AND BOUNCE OFF THAT TREE. BEING THAT LIGHT ALWAYS TRAVELS IN STRAIGHT LINES, THAT LIGHT RAY WILL BOUNCE OFF AT AN ANGLE. OUR TINFOIL PINHOLE CATCHES THAT REFLECTED RAY AND PROJECTS IT ONTO THE WALL UPSIDE DOWN. THIS IS HOW ALL REFLECTED LIGHT IS VIEWED, OUR BRAINS FLIP THE IMAGE FOR US.
PRETTY...
COOL!
MAKE IT!
HOWTOONS.COM

Experimenting with Light and Dark SENSORS

Use photoresistors, phototransistors, and photodiodes to make simple, powerful sensors for your projects.

Written by Forrest M. Mims III

Gunther Kirsch

Time Required: **1-2 Hours**

Cost: **$10-$30**

Easy, inexpensive circuits to give your projects sensitive "electric eyes."

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 more than 7 million copies.

Materials

Photoresistors, **phototransistors**, and **photodiodes** are available from RadioShack, Jameco, Digi-Key, Mouser, and many other sources.

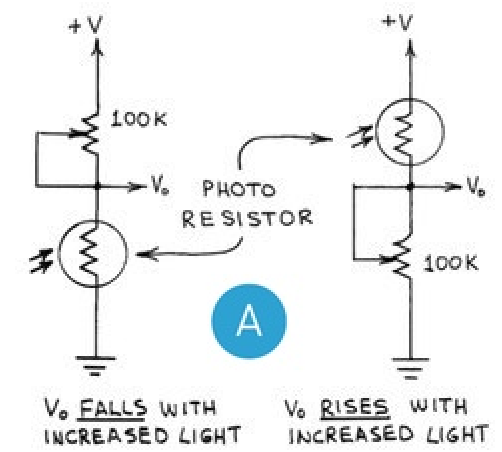
- » **Solderless breadboard**
- » **Power supply, 5V–15V** You can use a variable benchtop power supply or just a 9V battery with leads.
- » **Photoresistors, CdS type**
- » **Phototransistors**
- » **Photodiodes**
- » **Potentiometers, 100kΩ**
- » **(2)**
- » **Resistors: 1kΩ (2), 10kΩ (1), 10MΩ (1)**
- » **Integrated circuit (IC) chip, 555 timer**
- » **Integrated circuit (IC) chip, TLC271 op-amp**
- » **Speaker, 8Ω**
- » **Capacitors: 0.2μF (1), 1μF (1), 10μF (2), 200pF (1)**
- » **LEDs (2)**

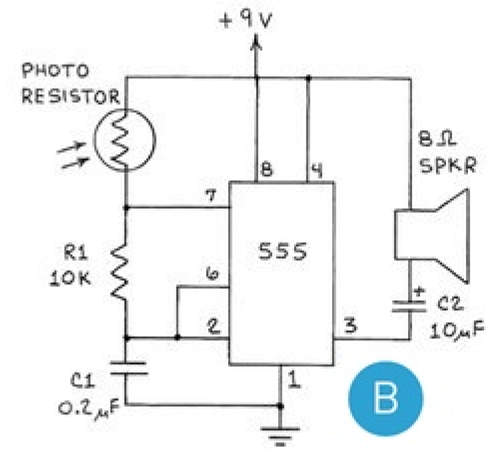
ROBOTICS, MANUFACTURING, INTRUDER DETECTION, AND SIGNALING. Dark-activated street lamps. Infrared remote control. These are just a few applications for electronic circuits that detect light. You can quickly learn to use a wide variety of semiconductor light sensors by plugging simple circuits into a solderless breadboard.

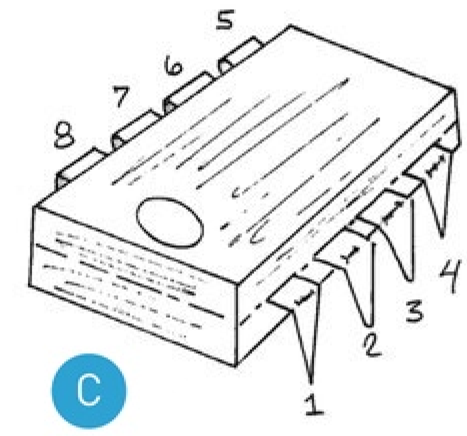
PHOTORESISTORS

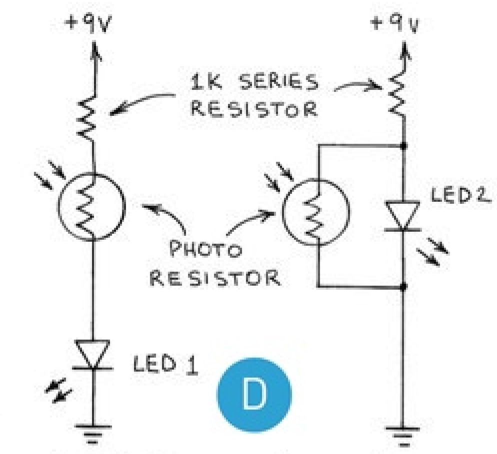
Photoresistors, also known as *photocells*, are inexpensive 2-lead devices with a light-sensitive film commonly made from cadmium sulfide (CdS). When dark, photoresistors have a high resistance, which light greatly reduces. You can connect an ohmmeter to a photoresistor to see how its resistance changes with light. **Figure A** shows how to convert changes in photoresistance into a voltage by means of simple voltage divider circuits. Both circuits use a potentiometer to calibrate the output voltage.

Photoresistors can be connected in either direction without regard to polarity, so they're easy









PHOTORESISTOR	LED 1	LED 2
LIGHT	ON	OFF
DARK	OFF	ON

to use. Their main drawback is that they respond more slowly than other kinds of light sensors.

Most CdS photoresistors respond from around 400nm in the violet to 750nm in the near infrared, much like the human eye (400nm to 700nm).

An Ultra-Sensitive Photoresistor Light Sensor

A simple 555 integrated circuit pulse generator like the one in **Figure B** is a good way to appreciate the high sensitivity of a CdS photoresistor. You can assemble it on a breadboard in minutes. **Figure C** shows the pin outline for the 555 IC.

Place the circuit in a dark room. The speaker will emit a click every few seconds. When you aim a flashlight near the CdS cell, the resistance of the photoresistor will decline, causing the interval between clicks to become briefer. With more light, the clicks will merge into a buzz or tone. If it's too loud, increase C2 to 1μF or 10μF.

Make Photoresistor Dark and Light Sensors

Photoresistors are ideal sensors for nightlights. The left circuit in **Figure D** activates LED1 when light strikes a photocell; the right circuit switches off LED2 when the photocell is illuminated.

PHOTOTRANSISTORS

In a *phototransistor*, light acts like a signal applied to the base of an ordinary transistor: It modulates a much larger current flowing between the collector and emitter. **Figure E** shows the emiter and collector leads of a typical epoxy-encapsulated phototransistor; they're easily confused with LEDs. Some phototransistors also have a base lead to allow their sensitivity to be adjusted by an external voltage divider. Phototransistors can often be substituted for photoresistors in low-voltage applications so long as proper polarity is observed.

Phototransistor Dark/Light Sensors

The photoresistors in **Figure D** can be replaced by phototransistors, as shown in **Figure F**. Note that the phototransistors must be installed in the correct direction.

PHOTODIODES

Light-sensitive *photodiodes* are made from a thin wafer of silicon having a much larger surface area than a standard diode in order to capture as much light as possible. They respond best to near-infrared light around 800nm–900nm. They also respond to visible light down to around 400nm.

Photodiodes generate a small electrical current that's generally linear with respect to the intensity of incoming light. This is the *photovoltaic* operating mode, and it is ideal for light meters. Photodiodes can also be operated in the *photoconductive* mode, in which a voltage is applied across a reverse-connected photodiode in series with a resistor. While this mode provides much faster response to light than the photovoltaic mode, it is less sensitive.

Solar cells and LEDs can double as photodiodes. (To use LEDs as detectors, see makezine.com/how-to-use-leds-to-detect-light.)

An Ultra-Sensitive Photodiode Light Sensor

Figure G shows how to use a photodiode to detect very low levels of light. This circuit uses an operational amplifier connected as a *transimpedance amplifier* that transforms a tiny photocurrent from the photodiode into a proportional output voltage. C1 prevents oscillation and should be around 200pF when resistor R_f is a few megohms. The gain of the circuit equals the feedback resistance in ohms (R_f). Thus, an R_f of 10,000,000 ohms will provide a gain of 10 million. Not all op-amps will provide this much gain. Among those that do is the TLC271 family from Texas Instruments.

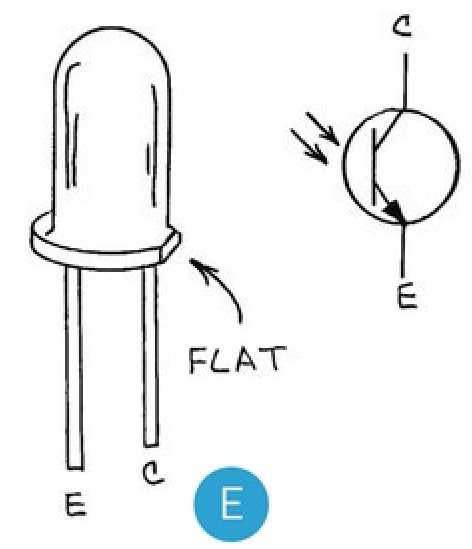
Going Further

The best way to learn more? Build some simple circuits and see how they work. You'll soon find ways to enhance your projects with a light sensor or two.

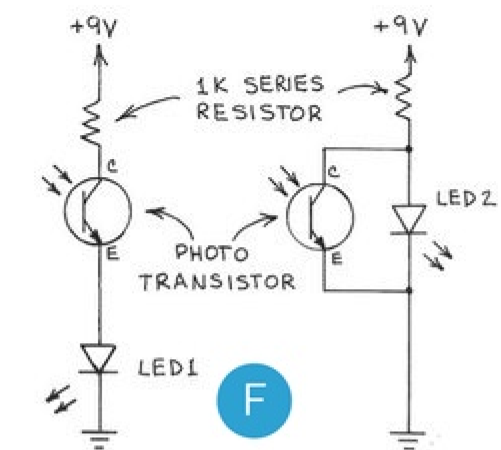
AMATEUR SCIENTIST

How will you use light sensors? Share at makezine.com/light-and-dark-sensors

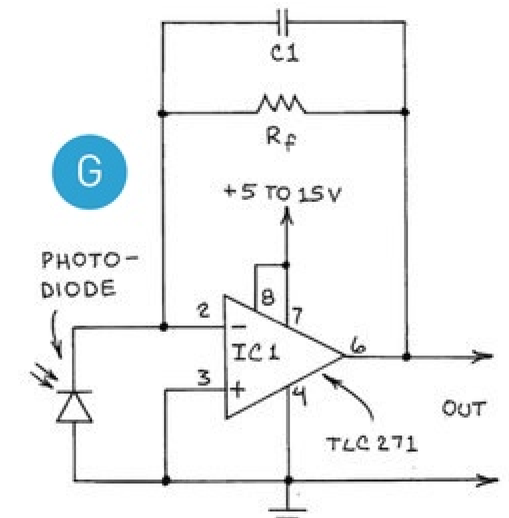
Share it: ***#lightdarksensors***



TIP: TO AVOID MIXUPS, MARK YOUR LEDS WITH COLORED DOTS, AND MARK THE ENTIRE BASE OF YOUR PHOTOTRANSISTORS BLACK.



PHOTOTRANSISTOR	LED 1	LED 2
LIGHT	ON	OFF
DARK	OFF	ON



DIY Sriracha "Rooster" Sauce

Impress your chili-head friends by busting out this homemade Sriracha-style hot sauce!

Written by Lisa Trifiro

Gunther Kirsch

Time Required: 9 Days
Cost: $5–$10

Ingredients

- **1¾ lbs ripe red chili peppers: Fresno, jalapeño, or serrano** I used Fresno peppers here. Serranos are hotter.
- **3 Thai chili peppers** for extra heat. Increase or decrease to taste.
- **3 cloves garlic**
- **2 Tbsp garlic powder**
- **2 Tbsp granulated sugar**
- **1 Tbsp light brown sugar**
- **1 Tbsp salt**
- **½ cup distilled white vinegar**
- **Water** as needed
- **Vegetable oil (optional)**
- **Fish sauce (optional)**

Tools

- **Gloves**
- **Glass jar, wide mouth, 2lb or 1qt**
- **Bottles or jars** For cool swing-top bottles, try specialtybottle.com. Also check out Cost Plus World Market, and a special Sriracha bottle from Etsy seller Libation Lab.
- **Funnel**
- **Strainer, metal**
- **Saucepan**
- **Food processor**
- **Wooden spoon**

LISA TRIFIRO is a self-taught chef and entrepreneur whose recipes have run in *Bon Appetit* and *The Huffington Post*. She built and sold a company dealing in artisanal sugars and exotic salts, and she recently competed in the World Food Championships, Bacon Category.

SRIRACHA PEPPER SAUCE AS WE KNOW IT TODAY HAS BEEN POPULARIZED BY HUY FONG FOODS in California and their big bottle with the rooster logo and bright green cap. The traditional Thai sauce, *nam phrik si racha*, has a rich history of its own. Here's a version you can make in your own kitchen. I adapted the recipe from *The Sriracha Cookbook* by Randy Clemens. It's not as spicy as the Huy Fong version, but you can adjust the heat to taste. It's got a great, addicting flavor — hot, sweet, and garlicky — and just like the real "rooster sauce," it tastes awesome on just about anything. Next time, I might try red serranos and a few extra Thai chilies to up the Scoville factor!

1. Prep the peppers and garlic. Stem and halve the peppers. That's it! You'll strain the seeds out later. Peel the garlic cloves.

2. Puree. In your food processor, add peppers, granulated sugar, garlic powder, garlic, brown sugar, and salt. Pulse until a coarse puree forms.

3. Stir daily. Transfer the mixture to a 1qt glass jar and seal. Store jar at room temperature.

Stir daily for 7 days. This creates a mild fermentation that lets the flavors develop.

4. Boil and simmer. Combine pepper mixture and vinegar in a saucepan over medium heat. Bring to a boil, then lower heat and simmer gently for 5 minutes. Let cool completely.

5. Strain and taste. Strain the sauce well through a metal strainer, then adjust to taste. You can add salt, garlic powder, vinegar, sugar, or even a little fish sauce. I added a bit of veggie oil to improve "mouthfeel."

6. Bottle and enjoy!

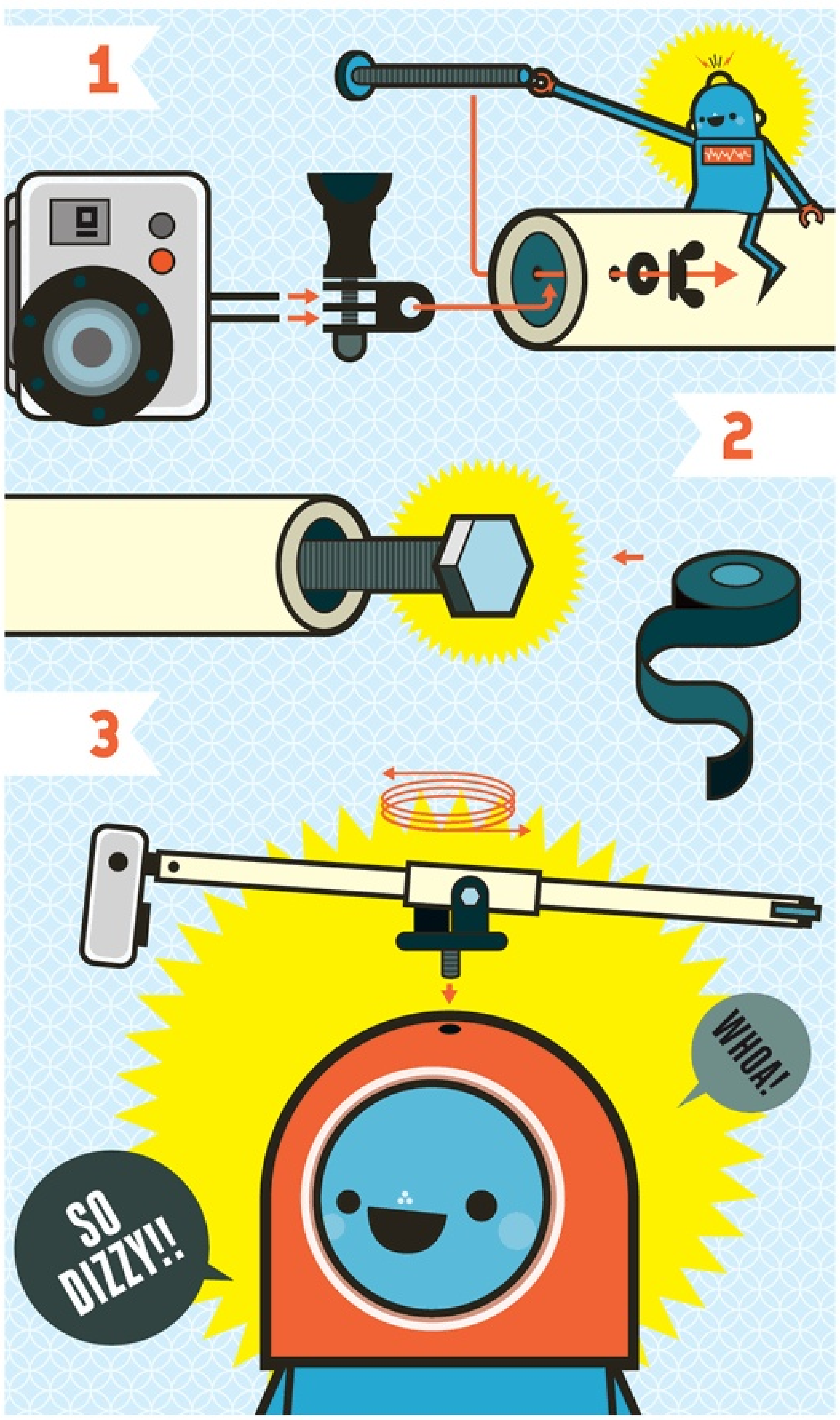
Get more photos, tips, and share your recipe tweaks at makezine.com/projects/diy-sriracha
Share it: ***#diysriracha***

Dual Chili Extruder

Can't get enough rooster? Try 3D-printing this twin nozzle from Thingiverse user Moko of Melbourne, Australia. "Double the nozzles for twice the spiciness in half the time!" thingiverse.com/thing:153580

1 2 3 GoPro Swivel Camera Mount

Written by Jake Spurlock ■ Illustrations by Julie West ■ Photos by Gunther Kirsch



For build details and videos of the GoPro Swivel Camera Mount in action, visit makezine.com/gopro-swivel-camera-mount.

SHARE *#goproswivelcameramount*

WATCHING A GOPRO VIDEO THE OTHER DAY, I SAW A CLIP WHERE THE CAMERA SPUN AROUND A SKIER'S HEAD. My jaw hit the floor, and I began to speculate about how the camera move was made. My brother Ty tipped me off to a shadow, which showed a helicopter-like helmet attachment. The camera was mounted on a caster-type mount, allowing the camera to spin around the skier. I had to build one, and I managed to do it with one trip to the hardware store and about 20 minutes in the garage.

1. Drill your holes

Drill a ¼" hole ½" from one end of the 24" PVC pipe. This will be the mount for the camera. » Insert a carriage bolt through the hole and attach the GoPro 3-Way Pivot Arm, with a washer and wing nut on the other side. If the bolt doesn't fit, use the ¼" drill bit to widen the hole in the pivot arm. » Drill a ¼" hole through the center of the PVC coupling.

2. Prepare the counterweight and the caster

Insert the heavy bolt into one end of the 18" PVC pipe and secure with electrical tape. » Remove the wheel from the swivel caster with a Dremel, hacksaw, or angle grinder. » Attach the caster to the PVC coupler with a carriage bolt, washer, and wing nut. Play with the tightness. You might want it looser for more movement in your shots. I prefer it tight, locking down the camera angle.

3. Assemble

Connect the 18" and 24" pipes into the PVC coupling. » Insert the caster into the hole in the top of the helmet. If needed, secure with an appropriate nut on the inside. Mine fits pretty tight in the top vent of my Pro-Tec bike helmet. » Attach the camera to the mount and shoot away!

JAKE SPURLOCK (jspurlock@makermedia.com) is a web developer at MAKE, a geek, a designer, and a dad. He is also a taker of photos and can often be found skiing and biking.

You will need:

- **PVC coupling, ¾"**
- **Carriage bolts, 1¾"×¼" (2)**
- **Wing nuts, ¼" (2)**
- **Washers (2)**
- **Swivel caster** Ideally, one with a single bolt
- **PVC pipe, ¾": 24" length (1), 18" length (1)**
- **Bolt, long and heavy** for the counterweight
- **Electrical tape**
- **GoPro camera with 3-Way Pivot Arm**
- **Skate, snow, or bike helmet** with small round vent hole in the top center
- **Drill press**
- **Dremel tool, hacksaw, or angle grinder**

Marie Kaziunas

CNC Maker Bench

Create custom, open-source CNC tables for your workshop using AtFab's parametric program — or just download and fabricate MAKE's design.

Written by Anna Kaziunas France

Time Required: 2 Weekends
Cost: $100–$180

ANNA KAZIUNAS FRANCE is the digital fabrication editor at MAKE. She's also the dean of students for the Global Fab Academy program, the co-author of *Getting Started with MakerBot*, and the editor of the book *Make: 3D Printing*.

WHERE TO GET CNC ACCESS?

All over the world, there are FabLabs, makerspaces, hackerspaces, and TechShops where you can access a large CNC router. Costs vary widely; at AS220 Labs, where I cut these files, 2 hours of machine time was just $25. You can also have independent fabricators like *Fabhub* and *100kGarages* cut the files for you.

Find a machine near you: makezine.com/where-to-get-digital-fabrication-tool-access

WE HAD JUST MOVED INTO MAKE'S OFFICE IN PROVIDENCE, AND WE NEEDED FURNITURE. I decided to create a set of standing-height plywood workbenches to house our 3D printers and other CNC machines. I have access to a large CNC router, and I wanted to design custom tables tailored to my measurements. And I prefer to stand when I'm wrenching on machines, rather than sitting in a desk chair.

So I used AtFab's parametric, open-source table configuration software (atfab.co) to create a table to my personalized ergonomic dimensions. I then adjusted the files in a CAD program, programmed the toolpaths, and cut the plywood on a ShopBot CNC router. Finally, the plywood was sanded and stained to give it the look of reclaimed, weathered wood, and then the bench was assembled by hand.

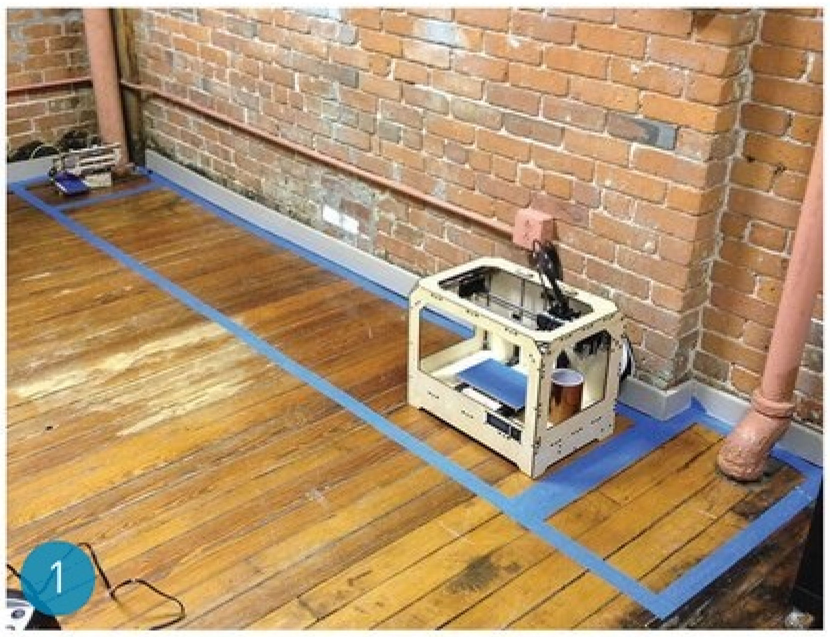
Depending on the tools and supplies on hand in your shop, you can build this CNC Maker Bench for as little as $100 unfinished, and up to about $180 nicely finished.

1. Measure your workspace

Mark off the area with masking tape, and check that light switches and other fixtures will still be accessible.

2. Make your ergonomic and design decisions

Where do your arms rest when you're standing? For good ergonomics, this table's height should be



1

at or just below your bent elbow height.

Determine the dimensions of your table and record them. You'll need to enter them into the AtFab parametric app. My table is 600mm wide, 1,520mm long, and 1,042mm high.

3. Procure your materials

I optimized my files for 18.5mm (3⁄4" nominal) plywood. Buy the nice veneer; it looks better and resists tearout during routing. Take care to get 2 straight sheets, without veneer gaps or "voids," from the same pallet if possible. And bring your calipers — if thickness varies radically (by say, a full millimeter), choose sheets that are closer to the same dimensions. For more tips, see the project page at makezine.com/cnc-maker-bench.

4. Measure your plywood (again)

Record each sheet's thickness at several points along its length and width. To ensure that your joints fit together, you'll input your maximum thickness measurement into the parametric app.

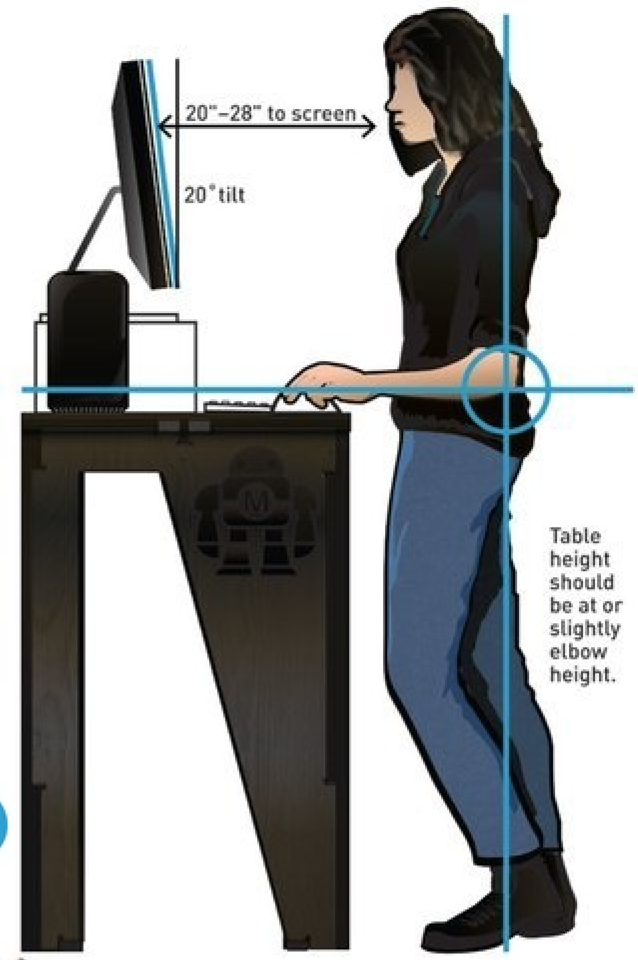
5. Create the CAD files

Now you'll actually design your table using computer-aided design (CAD) software. I used AtFab's Parametric "One to Several" Table program, which runs on the desktop in Processing. (It's slated to be available soon as an online app at the AtFab site.)

This table, created by award-winning architects Filson and Rohrbacher (filson-rohrbacher.com) can be configured into many different variations on the Processing app (**Figures 5a** and **5b**). You can also buy it preconfigured from atfab.co, along with 5 other furniture designs, or download those files for free from opendesk.cc/atfab.

Open the "One to Several" sketch in Processing, enter your values into the AtFab parametric design app (see **Chart A**, following page), and Save your custom design to a DXF file.

2



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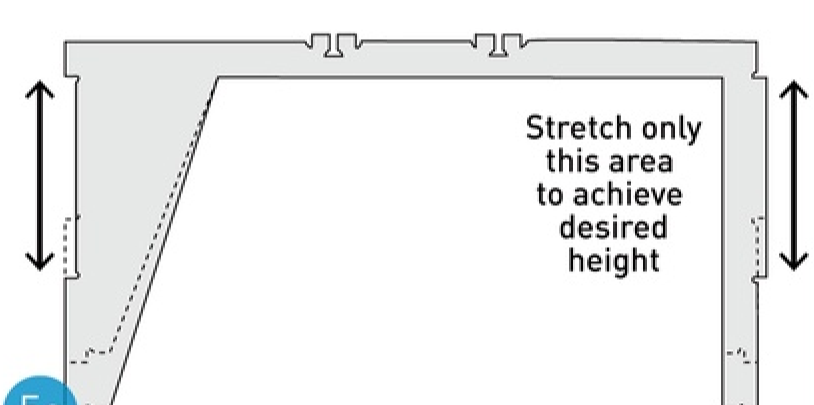
5a

5b

5c



Materials

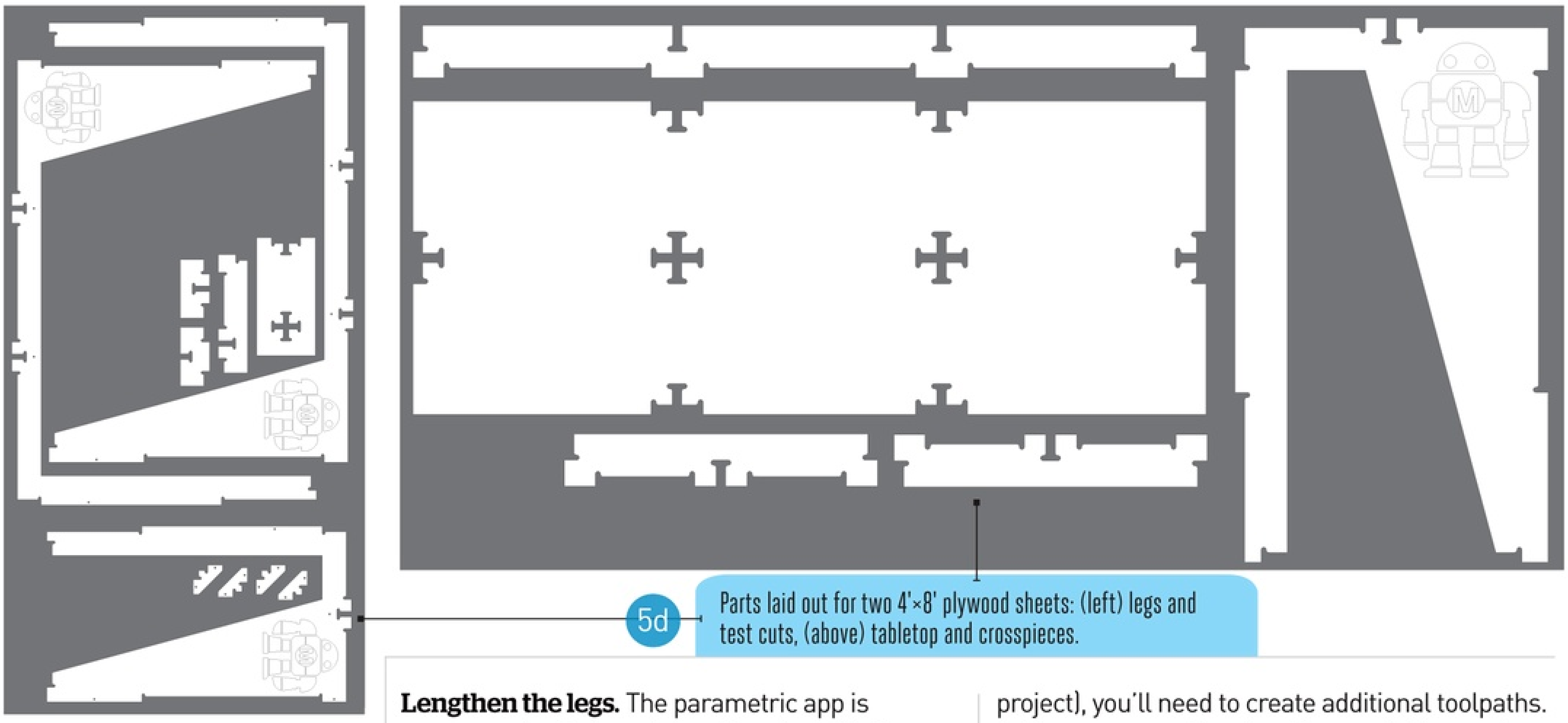
- **Plywood, 3⁄4" (18.5mm), 4'×8' sheets (2)** with a decent-looking veneer. I used Home Depot Pure Bond Plywood in birch ($48) and poplar ($40).
- **Sandpaper, 80 and 100 grit**
- **Tack cloth**
- **Dropcloth**
- **Rags**
- **Work gloves**
- **Wood screws** You can use dowels and glue for assembly, but our MAKE design uses #6 × 1⅝" drywall screws, Grip Rite #158SDDW1.
- **Dowels** (optional)
- **Wood glue, clear** (optional) such as Loctite Power Grab

For staining (optional):

- **Wood stain** I used Minwax Oil-Based Ebony Wood Finish Interior Stain.
- **Pre-stain treatment** I used Minwax 1-Qt. Pre-Stain Wood Conditioner.
- **Stain application pad**
- **Gloves, latex or nitrile**

Tools

- **CNC router, minimum 4'×6' cutting area** 4'×8' preferred.
- **Calipers, digital**
- **Drill with 5⁄16" bit and Phillips driver bit (optional)** if you use screws for assembly
- **Clamps (optional)** if you use glue. They're cheap at Harbor Freight (harborfreight.com).
- **Computer with software:**
  - **CAD or drawing software** that can manipulate vectors and open and export DXF files, such as Rhino, Illustrator, AutoCAD, or Inkscape
  - **Processing, version 1.5.1** processing.org/download/?processing
  - **ControlP5 library, version 1.5.2** code.google.com/p/controlp5/downloads
  - **AtFab "One to Several Table" parametric design program** github.com/akaziuna/cnc-standing-height-workbench



5d Parts laid out for two 4'×8' plywood sheets: (left) legs and test cuts, (above) tabletop and crosspieces.

A VALUES ENTERED INTO ATFAB APP

FIELD	INPUT
Table width	600mm
Table length	1520mm
Constant ratio	No
Lock proportion	No
Dowel holes	Yes
Sniglet rows	5.0
Material thickness	18.5mm
Dowel diameter	6.5mm

B BIT SIZES FOR TOOL PATHS

TOOL PATH	BIT SIZE*
Test cuts	¼"
Robot pocket	⅛"
Drill	¼"
Inside profile	¼"
Outside profile	¼"

*All bits used were 2-flute downcut bits.

C FEEDS AND SPEEDS FOR SHOPBOT PRS STANDARD

SETTING	FOR 1/4" ENDMILL	FOR 1/8" ENDMILL
Stepover	0.125	0.125
Spindle speed	12,000 rpm	14,000 rpm
Feed rate	3.2" /sec	3.27" /sec
Plunge rate	1.0"/sec	1.1" /sec

Lengthen the legs. The parametric app is awesome, but it doesn't lengthen the table legs to standing height. Use your favorite CAD program to lengthen them to your chosen height. Stretch only the straight middle portions of the legs, leaving the joints and feet intact (**Figure 5c**, preceding page).

Join vectors. Ensure that the vectors for each individual part are joined into one continuous shape. You'll need closed shapes to generate the toolpaths for machining. You can do this in your CAD program or use the Join tool in PartWorks or V-Carve Pro CAM software.

Rearrange the parts. Set your canvas size (sheet size) to 1,219.2mm × 2,438.4mm to avoid any possible resizing issues when importing into CAM software (DXFs exported from the app are in millimeters). You'll probably need to use screws to secure the wood to the router bed, so use an offset tool to create a 25.4mm border inside the canvas to avoid hitting these screws.

Then rearrange the parts to fit onto two 4'×8' sheets of plywood (**Figure 5d**). I used downspiral bits that pack the sawdust into the kerf, so I didn't need to create tabs to hold the parts in place while cutting. You can grab my final files at github.com/akaziuna/cnc-standing-height-workbench.

6. Program the toolpaths

You can cut your workbench with just 2 toolpaths: one *inside* cut (the "cross" or "plus" notches on the tabletop) and one *outside* cut for the rest of the file. (Inside and outside cuts refer to what side of the vector the router bit cuts on.) But if you're adding drill holes, or a decorative image etched into the surface of the wood (like the MAKE robot in this project), you'll need to create additional toolpaths. Before you start, download the machining and assembly instructions from opendesk.cc/atfab/one-to-several-table.

Plan toolpaths. If you're using dowels to assemble your table, you'll need to drill holes for them. I used screws instead and marked their locations with shallow 6.5mm (¼") holes.

Toolpaths must be cut in the proper order: first etching or "pocketing," then drilling, inside cuts, and finally, outside cuts. (You don't want to cut out a part and then try to drill or etch the loose part!)

Select bits. Preview your toolpaths in your CAM software, and make sure your router bit is small enough to cut any small features (**Chart B**).

Feeds and speeds. I've provided feeds and speeds settings for different sizes of 2-flute bits that worked well for me (**Chart C**). However, these numbers will vary according to your CNC's capabilities, the tooling used, and material machined. You want to move the tool as fast as the "chip load" for your bit will allow, without breaking the bit or sacrificing finish quality. If you move too slowly, the tool will heat up, wear out faster, and possibly burn the wood.

Create toolpaths. To do it in PartWorks, follow ShopBot's fantastic tutorial at shopbottools.com/msupport/tutorials.htm.

For more on bit selection and chip load, see the full tutorial at makezine.com/go/open-source-parametric-standing-height-cnced-workbench-tutorial.


8


9


10a


10b

7. Make some test cuts Cut your "Test cuts" toolpaths and slot your test pieces together. Ideally, you should be able to fit 1–3 business cards through the assembled joints, although mine were much tighter. You may need to adjust your files to get your parts to fit properly; for tips, check the OpenDesk machining and assembly instructions.

8. Cut the files This is the fun part, time to let the sawdust fly! Remember to wear eye and ear protection.

Load and secure the plywood, zero your axes, warm up your machine, load the appropriate bit, and cut your toolpaths in the correct order. (Drill or pocket cuts first, then profile cuts.) To see how I routed the MAKE robot, check out the videos on the project page.

9. Finish the wood (optional) I sanded and stained my tables for a dark, weathered look with visible grain. For more details, see the project page online.

10. Assembly Assemble the workbench in the following order, or it won't fit together properly: crosspieces, back, side, front, other side, top.

If the joints are a little too tight, give them some encouragement with a mallet and the plywood will give. If your screw heads are too big to fit inside the ¼" drill holes, chuck a 5⁄16" bit into your drill to countersink them.

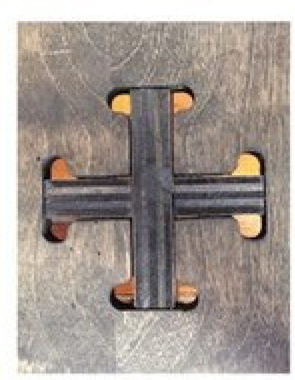
Then, making sure the parts are aligned, screw everything together. Plywood tends to bow a bit, so I used clamps to tightly align the leg joints when adding the screws.

You're done. Stand back and admire your work. Then put your machines on it!

Share Your Design. We want to see your parametric table variations! Send your designs and stories to anna@makermedia.com.

Get your CNC on! Complete step-by-step documentation at: makezine.com/cnc-maker-bench

Share it: ***#CNCMakerBench***




10c

TOOLBOX

Gadgets and gear for makers
Tell us about your faves: *editor@makezine.com*

NEW MAKER TECH

V.I.O. Stream Camera

$325–$599, vio-pov.com

HD cameras are useful for many applications, from POV video capture of extreme sports to robotic video streaming. The V.I.O. Stream is the first one I've tried that features an open API for customized application development and communications with the device. It can record full HD 1080p video on microSD and stream (RTSP) through IP over USB and wi-fi. It can also serve up its own wi-fi station, so you may log into it remotely to send HTTP or XML commands — such as when to start and stop recording, annotate frames with text overlays on the fly, and adjust camera exposure settings. *—John Edgar Park*

Available as a USB-powered model housed in a magnesium case ($499)

Naked dev board ($325)

And a LiPo battery-powered model ($599, not pictured) coming soon

Resistor Color Code Training Game

99¢, adafruit.com

Adafruit has always done a great job celebrating the resistor color-code as a fun challenge for beginners, and their latest offering — a training video game for iOS devices called Mho's Resistance — is a worthy addition to that effort. Gameplay is divided into three modes (practice, arcade, and quest), each with subtle variations on the same basic mechanic: Prompted with a resistor value, you must swipe to dial in the right series of color bands.

Quest mode is my favorite. It comes in "beginner" and "veteran" stages, each consisting of five circuits/levels. Completing all five unlocks an interactive simulation of the working device you just "built." I won't spoil the surprise other than to say that — at least for the "beginner" stage I've been able to complete so far — I found this to be a very effective, satisfying, and entertaining reward mechanism.

The info screen includes a link to a one-time discount code in the Adafruit store good for the purchase price of the game, which would be worth the price of admission even without it.

—Sean Michael Ragan

Belkin WeMo Maker

belkin.com

Belkin's WeMo platform of connected home products is growing to include a hacker-friendly module called the WeMo Maker. Designed for the person who wants to create, explore, and invent," according to Belkin Product Manager Jake Whisler, the wi-fi-enabled device allows you to switch up to 36 volts DC or take readings from 5 volt analog sensors. All of this can be done remotely with Belkin's app via their cloud service. For local control, you can use the WeMo SDK for iPhone or Android to roll your own service if you prefer.

Announced at CES 2014, Belkin expects to release WeMo Maker this summer (price not available at press time). *—Matt Richardson*

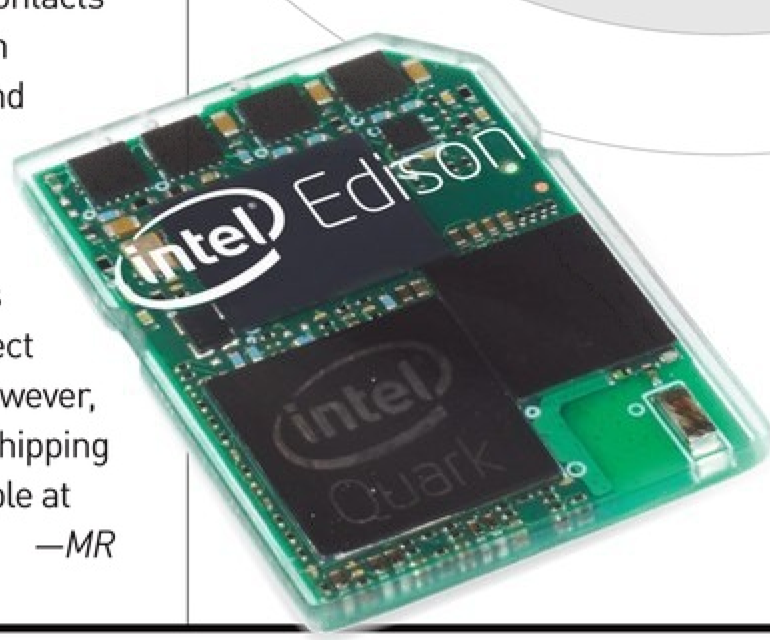
Intel Edison

intel.com

According to Intel, "It can be designed to work with most any device — not just computers, phones, or tablets, but chairs, coffee makers, and even coffee cups."

At International CES 2014 in Las Vegas, Intel was showing off a Linux computer shrunk down to fit into an SD card form factor. Dubbed Edison, the development platform has a 400MHz Quark processor with two cores, one of which runs Linux and the other runs a power-efficient real-time operating system. The board has built-in wi-fi and Bluetooth for connectivity and can be programmed from your computer's card reader. On the bottom of the board, contacts are broken out so that you can access its GPIO, UART, I2C, and PWM functionality.

While Edison isn't aimed squarely at makers (rather "entrepreneurs and inventors of all kinds"), it might be perfect for DIY connected devices. However, that remains to be seen. No shipping or pricing details were available at press time. *—MR*



Ten-Tec Rebel Pro

$199, tentec.com

I've been an active ham radio operator — writing about the hobby for more than 30 years — and I have seen many advances in technology in that time. The Ten-Tec Rebel low-power amateur radio transceiver is a modern return to the era where hobbyists would routinely modify, change, and improve their equipment. But now, in addition to modifying the electronic circuit, the ham hobbyist can further enhance this radio through reprogramming the processor.

Generating 5 watts in the 20 and 40 meter CW (Morse Code) ham bands, as shipped, any properly licensed amateur can get on the air immediately by simply connecting an antenna, key, and 10–15V DC power. As a standalone, low-power (QRP) transceiver, this unit is already a useful tool. But this is only the beginning of the adventure. It's built around the Arduino-compatible ChipKIT Uno 32 processor.

Using the open-source Arduino programming environment, the user can adjust and modify the existing functions of this unit, or go further to add features beyond its basic design. Internally, the transceiver contains direct pin-outs to all connections on the processor board, making it possible to design "shields" to enhance and improve the radio's performance. Active online groups supporting the Arduino, the ChipKit Uno 32, as well as the Rebel itself, are already building a base of user ideas and experiments to take this rig far beyond its basic platform.

Electronic hobbyists who want to join the world of amateur radio will find this $199 unit an excellent way to get on the air. Hams who want to experiment with Arduino hardware and software now have a great place to start.

—Thomas "Skip" Arey

ONE PCB TO RULER THEM ALL

$5, adafruit.com

Beautiful, useful, clever, and cheap. Where have you been all my life? Yes, it's just a ruler. But it's a ruler fabricated in a PCB house, using PCB processes, for the express purpose of assembling, reverse-engineering, and generally hacking on other PCBs. Perhaps best of all, from a product design perspective, the ruler is itself a kind of hack — a non-PCB product designed and manufactured using the highly evolved industrial PCB toolset. *—SMR*

A SUPERB STORAGE SOLUTION

$30/pack of 12, smartjars.com

SmartJars are a new modular storage bin system that pairs clear hinged-lid containers with pegboard-mountable docks. SmartJars were successfully backed in a late-2013 Kickstarter campaign, and we're hoping to see these hit stores this year.

—Stuart Deutsch, ToolGuyd.com

HOLD, PLEASE

$35, sparkfun.com

Third-hand tools are useful for holding components in place for soldering. You can make a Loc-Line modular hose-style third-hand kit yourself (instructables.com), but cutting, drilling, and tapping a solid base can be a hassle. SparkFun's kit comes with two complete arms and a tapped base plate that can accept additional arms ($2/each). *—SD*

PROXXON MINIATURE POWER TOOLS

$200-$360 : proxxon.com

For my work building models and automata, I own two Proxxon miniature power tools, and they're both amazing. Not amazing for their size — just plain amazing. The Proxxon Miter Saw ($200) is great for making 90° and 45° cuts in a variety of materials. There are detents every 15° for cutting a range of angles.

The Mini Table Saw ($360) can make a clean cut in ¾" hardwood, and it's barely bigger than a toaster. Unlike another miniature table saw I own, there are a ton of useful accessories available for the Proxxon — some that are simply not available for full-sized machines. The variable-speed control also sets this saw apart from lesser miniature table saws, allowing me to adjust the speed depending on the blade in use and the material being cut. This can make the difference between clean, smooth cuts and ruined materials.

The truly handy thing about owning the miter saw and the table saw is that they use the same blades, and a surprisingly wide variety at that. I can get blades for slitting, cutting wood, and cutting metals, and they're all interchangeable between the two tools. Consider, for example, the diamond-coated blade, which allows me to cut things as hard as tile and stone. *—Dug North*

TECHNICAL SPECS WHERE THEY COUNT, BUT NO FRILLY PACKAGE-PUFFING

NO BS USB MICROSCOPE

$80, adafruit.com

The hardest part about working on modern electronics is that *you have to be able to flipping see what you're doing*. If you, like us, don't have the eagle eyes of an 18-year old, this USB microscope can be a real lifesaver.

You may have noticed that industrial electronics are now pretty much universally built using surface-mount devices, rather than through-hole soldering techniques. Among the many advantages of surface-mount components, they are a heckuva lot smaller than their through-hole counterparts.

This is undoubtedly better for industry, but it can be a real pain in the posterior for hackers, fixers, and other hands-on types who might want to actually get their big meaty human fingers in there and physically change stuff.

Enter our friend here — this USB microscope will help you see the tiny details of your board and components and minimize the frustrations of proper placement.

Our pals at Adafruit have worked hard to strike a balance of cost and professional capabilities in selecting this unit for their catalog. It has the technical specs where they count, but leaves off the frilly package-puffing you don't really want to pay for. *—SMR*

BIGSHOT CAMERA

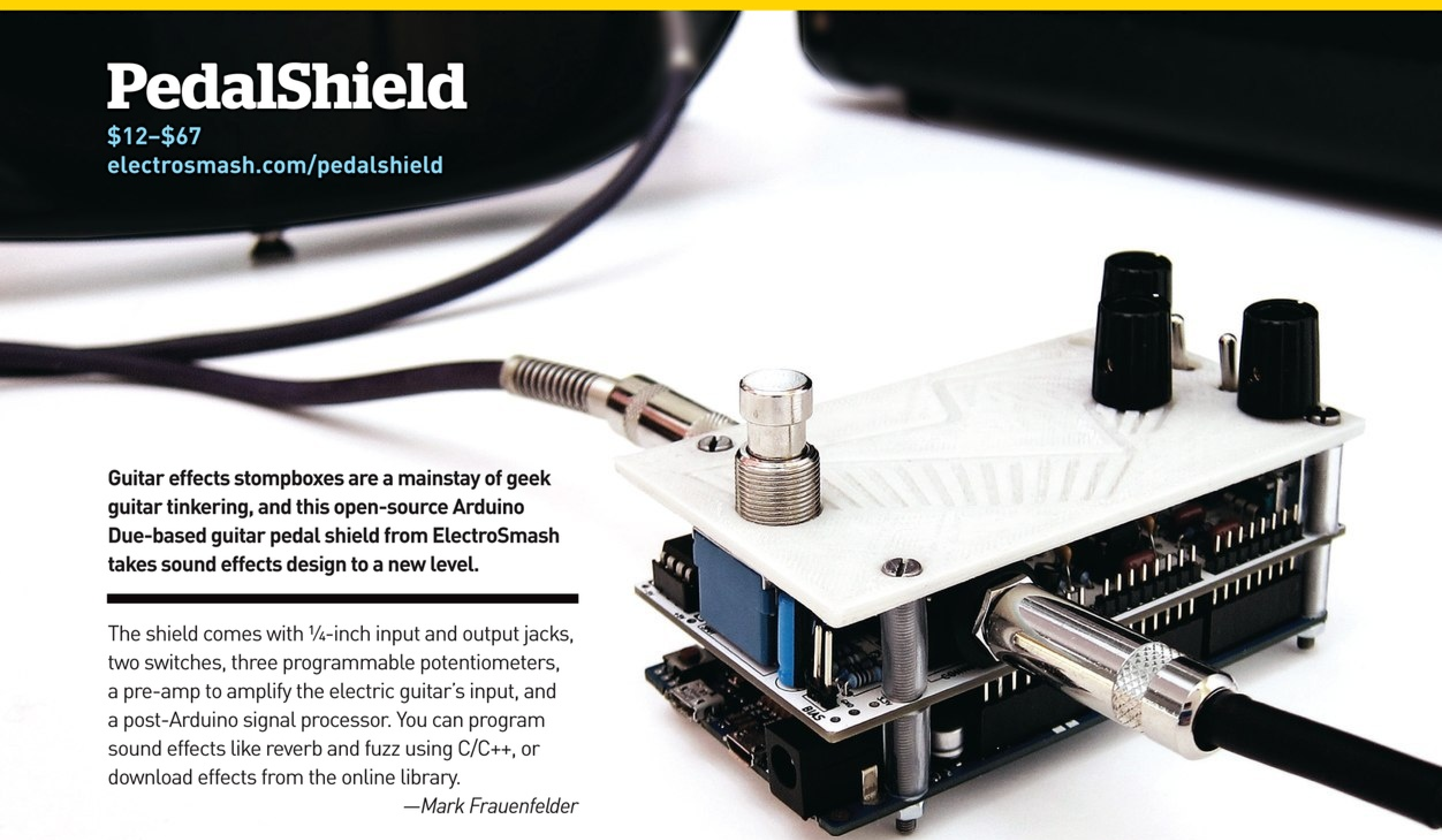
$90, makershed.com

Building your own digital camera from a kit is a fantastic way to learn about optics, mechanics, electromagnetism, electronics, and image processing.

Bigshot is a build-it-yourself camera kit meant for learning, creativity, and fun. After building the camera and learning how it works, you can then experiment with framing, lighting, motion, and lens selection.

The kit also promotes concepts beyond photographic principles. "What's unique about the kit is that it allows you to juxtapose an experience in the sciences with an experience in the arts," says Bigshot creator Shree Nayar, a professor of computer science at Columbia University, who debuted the kit at World Maker Faire New York this past September.

Power is supplied via a crank on the side that charges the battery, another element of education for its maker. "The whole idea here is to include features that would expose the kids to not just how a camera works, but rather a variety of science and engineering concepts related to the camera." *—MR*



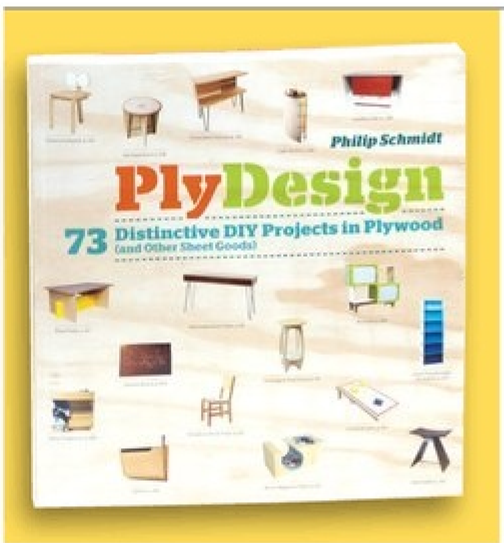
PedalShield

$12–$67
electrosmash.com/pedalshield

Guitar effects stompboxes are a mainstay of geek guitar tinkering, and this open-source Arduino Due-based guitar pedal shield from ElectroSmash takes sound effects design to a new level.

The shield comes with ¼-inch input and output jacks, two switches, three programmable potentiometers, a pre-amp to amplify the electric guitar's input, and a post-Arduino signal processor. You can program sound effects like reverb and fuzz using C/C++, or download effects from the online library.

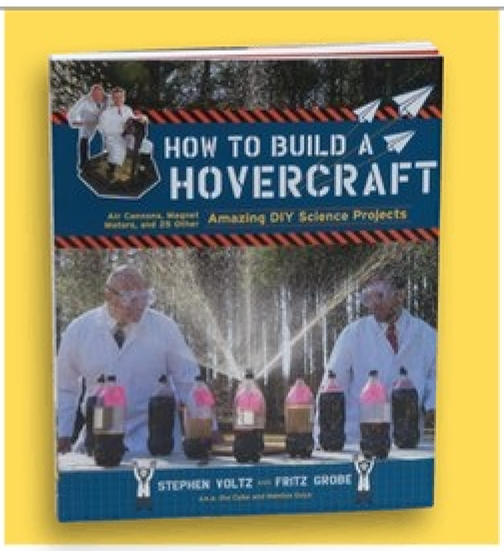
—Mark Frauenfelder



PLY DESIGN: 73 DISTINCTIVE DIY PROJECTS IN PLYWOOD

by Philip Schmidt
$25 : Storey Publishing

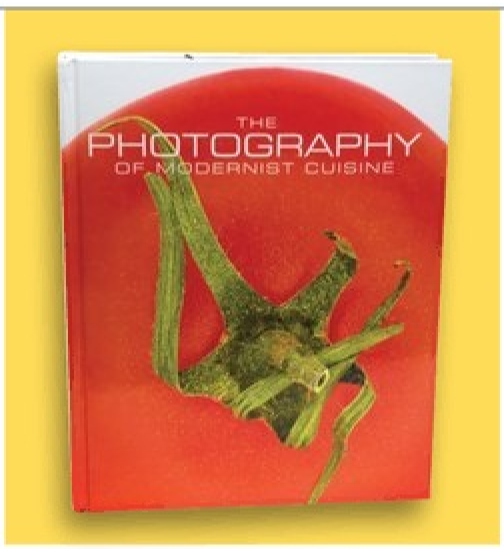
I've made skateboards and chairs out of plywood, but I didn't know what I was doing and ended up with a lot of splinters and poorly cut pieces of wood. If I'd gotten hold of Philip Schmidt's book first, I'd have had a better start. As a fan of the great designers Charles and Ray Eames (masters of making beautiful things out of plywood), Schmidt has written 73 well-described projects with a mid-century modern vibe that resonates with my taste. From lap desks to tea tables, and head-boards to doghouses, there are enough projects here to fill your home with useful and attractive furniture. *—MF*



HOW TO BUILD A HOVERCRAFT

by Stephen Voltz and Fritz Grobe
$25 : Chronicle Books

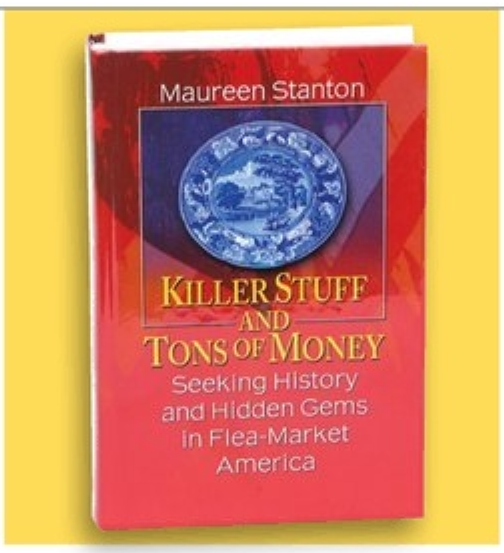
Stephen Voltz and Fritz Grobe run the EepyBird Laboratory in Maine, where they create science-based entertainment. You probably know them through their Diet Coke and Mentos performances, where they soak appreciative audiences with gallons and gallons of artificially sweetened cola (they're a perennial Maker Faire favorite). In this book, Voltz and Grobe take you into their lab and teach you how to make a couple dozen amusing projects, including a self-crushing can, magnet motor chimes, sticky-note waterfalls, and a leaf-blower hover-craft. Best of all, they show you how to make a 10-bottle Diet Coke and Mentos geyser so you can hold your own backyard extravaganza. *—MF*



THE PHOTOGRAPHY OF MODERNIST CUISINE

by Nathan Myhrvold
$120 : The Cooking Lab

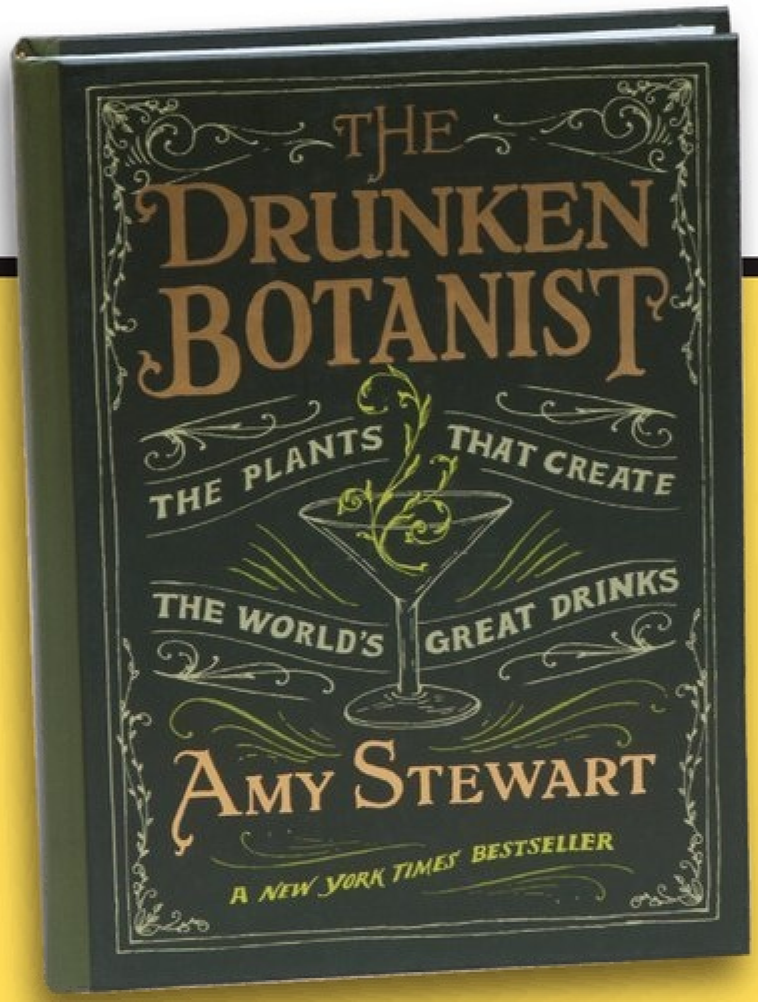
When I reviewed *Modernist Cuisine* (MAKE Volume 28) I was entranced by the gorgeous photography. Author, and former Microsoft CTO, Nathan Myhrvold set out to illustrate the art and science of food and cooking as never before through the use of photography, microscopy, and digital image editing. He succeeded, and nearly redefined what it is to capture food imagery in the process. *The Photography of Modernist Cuisine* celebrates that success by present-ing the breathtaking, minimalist photos on their own in a strikingly beautiful (and large!) coffee table book. With chapters on plants, meats, cutaways, cooking, phenom-ena, and a wonderful behind-the-scenes look at photographic technique, this could be considered the definitive tome on unstaged, naked food imagery. *—JEP*



KILLER STUFF AND TONS OF MONEY: SEEKING HISTORY AND HIDDEN GEMS IN FLEA-MARKET AMERICA

by Maureen Stanton
$15 : Penguin

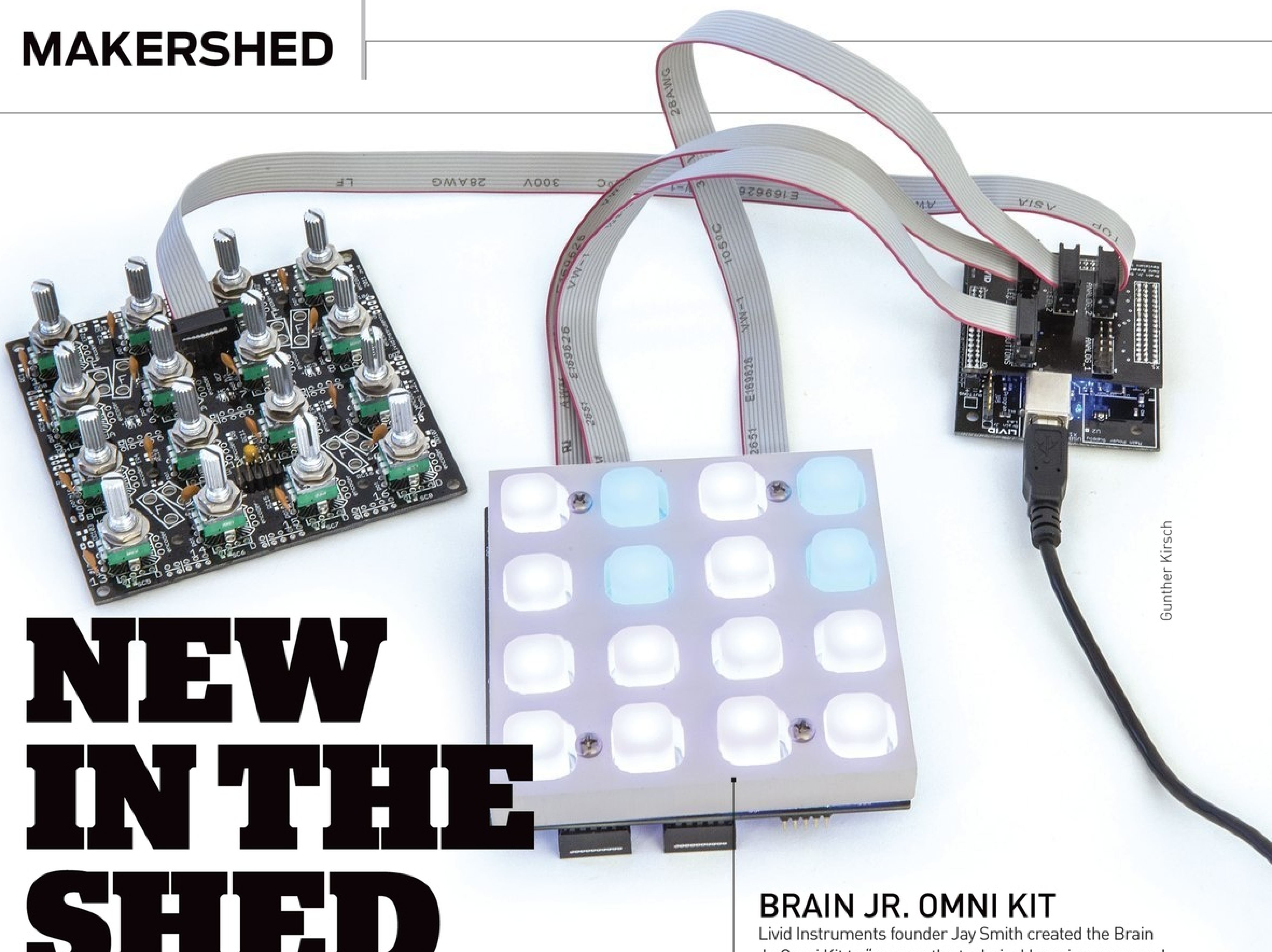
If you're ever at an antiques sale with Curt Avery and he says "Dude, that rocks!", put the item down — it's his code word for "fake." In *Killer Stuff and Tons of Money*, author Mau-reen Stanton joins Avery (a pseud-onym) on a tour through the under-belly of the American flea market. We witness Avery make great profits because he has learned, sometimes the hard way, details such as how white jade snuff bottles turn orange from iron impurities. Stanton also explores the thin line between repairing and counterfeiting walked by a master Windsor chair restorer. Ultimately, *Killer Stuff* argues against the emptiness of throw-away, re-production items, while it celebrates the soul of real, storied objects and the passionate people who hunt for them. *—JEP*



THE DRUNKEN BOTANIST: THE PLANTS THAT CREATE THE WORLD'S GREAT DRINKS

by Amy Stewart
$15 : Algonquin Books

Have you ever diluted a glass of absinthe with a cold-water drip and wondered, "Why doesn't the molecule anethole, which forms the milky white louche cloud, float up to the surface as it comes out of solution?" Me neither, but now I know, thanks to *The Drunken Botanist* by Amy Stewart, that it's due to the low interfacial tension of anethole, the licorice-flavor molecule which is derived from a number of different, unrelated plants including anise, fennel, hyssop, sweet cicely, and licorice itself. This wonderfully entertaining and informative book covers all manner of adult beverages and the amazing herbs, spices, flowers, trees, roots, fruits, nuts, seeds, berries, and vines that are fermented, distilled, macerated, and infused to make them. *—JEP*



Gunther Kirsch

NEW IN THE SHED

ADD MULTIMEDIA TO YOUR PROJECTS

FROM CLEVER RASPBERRY PI ACCESSORIES TO SLICK NEW DRONES, the Maker Shed (makershed.com) sells fascinating and unique maker-made products created by innovators — often MAKE readers themselves. The following brand-new items offer easy ways to build multimedia capabilities into your projects, from photo and video to music to interactive gaming.

We're always elated to discover new products, so if you have a kit you'd like us to sell, send the info our way at kits@makezine.com. And we're cooking up some new kits of our own in the MAKE Labs — stay tuned for some awesome new concoctions from the Shed team!

Written by Natalie Wiersma

Maker Shed

BRAIN JR. OMNI KIT

Livid Instruments founder Jay Smith created the Brain Jr. Omni Kit to "remove the technical learning curve and make it easy to build interactive devices so more time is spent being creative." The kit reinvents the traditional MIDI, giving you infinite creative options to trigger loops, sequence tracks, and explore new ways to create music in a tiny package about the size of a credit card. Use it with software like Ableton Live or GarageBand and explore its unlimited uses, like creating light shows or unleashing a flame organ!

■ **MKLV01** ■ **$169**

GAMEDUINO 2.0

James Bowman's Kickstarted Arduino gaming shield, the GameDuino 2.0, transforms your Arduino into the equivalent of a modern handheld gaming system. It features a big, bright 4.3" touch screen, 3-axis accelerometer, microSD storage, and an amplified headphone output. The GameDuino 2.0 utilizes an onboard graphics engine capable of 32 bit color, up to 2,000 sprites, and an OpenGL-style command set. Create and play your own video games on Arduino with the Gameduino 2.0!

■ **MKEX01** ■ **$69**

USB CAMERA FROM GAKKEN

While we love all of Gakken's kits, we were particularly eager to play with the USB Camera, a miniature video camera with a handheld crane attachment. This camera is perfect for use with scaled filming akin to the dramatic Japanese film style Tokusatsu, which was notably used in the original Godzilla movie. The USB Camera also records sound, so the only limitation is your imagination — and the length of the USB power cable. Unleash the great director inside and design your sets with Legos or grab your action figures for your next epic film!

■ **MKGK45** ■ **$54**

NWAZET PI CAMERA BOX BUNDLE

French-born Fabien Royer and Bertrand Le Roy are no strangers to the tech industry — both worked for Microsoft and were a part of the Open Source movement before co-founding Nwazet. Their Pi Camera Box Bundle is great for time lapses, computer vision, robotics, surveillance projects, or even video conferencing. If you've already picked up the Raspberry Pi Camera, but have yet to develop a secure mounting system for it, this Box Bundle is for you.

■ **MKNWZ07** ■ **$30**

UDOO QUAD CORE

Udoo combines the power of four Raspberry Pi's plus the ubiquity of the Arduino Due in a low-cost, open-hardware computer equipped with two powerful processors: an ARM i.MX6 for Android and Linux development alongside an ARM Cortex M3 chip. The UDOO is filled with an incredible 76 GPIO pins, HDMI, multiple USB ports (including an OTG one), analog audio and mic ports, an onboard wi-fi module, and much more. The huge number of capabilities this board has makes it great for all sorts of development and prototyping, especially for those interested in exploring internet-connected projects.

■ **MKUD01** ■ **$135**

SOLAR USB CHARGER KIT 2.0

Joshua Zimmerman

Brown Dog Gadgets whiz Joshua Zimmerman initially created the Solar USB Charger Kit for his middle-school classroom to teach his students about solar power. When he was creating this kit, he had utility in mind rather than simply harnessing the energy of the sun. Since then, Zimmerman has been excited to see the uses of this palm-sized gadget with its quirky puzzle-esque enclosure. From simple Boy Scout troop projects to hurricane victims in need of a power source, this educational kit has numerous uses in our power-hungry world.

■ **MKBR01** ■ **$40**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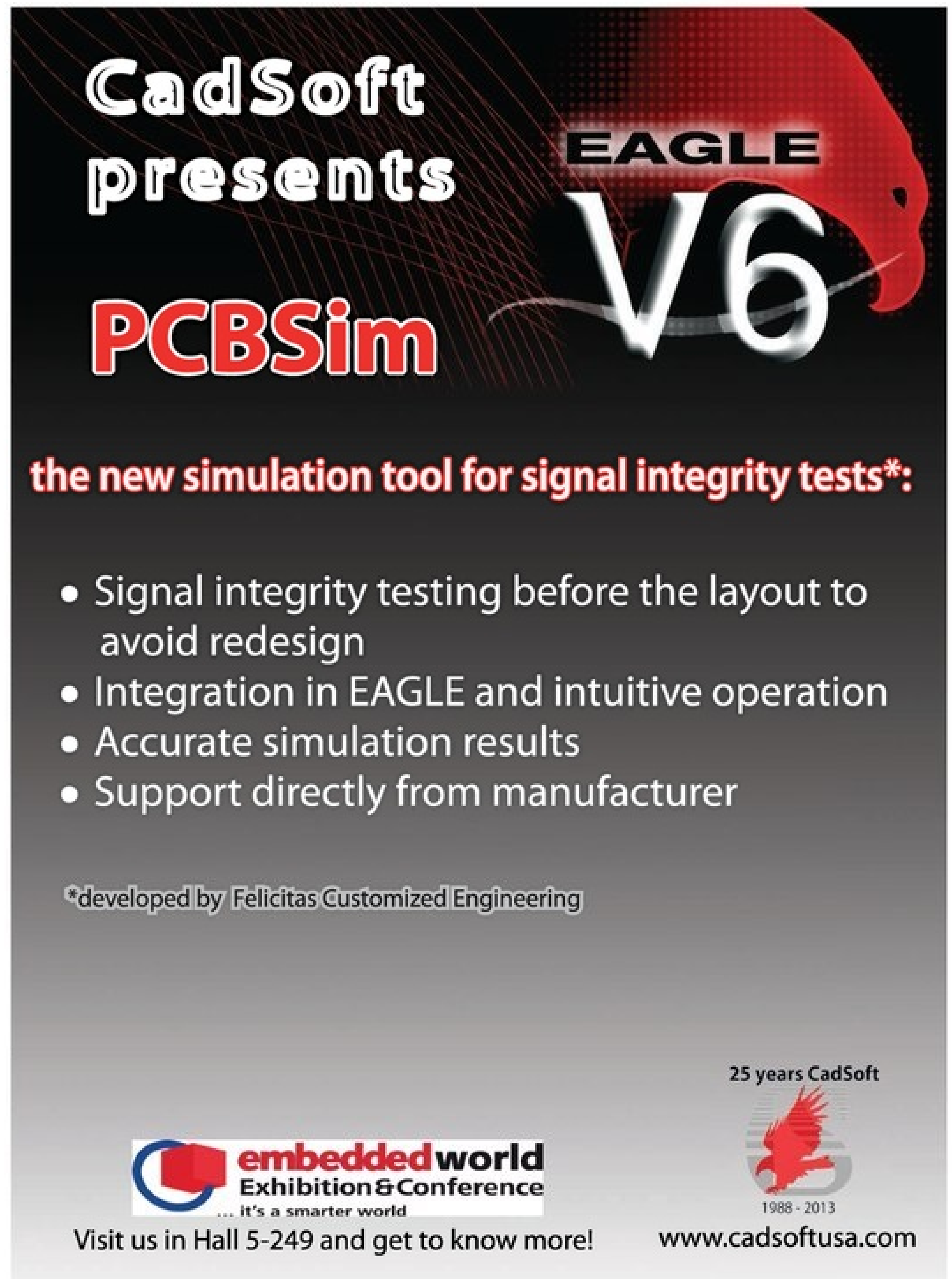
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www.pcduino.com
www.linksprite.com
pcDuino is a mini PC that runs Ubuntu/Android. It has Arduino headers so that existing Arduino Shields can be used with pcDuino. It is a platform that bridges the open software community and open hardware community.
Specification
• CPU: 1GHZ ARM Cortex A8
• GPU: OpenGL ES2.0, OpenVG 1.1 Mali 400 core
• DRAM: 1GB
• Flash: 2GB, with SD card supports up to 32GB
• HDMI 1080p video output
• OS: Ubuntu and Android
• Hardware: Arduino interface
• Network: Built-in WiFi and Ethernet
What pcDuino can do?
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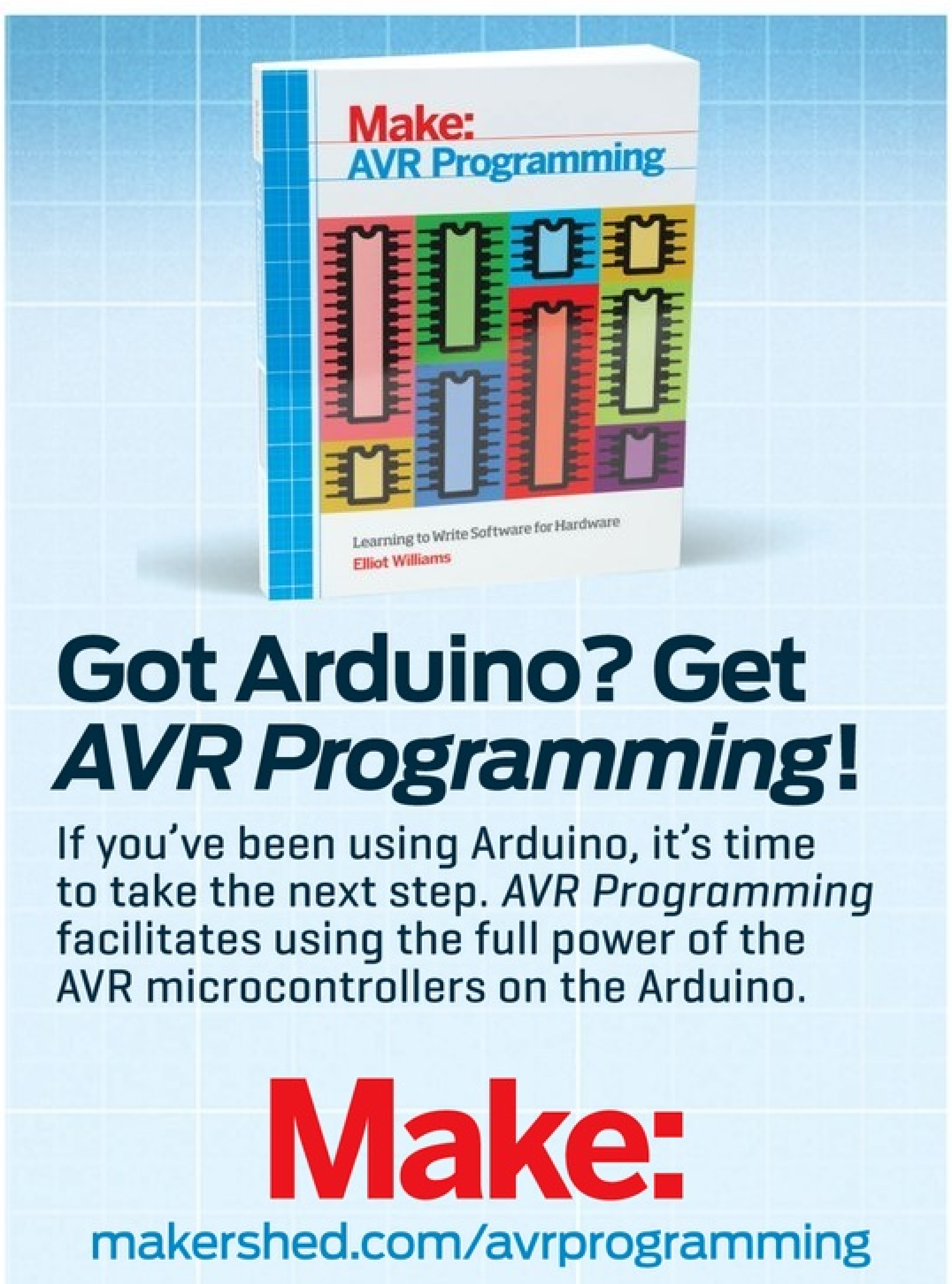
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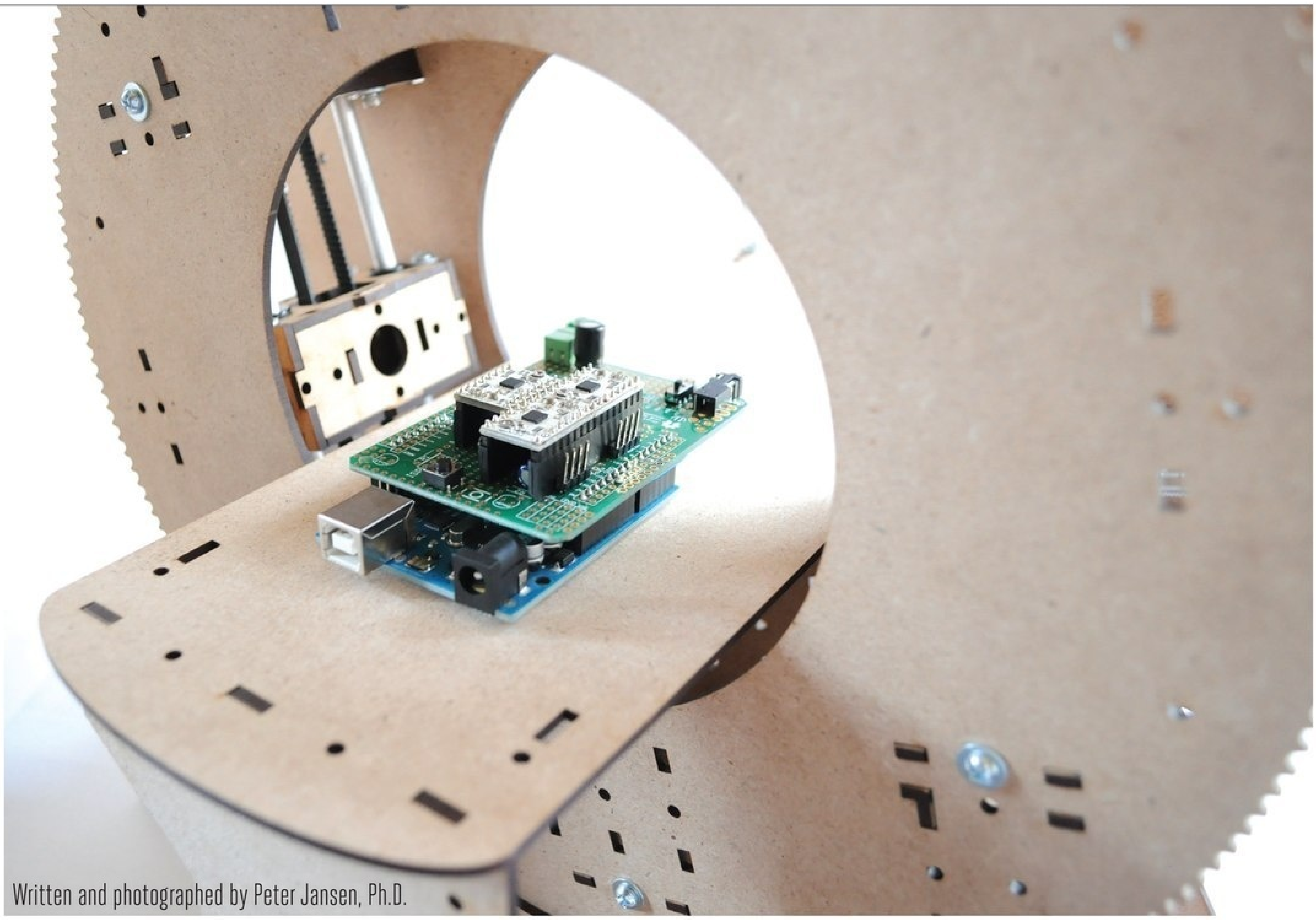
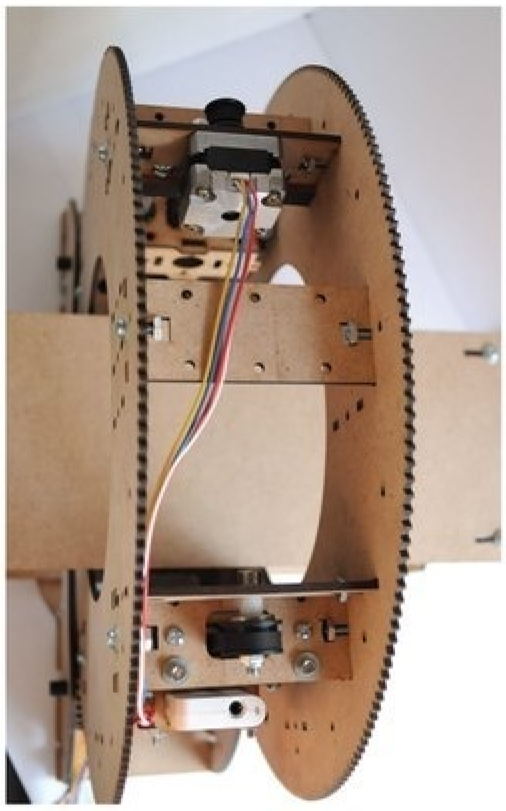


Written and photographed by Peter Jansen, Ph.D.

Open Source CT Scanner



PETER JANSEN, PH.D. is a postdoctoral researcher who teaches computers to learn language and the founder of the open-source science tricorder project.

BY FAR THE MOST INTERESTING CLASS I'VE EVER TAKEN was advanced brain imaging in graduate school, which introduced me to what I believe are some of the most amazing machines humans have ever built: the magnetic resonance imaging (MRI) and computed tomography (CT) scanners. These are volumetric 3D scanners that allow you to scan not only the surface of an object, but also see inside that object. And I really wanted to build one.

These scanners are fantastically expensive and usually only found in hospitals. As a Canadian living abroad, I recently had my first real contact with the U.S. health care system, and it was a very uncomfortable experience. Without belaboring the point, universal health care is very important to me. It's something that many consider a basic human right, and most people in the developed world, except for the U.S., have access to it. After seeing the cost for my CT scan, I decided it was time to try to build an open-source desktop CT scanner for small objects, and to do it for much less than the cost of a single scan.

Mechanically, this prototype scanner is very similar to the first generation of CT scanners, and it's almost entirely laser cut. An object is placed on a moving table that goes through the center of a rotating ring. Inside the ring there's a very low intensity x-ray source, and on the other side a detector. An Arduino Uno with a custom shield controls four stepper motors and interfaces with the detector. For safety I'm using a radioisotope x-ray source that's barely above background levels, so every photon counts, and I've only just recalibrated the detector. I'm expecting the first images with a few more weekends of work.

I confess that I laughed and started to feel like Doc Brown when the "only" thing my CT scanner needed was something radioactive, but with luck, projects like this will mature into desktop scanners for the maker community, and perhaps even medical scanners for impoverished countries, where they're most needed.

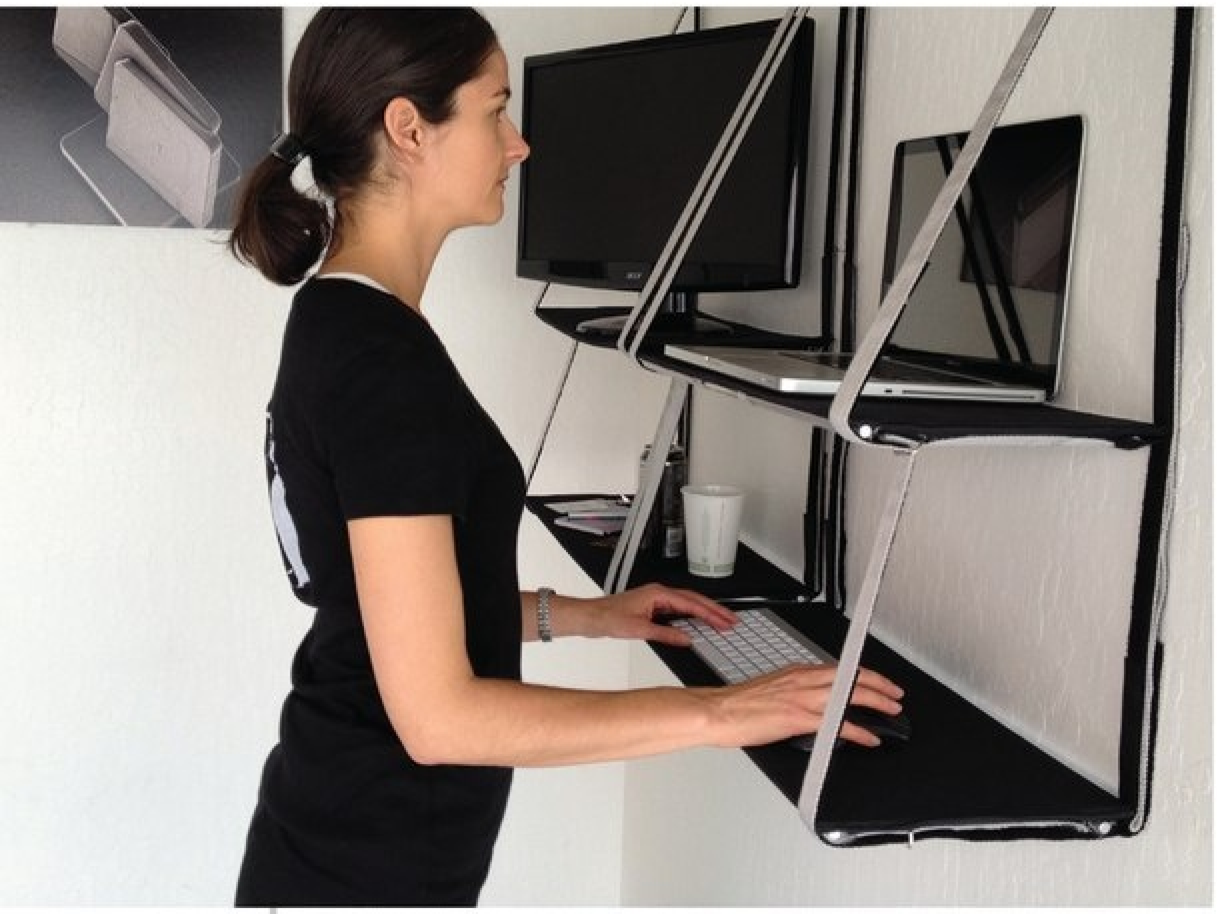
+ Build notes, additional photos, and more: tricorderproject.org/openct

The Ninja of Back-Savers Designed and Built at a TechShop

Where: San Francisco, CA
Website: NinjaStandingDesk.com
Tools: ShopBot 96 x 48 CNC Router and other tools at TechShop SF

Dan McDonley's back was hurting. Chronic pain from Martial Arts training was getting worse due to a highly un-athletic activity: sitting at a computer. Standing desks are great solutions, but permanent ones are expensive. So "Ninja Dan" designed and now builds a portable version. Compact and lightweight, the Ninja Standing Desk is perfect for travelers, contractors, and anyone who is tight on space — a fully adjustable standing desk at a price anyone can afford.

"TechShop has opened up a world of possibilities for me as an entrepreneur."



A successful Kickstarter provided Dan production seed money. He works with the ShopBot, panel saw and chop saw to manufacture folding shelves out of tempered hardboard, and cut metal parts. He also relies on a dozen vendors around the U.S. for other needed materials. One resource Dan used to research subcontractors was the digital fabber's community site, 100kGarages.com.

A huge supporter of the Maker movement, Dan has taught at TechShop in addition to his membership there. He created and led two mastermind entrepreneur groups, and participated in the Maker Startup Weekend sponsored by the Kauffman Foundation. In addition, Dan is dedicated to giving back to the community, volunteering with SPARK to inspire middle-school students.