Make:

22 GREAT **PROJECTS** YOU CAN BUILD!

TRY THE NEW TINY HACKABLE COMPUTER **RASPBERRY PI**

Power Racing

Mod a Toy Car and Race It at Maker Faire!

SOFTWARE FOR MAKERS

WHAT'S COOL IN ARDUINO

MAKE'S ROVERA ROBOT KIT

+ LEARN **CNC JOINERY** // GROW INCENDIARY **GHOST CHILIES**

O'REILLY

makezine.com

BUILD & RACE SOLAR CHARIOTS!

THE GREAT CREATE

A CELEBRATION OF AMAZING CREATIONS AND THE PARTS THAT MADE THEM POSSIBLE.

Use a simple circuit, DC motors, and solar cells to build autonomous racers.

BEAM (biology, electronics, aesthetics, mechanics) is a type of robotic design that makes use of simple components and bits of techno-junk to create cool robo-critters, many of them inspired by nature. Clever circuit designs, analog parts, and minimal components make it a perfect type of robot-building for beginners and kids.

One of the basic BEAM circuits is called the Solar Engine, a simple means of collecting a solar cell's output and using it to power a motor. The Solar Engine can be used to drive all sorts of BEAMbots. In this project we'll use it as the muscle to power a little solar race car and a top-like spinner.

Let's Get Started:

The list below includes enough parts to make two solar engines. To assemble each one, follow the diagram and wire together all components as shown. Note that the flat sides of the transistors face each other. (You can use heat-shrink tubing to hold them together.)

PARTS

- ☐ (2) Transistor 2N3904 ("3904") NPN #276-2016
- ☐ (2) Transistor 2N3906 PNP #276-1604
- ☐ (2) Flashing LEDs #276-036
- ☐ (2) 1/4W 2.2K resistor #271-1325
- ☐ (6) 4700uF capacitors #55047495
- ☐ (2) 4.5V solar cell
- ☐ (2) DC motors (salvaged from portable cassette player)
- ☐ (4) Socket pins
- ☐ Heat-shrink tubing #278-1610
- ☐ Hex nuts
- ☐ Machine screws
- ☐ 1/8" telescoping metal tube

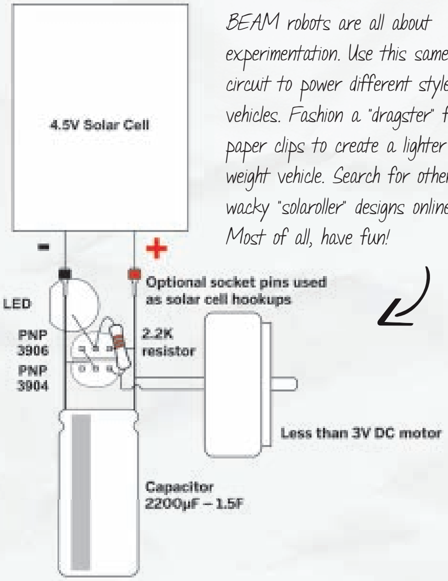
This type of solar engine is called a FLED-type, for "flashing LED." The LED is not used as a light, but as a trigger to dump the charge from our capacitors (or polyacene battery). When the charge is high enough to flash the LED, it becomes a conductor and allows the current to flow through the circuit and turn the motor. When the charge is dissipated, the resistance goes back up and the charging phase begins again.

Our Chariots make innovative use of some "techno-junk" in their construction, including the roller wheel from a portable cassette player.

Solar Chariots, ready for action. BEAM is inspired by biology and these mechanical critters move like lazy, sun-drenched bugs. They are more tortoise-crawlers than rabbit-runners, but no less fun to race!

Whether you decide to build the Roller or Symet vehicle, both are built using the same circuit design, modified to suit their forms. These chariots are commonly referred to as a roller and a spinner, respectively. Other types of bots in the BEAM taxonomy include walkers, fliers, squirmers, and sitters – named for the type of movement they produce (and yes, sitters simply sit).

BEAM robots are all about experimentation. Use this same circuit to power different style vehicles. Fashion a "dragster" from paper clips to create a lighter weight vehicle. Search for other wacky "solaroller" designs online. Most of all, have fun!



If you're building the Symet Solar Chariot, which uses three capacitors, you'll want to attach three 4700µF capacitors where one is shown in the diagram.

We have downloadable templates available on the project page (makeprojects.com/project/b/1939) for the wooden wheels we cut with a laser cutter. But you don't need a high-tech machine. Stiff cardstock will work just as well. Just cut carefully!

When you're done assembling the parts from the template, you can attach the circuit to your motor and the solar cell to your circuit. (Again, see the project online for details.) Now take your racers into the sunlight and start your engines! The Symet will spin and move when it releases its charge, and the Roller will race forward like a solar-power dragster. For maximum racing fun, build two Symets or two Rollers and race against your friends. To see full build instructions, visit radioshackdiy.com/project-gallery/beam-solar-chariots.

By MAKE Editorial Director Gareth Branwyn, and Zach and Kim DeBord

Make: Volume 33

COLUMNS

FEATURES

NEVER GROW UP: Peter Novotnak from Sector67 races Black Beauty at World Maker Faire New York 2012. Photograph by Andrew Kelly. Art Direction by Jason Babler.

BEGINNER

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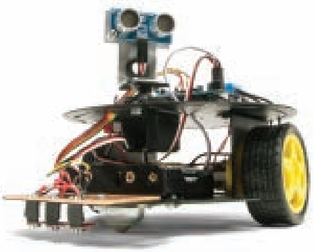
'DUINO BOTS:
The new Rovera kit comes with fun included.



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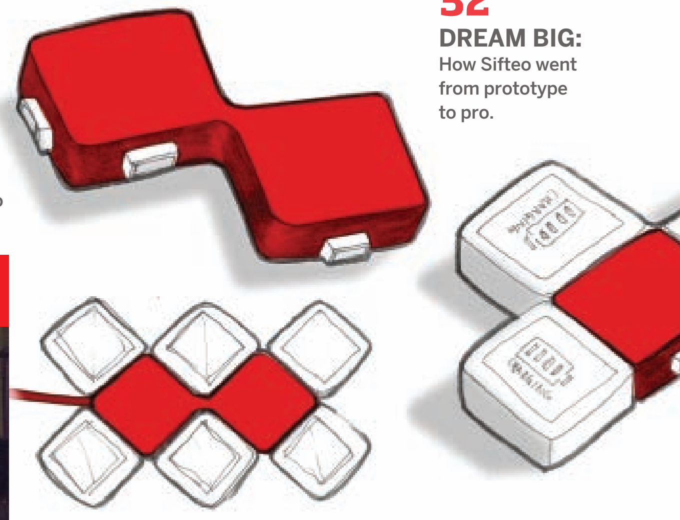
DREAM BIG:
How Sifteo went from prototype to pro.



HOBBY HORSE:
Link Scratch to your bronco for rockin' good times.

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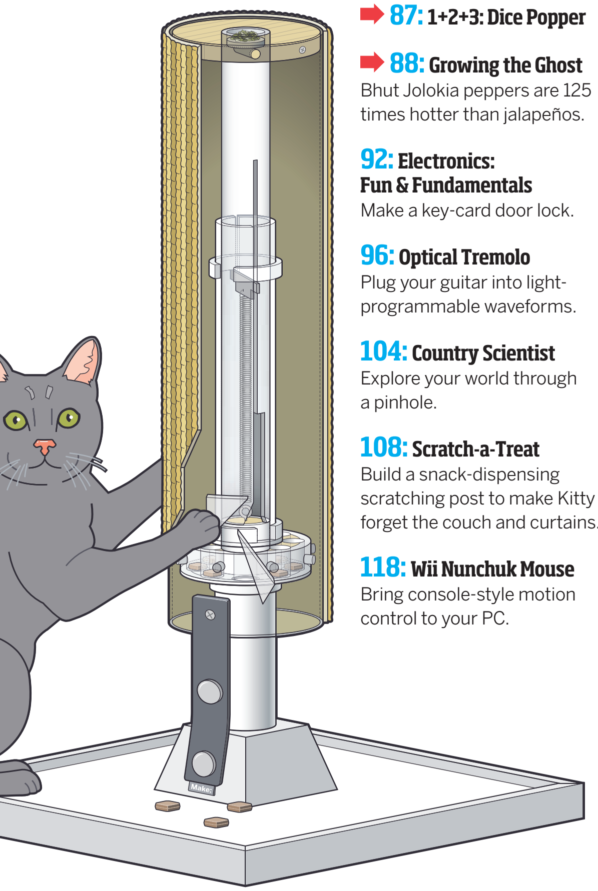
Vol. 33, Jan 2013. MAKE (ISSN 1556-2336) is published quarterly by O'Reilly Media, Inc. in the months of January, April, July, and October. O'Reilly Media is located at 1005 Gravenstein Hwy. North, Sebastopol, CA 95472, (707) 827-7000. SUBSCRIPTIONS: Send all subscription requests to MAKE, P.O. Box 17046, North Hollywood, CA 91615-9588 or subscribe online at makezine.com/offer or via phone at (866) 289-8847 (U.S. and Canada); all other countries call (818) 487-2037. Subscriptions are available for $34.95 for 1 year (4 quarterly issues) in the United States; in Canada: $39.95 USD; all other countries: $49.95 USD. Periodicals Postage Paid at Sebastopol, CA, and at additional mailing offices. POSTMASTER: Send address changes to MAKE, P.O. Box 17046, North Hollywood, CA 91615-9588. Canada Post Publications Mail Agreement Number 41129568. CANADA POSTMASTER: Send address changes to: O'Reilly Media, PO Box 456, Niagara Falls, ON L2E 6V2


Detention Punishment:
Write "I will not play video games in class"
300 Times
10 X = 0
20 Print "I will not play video games in class"
30 X = X + 1
40 IF X < 300 GOTO 20
50 END

READ ME Always check makezine.com/33 before you get started. There may be important updates or corrections.

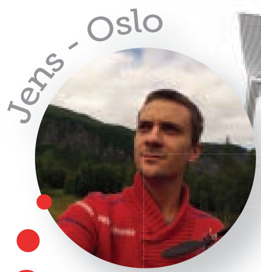
Make: Volume 33



PROJECTS

They met through 100kGarages.

Jens is a designer in Oslo.
Lee's a fabber in Sugar Grove, Illinois.
Together, they're doing
distributed manufacturing.



Now they're in business.

Lee Bernard is a designer and fabber who's worked for a number of years with natural stone, wood and metals (his website: cnc.rockspainc.com). Lee's digital fabrication tool is a CNC router with 5'x 11' bed that he designed and built himself.

He signed up on 100kGarages just a few months ago. Lee says, "I searched the site for possible collaborators, put the word out to a handful, and connected with product designer Jens Dyvik (www.dyvikdesign.com) from Norway. We hit it off, and now we're collaborating to fab his chairs for sale here in the Midwest. We're excited to use the distributed manufacturing business model!"

The third industrial revolution lives at 100kGarages.com. So be a part of it! If you're looking for a custom product to be designed and fabbed, or if you're a designer or fabber looking to make connections, 100kGarages is for you.

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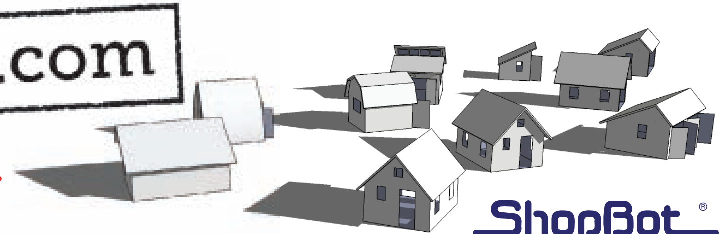

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"Beauty is more important in computing than anywhere else in technology because software is so complicated. Beauty is the ultimate defense against complexity."
—David Gelernter

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PUBLISHED BY
O'REILLY MEDIA, INC.
Tim O'Reilly, CEO
Laura Baldwin, President

Printed in the USA by Schumann Printers, Inc.

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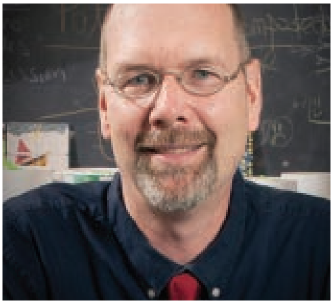
CONTRIBUTORS

Shaw Nielsen (*Software for Makers* illustrations) is a pretty snazzy illustrator, if he does say so himself. He lives in Denver, Colo., and says, "I doodle during the week and escape to the mountains on the weekend with my dog and girlfriend." Not only does he like outdoor activities such as hiking, camping, and skiing, but he also loves beer, sunshine, and puppies. Nielsen enjoys making delicious food ("usually by adding bacon to it"), and is working on building "the world's best indoor winter herb garden." As a designer and big fan of all things web- and design-related, he's happy to see that the web is really evolving as a much more richly designed environment.



Chris Connors (*Vinyl PCB Resist*) likes to mix it up, try things that he's not had a chance to take on before, and "do the most with the least amount of tools and supplies." He lives a mile from where he grew up, in Duxbury, Mass., with his wife, Liz, but they have taken their two daughters to places as far-flung as Alaska and Malawi. Connors was a public school teacher for 18 years, teaching fashion illustration, principles of technology, drafting, CAD, radio broadcasting, audio production, communication, graphic design, printmaking, web design, C++, Java, robotics, engineering, fashioning technology, and digital fabrication, to name a few subjects.

Timmy Kucynda (*Scratch-a-Treat* illustration), known as "Tim" to his dog Munky, is a graphic artist practicing out of San Francisco's Upper Haight. When not changing pee pads and searing raw food for his senior Chihuahua, Timmy provides illustrations for a variety of studios, agencies, and publications, and is proud to have been a contributor to MAKE magazine since its inception. Timmy would like to finish these 100 words or less by thanking the family, friends, and all the talented people he has worked with over the years. Their confidence and support has meant the world.

Tim Hunkin (*Victorian Microtech*) trained as an engineer but then became a cartoonist, drawing a strip for *The Observer*, a U.K. Sunday paper, called "The Rudiments of Wisdom" for 15 years. His next career was in television, writing and presenting three series called *The Secret Life of Machines* for Channel 4. For the next ten years he worked for museums, building interactive exhibits, and curating and designing exhibitions. Since 2001, when not distracted by building enormous public clocks and other entertaining projects, he's been obsessed with his amusement arcade on Southwold Pier called the Under the Pier Show.

Sam Freeman (Make: Labs intern coordinator) describes himself as follows: "I spent 1,000 years frozen in an ancient cryogenics lab, and was thawed out 12 years ago. I now enjoy traveling, hiking, and root beer floats. But I have a weird sense of humor." He loves traveling, both the road trip and backpack variety, as well as photography and bike riding. He thrives on variety. His project list "is long (and backed up), but somewhere on it is a raygun, an arcade console, and a six-foot-tall flaming tiki head." MAKE duties aside, he's most thrilled by "the slightest possibility of cloning a Tasmanian tiger" though he'd prefer that species stopped going extinct in the first place.

Chris Hackett (*DIY Welding Rod*) is an artist, founder and director of the Madagascar Institute (madagascarinstitute.com), occasional television presenter (most recently on Discovery's *Stuck With Hackett*), and sometimes teacher (adjunct professor at New York University's ITP). He's usually slogging away at a couple of concurrent projects: individual, personal, small-scale builds, and larger, collaborative Madagascar Institute projects, like the Mandee Amplifier: a 14-foot-tall, fully mobile, clattering, singing construction of Awesome. Hackett likes his coffee strong, his physics Newtonian, and is a firm believer in "Build it, then measure it."

David Neff (Chris Connors)

Geek Sports!

By Gareth Branwyn

Years ago, I was channel surfing and happened upon something I first thought was ridiculous. ESPN2 was broadcasting *Magic: The Gathering World Championship*. They had all of the sport broadcast trappings: announcer, color commentator, referee, engrossed spectators in bleachers, scoreboard, and onscreen graphics to reinforce the action. An hour later, finding myself enthralled and rooting for a specific player and his unstoppable monstrous cave troll (or whatever), I didn't think it was so silly. Ever since then I've been fascinated by the concept of "brain sports" — fun, competitive games for brainiacs and creative thinkers, more inclusive and less cerebral (and serious) than the original geek sport: chess.

Maker Faire, our large-scale DIY festival, has done its part in hosting (and in some cases creating) such sport. At the very first Maker Faire Bay Area in 2006, we saw Segway polo matches. Since then we've witnessed human-powered Chariot Races, Model Warship Battles, Nerdy Derby (think: Pinewood Derby, only nerdier), Turtle Shell Racers (3D-printed racing turtles), Death Defying Figure 8 Pedal Car races, and more. And then there's the Power Racing Series, a sport that grew out of a Chicago hackerspace (Pumping Station: One) and has captured the imaginations of a growing number of hackerspaces and individuals.

Power Racing, which involves modifying and racing electric Power Wheels kiddie vehicles, made its big debut in 2009 at Maker Faire Detroit (and has been at every Detroit Faire since). Last year, the race made it to World Maker Faire in New York, and it'll likely be coming to the Bay Area this year as well.

With an ever-expanding roster of races and racers, commercial sponsorship, and a growing fanbase, the future of Power Racing looks as bright as a jacked-up pink Barbie trike. See our eight-page feature in this issue (page 24) to learn more about the history and ethos of Power Racing and how you can get involved in this challenging and wacky sport.

Some posit that the maker movement is partly driven by the need for all of us pixel-pushers to get up from our computers and do something tangible, physical, and grounding. So we've ended up hardware hacking, 3D printing, robot building, or stepping further away from high-tech altogether and into more traditional forms of making like woodworking, metalworking, and handicrafts. Often, though, in pursuing some of these more physical forms of making, we find ourselves back at our computers, using special software for running our CNC cutters or 3D printers, or to design our custom-printed circuit boards. In this issue of MAKE (starting on page 44), we take a look at the critical programs you need to create CAD models, work with microcontrollers, design circuit boards, and teach kids programming.

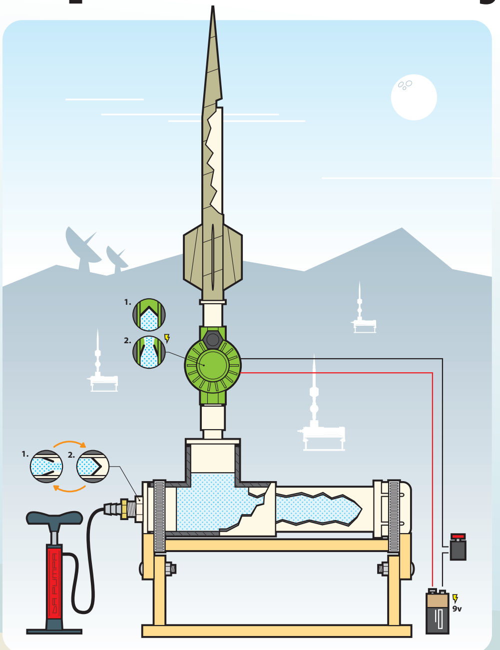
From hacking children's toys into adult race cars, to programming robots and tiny computers, to growing painfully hot peppers and brewing your own sake (all detailed in this issue), you can't say that makers don't have diverse interests!

Gareth Branwyn is the editorial director at MAKE.

Juan Leguizamon

READER INPUT

Rocket sugar-rush, drill press safety, an energy-saving bear, and a trip down memory lane.



For more comments, mods, and tips on the Compressed Air Rocket project, visit makezine.com/go/carockets.

» I can't thank you enough for putting this project ["Compressed Air Rocket," Volume 15] out here! I started out building the launcher to entertain my two boys. The sugar-rush-like symptoms it gave my inner child are just a bonus! I built ours using the tire valve and it seems to work very well. I have two tips for making the rockets that really made things easier for me:

1. Use a spray bottle to mist the cardstock lightly before forming the tube and cone, but give them a minute to dry before taping.

2. After you have a finished cone that you're happy with, use it to form the moist cardstock over for the next one.

Thanks again!

—Robert Wade, Vancouver, Wash.

» I just made the "Charlie's RFID Teddy Bear" project from Volume 28 (makeprojects.com/project/r/1411) for my 15-month-old daughter. We're attaching the RFID tags to pictures of family members so she can hear their recorded voices, because all my family lives out of town. It was my first MAKE project ever, although I'm a longtime maker. It works great!

One easy and cheap add-on I highly recommend is the Pololu Pushbutton Power Switch (item #750 at pololu.com, $7). It lets you turn the bear on and lets the software turn the bear off automatically after a timeout of no use — saves lots of batteries!

You can also modify it so the button can only power the unit on, not off (see makezine.com/go/polswitch). This makes it less confusing for my daughter!

—Stephen Schwartz-Fenwick, Chicago, Ill.

» I really enjoyed Donald Simanek's article on polarized light ["Screwy Light," Volume 32]. When I was growing up in the 1950s, one of my best friends was Jay Ballance. His father owned a fascinating company, Technical Animations, Inc., in our hometown of Port Washington, N.Y. Among other clever things, he used a combination of polarized filters with Scotch cellophane tape to create animated representations of complicated mechanisms, fluid flows, etc., using the same color effects pointed out in the MAKE article.

John Ballance, the father, died an untimely death from a heart attack in the late 1950s, but I see his wife followed up on his patents for the technique (makezine.com/go/ballance). Evidently the company continued at least into the 1970s based on additional patents, but I can't find any later references. Thanks for a great article and a trip down memory lane!

—Walt Scrivens, Delray Beach, Fla.

» Figure 1h of Volume 31's Fetch-O-Matic build illustrates some very bad safety, and 1j isn't much better. It's interesting to learn that a main accident mode of a drill press isn't making a hole in your hand with the bit — it's having the bit grab the work piece and spin it into you.

It's the same with many other tools. A table saw blade can jam in a board and send it shooting across the shop so someone nowhere near the blade goes to the hospital. There was a neat 2×4 hole in the wall way behind our saw at school that was purposefully never repaired.

Figure 1h has a couple of things wrong:
1. A spade bit should never go in a press, because they are very prone to sticking in the work piece. The package they come in usually says "hand drill only," or something similar.
2. The work piece should always be either clamped to the table or placed against something that will stop it from spinning if the bit grabs it. Often you can stick the piece against the post — quick and easy! Figure 1h looks like the work could have rested against the post and not the dude's hand (though really that bit should be in a hand drill). In Figure 1j, the piece might be too small to clamp, but it could have been placed against something clamped to the table.

All the really good safety lessons I ever got about tools taught me something that wasn't obvious. I'll never forget to treat gas cylinders with respect after hearing the story of my welding instructor, who saw a gas cylinder go rocketing down the deck of an aircraft carrier he was building during WWII. Please keep encouraging your readers to do dangerous things safely.

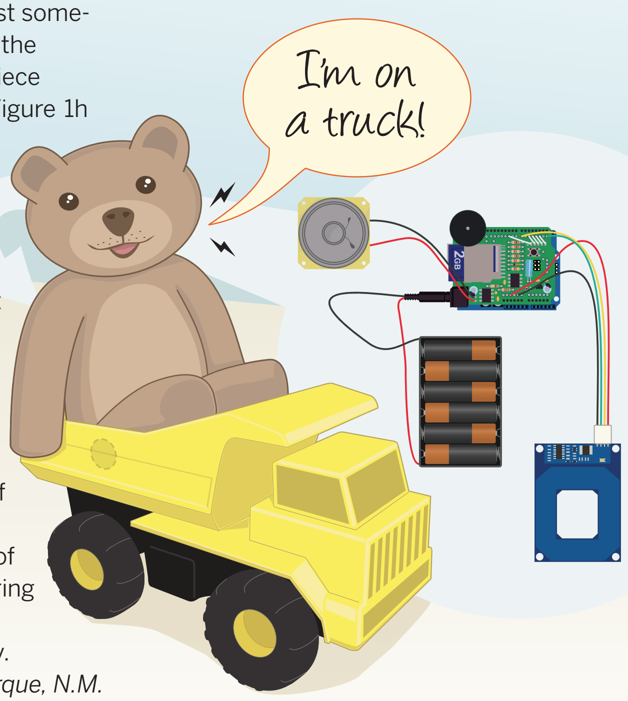
—Andrew Collins, Albuquerque, N.M.

» Thanks to William Gurstelle for Volume 30's "Keybanging" project. The Monster Guts Nerve Center is an interesting device but seems underpowered for $69. That's the same price as a basic Click PLC from Automation Direct. Whereas the Nerve Center offers but one input and two outputs, the Click offers eight inputs and six outputs, with the option of additional I/O modules. Further, the Click supports Modbus, allowing software like Mach3 to interface with it. Click PLCs can also communicate with each other.

On the other hand, I like the Nerve Center's audio feature, and the Click requires 24V DC, whereas the Nerve Center can run on AC. And Click doesn't come with a programming cable, although the software (it's programmed in relay ladder logic) is free. For most of my applications, the Click would be my choice.

—Paul Anderson, Windsor, Ontario, Canada

Author William Gurstelle replies: Paul, thanks for the tip! My goal in this article was to automate without programming, so I skipped the PLCs in favor of pushbutton simplicity. For more on programmable logic controllers, check out "Building with PLCs" in MAKE Volume 23, page 104.



MAKING MAKERS

Why Make?

By AnnMarie Thomas
Engineer Educator

Last year, I took a friend to her first Maker Faire. We walked around looking at projects and exhibits, and she had a question for me: "Why?" She was impressed by what she saw, but really curious about the motivation behind it. Why do makers make?

The projects you flip through in this magazine aren't typically part of someone's job or homework assignment. Rather, making is so often the result of intrinsic motivation. Many makers spend countless hours in the library, lab, garage, or makerspace working, alone or in a group, on projects that no one has told them to take on. Projects that, truth be told, may never work. Projects that likely have no due date, no entry rules, and no complete how-to instructions. Projects undertaken for the sheer joy of figuring out whether something can be done, or because there's a problem for which no one has found a good solution, or because it'd be neat to have a light-up costume or pet robot.

Anyone who has ever been around a roomful of children with access to a pile of craft or building materials has likely seen the happiness that typically accompanies such endeavor. Unbounded youthful creativity combined with readily available materials often leads to an all-out whirlwind of wonderful things. It usually doesn't take much effort, or the creation of any incentives, to convince young children to jump in and start making.

As the age of the group gets older, though, the dynamic sometimes changes. We start to hear more questions: Why should we do this? Am I doing this the right way? I've made Squishy Circuits (a method for using conductive play dough to sculpt working circuits) with people of all ages, and I've rarely had a child turn down the opportunity to try it out. With adults, though, I've often seen reticence or protests of "I'm not good at that sort of thing." Making is about a willingness to try, and a confidence in your ability to learn new things, often with help from others.

One of my greatest hopes for my daughters is that they can find the combination of curiosity, passion, and confidence that will allow them to see the world as a place they can actively help create. Thus, whenever I meet a maker who has spent hours/days/years working on a project simply because it brings them joy, I often ask them about their childhood in hopes of gleaning some parenting advice.

Their stories often include a supportive adult who encouraged them in their projects (even when the adult didn't completely understand what the young maker was doing). This supportive adult was also typically someone who pursued her own projects, which is key. If we want to encourage children to be makers, we need to demonstrate it.

This is why I make a concerted effort to work on my own projects, even small ones, and to show my daughters what I'm doing. This is also why I recently brought my 4-year-old to her first Maker Faire. While I was excited for her to take in the amazing projects, it was the makers themselves that I most wanted her to see.

I wonder whether, years from now, she'll remember meeting the 11-year-old who creates her own maker how-to videos, or the man who painstakingly recreates landmarks out of toothpicks. I hope that one day she is equally passionate about her own work and takes the time to share it with some other inquisitive little girl or boy.

AnnMarie Thomas, mother of two young makers, is the executive director of the Maker Education Initiative (makered.org).

Juan Leguizamon

FEB MAR APR

Mini Maker Faires

Community-based, independently produced Maker Faires are taking place all over the globe. For more information on starting a Mini Maker Faire where you live, and to see a complete listing of upcoming Faires, head to makerfaire.com.

Feb. 2, Las Vegas, Nev.
makerfairevegas.com

Mar. 23, Tyler, Texas
tylermakerfaire.com

Apr. 7, Edinburgh, Scotland
makerfaireedinburgh.com

Maker's Calendar

Our favorite events from around the world.

Compiled by William Gurstelle

Join the editors of MAKE on Google+ for Hangouts on Air every Tue., Wed., Thurs. @2pm PST / 5pm EST. google.com/+MAKE

TEDActive

Feb. 25-Mar. 1, Palm Springs, Calif.

Big thinkers and change masters from around the world present their ideas about work, play, and innovation. Aside from the signature 18-minute-long talks, participants attend workshops on subjects such as bike building, sculpting in cardboard, 3D printing, and home brewing beer. makezine.com/go/tedactive

DIY Santa Fe

Mar. 1-31, Santa Fe, N.M.

Santa Fe's famous creative community opens the doors of their studios and workshops to share their knowledge of painting, glass working, photography, and craft making. Visitors will enjoy a variety of workshops, classes, and other experiences. makezine.com/go/diysantafe

Spring Classic Swamp Buggy Races

Mar. 2-3, Naples, Fla.

These strange-looking vehicles feature big engines, bigger tires, gun racks, and unusual names like "Dirt Dobber" and "Tumblebug." Loud and inspiring, the handmade, one-of-a-kind swamp buggies can move through the deepest and muckiest terrain imaginable. swampbuggy.com

The Launch Festival

Mar. 4-6, San Francisco

Individuals and companies present their new product ideas and get feedback from experts. If the idea is good enough, it could be launched into the big time. conference.launch.co

AXPONA

Mar. 8-10, Chicago

Thousands of attendees come to the Audio Expo of North America to hear the best home audio equipment and software on the planet, showcased by hundreds of exhibitors. Seminars include room acoustics, system setup, and current music trends. axpona.com

Maker Faire UK

Apr. 28-29, Newcastle, U.K.

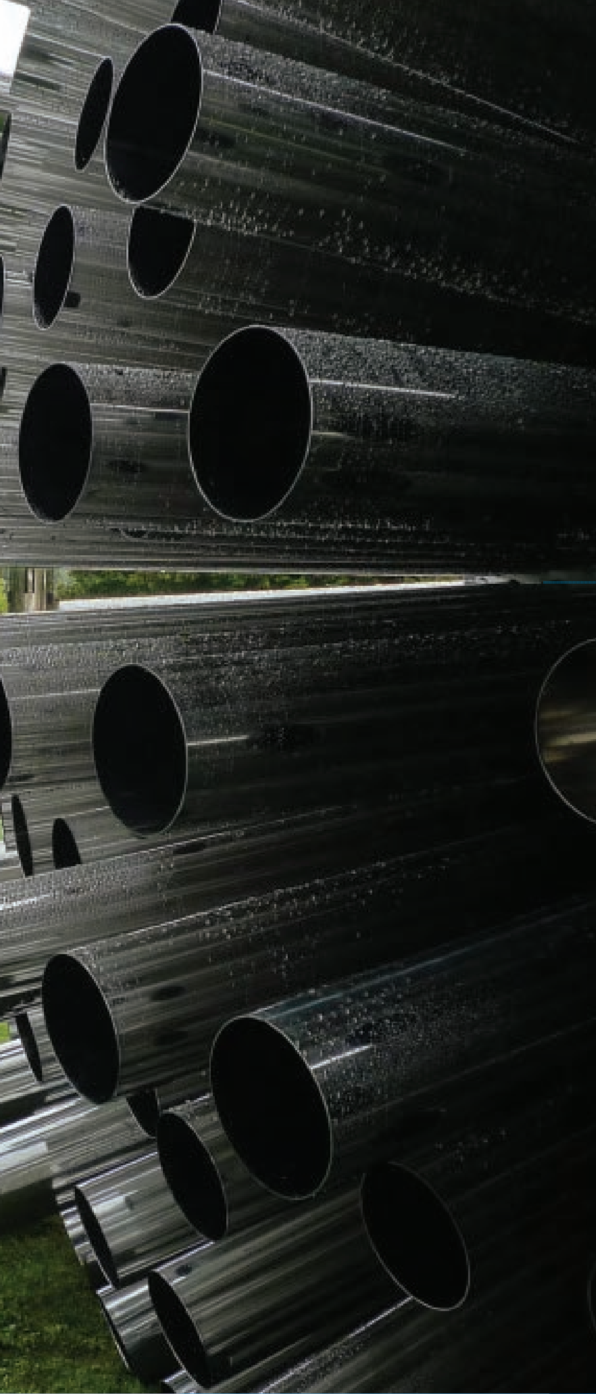
Co-produced by O'Reilly Media UK and the Centre for Life since 2009, this largest gathering of makers in Europe will showcase 300 maker exhibits and welcome upwards of 10,000 visitors. makerfaireuk.com

IMPORTANT: All times, dates, locations, and events are unconfirmed and subject to change. Verify all information before making plans to attend. Know of an event that should be included? Send event listing for possible inclusion to: events@makezine.com. Sorry, it is not possible to include all submitted events.

Gregory Hayes

Sing with the Wind

By *Gregory Hayes* **lukejerram.com/aeolus**



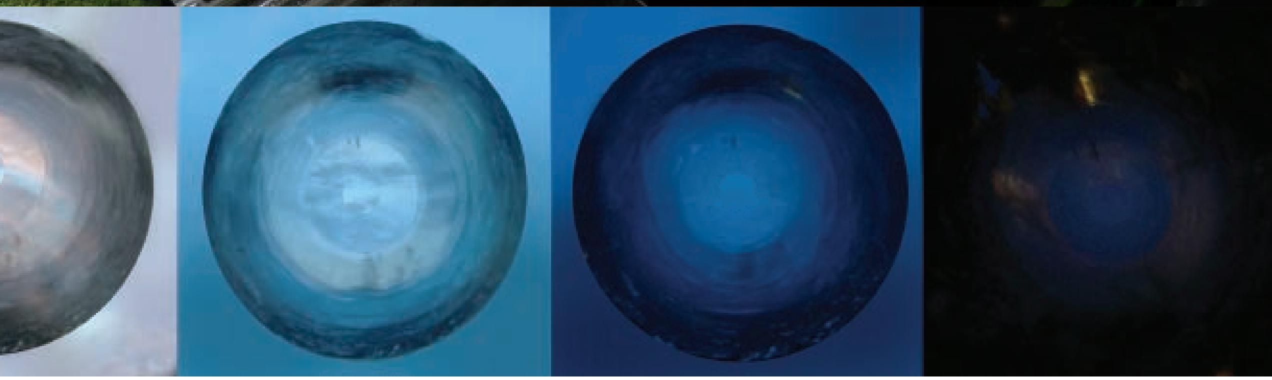
Luke Jerram; Richard Deane (inset, left)

The *Aeolus* acoustic wind pavilion, named for the ancient Greek ruler of the winds, could be described as a sculpture, a giant aeolian harp, an optical pavilion, and even an important artwork. Considering its genesis, perhaps it would be more accurate to call it a temple to the senses.

Luke Jerram, the artist behind the work, got the idea during a visit to Iran. There, desert well-diggers using only an axe will dig straight down through the sand and rock to the water table, then tunnel across to transfer water from the wells to the towns. Every 50 meters or so they'll add an air vent. "I spoke with a desert well-digger who had been doing this his whole life," says Jerram, "and he talked about how sometimes the wells would sing and make noise as the wind blew over the top. That got me thinking about other pieces of architecture that might create sound, and to indeed create a building that would resonate and sing with the wind.

"The geometry of this artwork is inspired by visiting mosques, thinking about domes of mosques, and how light is used and considered in sacred architecture. And again, in the Basilica in Rome, they've got a solar clock with a small hole in a window, and at certain times of day the sun comes through to create a huge spot on the nave of the basilica."

Aeolus echoes these experiences for a visitor. Even when the wind isn't blowing, the tubes filter ambient sound, tuned to the Aeolian scale. The same tubes are highly polished inside and reflect the surrounding landscape in brilliant abstractions.



Glittering Cloud

By *Craig Couden* **incandescentcloud.wordpress.com**

Inspired by light, communal art, and cloud-gazing, artists **Caitlind r.c. Brown** and **Wayne Garrett** created *Cloud*, an interactive sculpture composed of around 6,000 new and used light bulbs donated from local homes, businesses, museums, and eco stations. The sculpture stood for a single night in September as part of the Nuit Blanche late-night arts festival in Calgary, Alberta.

Brown and Garrett attached thousands of new and burnt-out incandescent light bulbs to 1-inch chicken wire and reinforced them with glue. This shell of bulbs formed the translucent cloud shape, while 250 compact fluorescent bulbs illuminated the structure from within. Each of these working bulbs was connected to a pull-string switch, so visitors could turn each light on and off individually. The team spent three weeks working in a metal shop at the Alberta College of Art and Design followed by four days (and late nights) of setup on-site leading up to the festival.

Brown and Garrett weren't sure how people would react to the piece, because conventional art protocol (and countless museum signs) often stresses "do not touch." However, throughout the night many visitors played with the ball-chain pull-strings, cut to different lengths to resemble falling rain. One enterprising group worked together to turn off as many lights as possible — and then turn the entire sculpture on again with one coordinated tug.

"It was pretty magical to watch — although we definitely had to back away and give the sculpture space from time to time," says Brown. "It's surprisingly hard to watch people test the limits of endurance on something you've spent a month building."

Doug Wong

Split-Flap Storytelling

By ***Matt Richardson***
mechanicalflipbook.com

In a nod to Eadweard Muybridge's contribution to the early development of motion pictures, **Wendy Marvel** and **Mark Arnon Rosen**'s Mechanical Flip Books tell a very short story in just 24 frames. These handcrafted boxes use a motor-driven spindle that flips through distressed pages of an animation in under four seconds.

Their first flip book was created from scrapped inkjet printer parts. But the variations in discarded printer components made it difficult to create a repeatable design. Since then, they've sourced motors that have the right electromechanical characteristics and "sound just right." Even the page material is selected to ensure that they'll flip gently and yet won't fray or wear out.

The mechanics and materials aren't the only challenge, however. The animation that the box displays must be carefully considered. After a few days of concept development, they plan out the timing and make sure that the composition fits well in the confines of the box's frame before they produce the pages. The physical design has even evolved to allow more complex storytelling: by adding sensors and an Arduino, it's possible to link several boxes together and let the animation travel from one box to another.

Marvel and Rosen were initially apprehensive to show the Mechanical Flip Books at Maker Faire Bay Area along with their fellow members of L.A. hackerspace, Crash Space — they didn't know how they would be received. But Maker Faire visitors loved them. "Seeing so many people excited and full of questions was an amazing adrenaline rush," says Marvel. "At night we were completely exhausted, grinning like Cheshire cats as our heads hit the pillows."

Patrick Posta

Made of America

By *Joe Sandor* **felionstudios.com/pans**

Back in the old days, pioneers traveled with round cast iron skillets. You could make round pancakes, round eggs, and throw some rectangular strips of bacon on the side. But today, thanks to **Alisa Toninato** of FeLion Studios, you can cook a quiche in the shape of your home state.

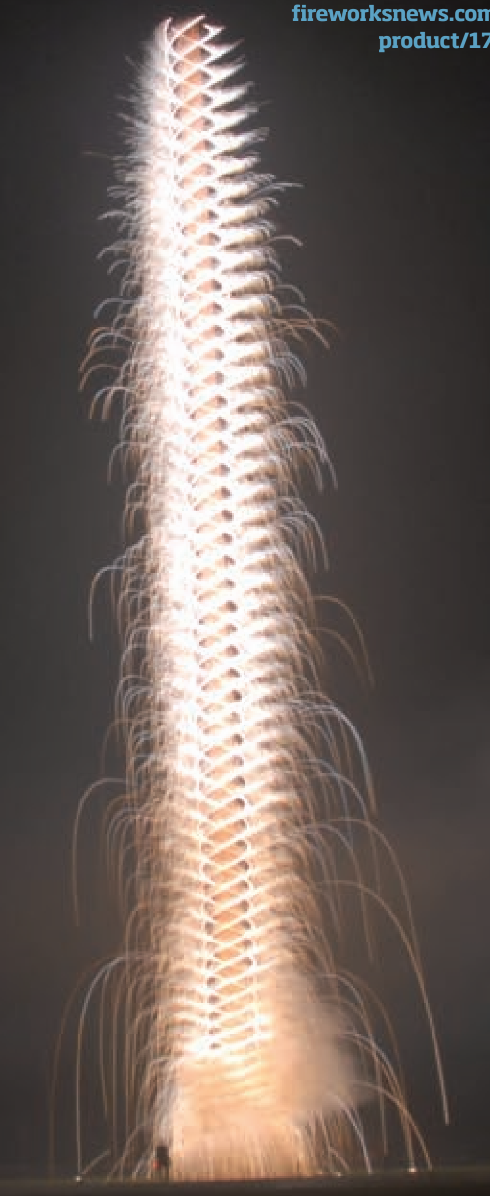
Toninato made her first skillet in the familiar shape of the great dairy state, Wisconsin, in her own DIY backyard foundry at the first annual "Pour'n Yer Heart Out" iron pour in Milwaukee. Shortly after, while on a flight to L.A., she used the inflight map in her seat to draw out handles on all the states of the union, thus giving birth to the Made In America cast iron skillet map of the U.S.

Now FeLion Studios is in full swing production, offering castings of any state in the continental U.S. You could cook at least a dozen steaks in Texas alone. Recently, she ambitiously mapped out Canada with a whole new set of land mass challenges. Though the proportional sizes of Alaska and Hawaii give her pause: "I see Hawaii as a muffin tin instead of a skillet!"

Joe Sandor (egg), Paulius Musteikis (pouring/welding), FeLion Studios (skillet map)

Pyrotechnic Pillars

By ***William Gurstelle***
fireworksnews.com/product/175



John Morgan; Barbara Dimock (inset)

Imagine a helicopter exploding and falling up, and you'll get the basic idea of a girandola, an arcane type of firework. A girandola is a whirling, spark-spitting fountain of burning chemicals, paper, and bamboo that rises as much as 100 feet into the air.

Among pyros, girandolas are considered one of the most finicky, challenging, and (on those occasions when they actually work) satisfying of all fireworks. Sixty-four-year-old **Tom Dimock** was hooked as soon as he built his first one. Dimock, who splits his time between Ithaca, N.Y. and Jamaica, is known among his fireworks-making peers as a master of the craft, and when it comes to girandolas, he literally wrote the book.

To make his girandolas, Dimock builds a jig around which he wraps bamboo, tying it into place with tar-impregnated string. Next, he builds the chemical drivers that lift the device through the air: a sort of black powder rocket motor, specially designed to provide enough thrust to lift and spin the device, but not so much that it tears the bamboo framework apart. Finally, he attaches the drivers and other carefully selected fireworks with more tar string. A single large girandola, some of which are nearly four feet across, takes him a week to make.

Since they are so complicated and exacting, a girandola succeeds about half the time. But that doesn't get Dimock down. "When girandolas do what they're supposed to do, they are wonderful and spectacular," he reflects. "And when they don't work, they are still wonderful and spectacular."

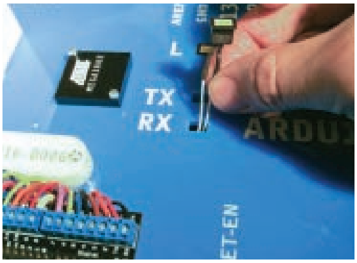
John Edgar Park showcases his Arduino Grande at Maker Faire New York, while co-founder of the Arduino project, Massimo Banzi (background), holds the standard size.

Honey I Shrunk the Maker

By *Laura Cochrane* **makezine.com/go/arduinogrande**

"Arduino is going to be really big at Maker Faire this year." As these words rang in MAKE editor John Edgar Park's ears, the thought occurred to him that he could make Arduino even bigger — literally.

Using 3D modeling software, Park designed a giant version of the Arduino Uno microcontroller board. He then turned his delightful dream into reality by laser cutting, soldering, etching, and painting.



The result? Arduino Grande, a working microcontroller (thanks to a normal Uno mounted on the board) six times larger than life. In the top left corner (the location where a regular-sized Arduino declares its Italian origins), Arduino Grande proudly announces, "Made in Burbank" (Calif.). Park is pleased with his results: "The first time I hoisted it up on my shoulder like a boombox I was pretty darned psyched!"

Gregory Hayes (top); John Edgar Park (bottom)

Jack Long

Fluid Suspensions

By *Laura Cochrane*
behance.net/jacklongphoto

Sculpting liquid into exquisite, ephemeral sculptures and capturing them on camera requires a creative eye, mechanical know-how, precision, and most importantly, an abundance of patience. **Jack Long** of Milwaukee possesses all of these qualities, thanks to his experiences as a professional photographer and amateur tinkerer. He originally got into high-speed photography a few years ago, when he was working on photographing beverages flying through the air. As Long experimented with creating more traditional liquid "splash" imagery for his professional work, he became fascinated by the interesting shapes that liquid takes when airborne.

Today, he regularly experiments with capturing these split-second liquid sculptures in his garage, constantly asking the question "what if," and constructing various mechanical devices to direct the liquid in ways that will achieve different looks. Some of his sculptures resemble real objects, like flowers in a vase or jellyfish, while others are abstract and lend themselves to any number of interpretations. "I took the basic forms I was getting and experimented with color, texture, and shape," he explains. The images are single capture, non-composite photos, where Long is usually the sole stylist and photographer, which translates to a painstaking process of several days of preparation followed by one full day of shooting. He only recently commissioned an associate to build him an Arduino-based electronic timing device to help orchestrate events during his elaborate shoots. "[It] has become a near obsession," Long admits.

HACK

THE TRACK

Anne Petersen

MOVE OVER FORMULA 1, THE POWER RACING SERIES IS IN TOWN.

by **Goli Mohammadi**

TEAM CHALLENGE: Modify to oblivion an existing ride-on electric toy of the Power Wheels persuasion, on a budget of no more than $500. Then compete in a series of races, while making a rowdy crowd-pleasing spectacle and trying not to catch on fire. It might just be the most fun you've ever had. Wanna race? We caught up with event organizer Jim Burke to get the skinny on the (maker) world-famous Power Racing Series.

KEEP RIGHT →

How did the "Pow-Pow" Power Racing Series (PPPRS) get its start?

We started the series in 2009, and held our inaugural event in a dirt lot that the landlord of our hackerspace owned. We had just six teams, all from Pumping Station: One [a Chicago hackerspace], and the cars were nearly stock machines. Friends and a bunch of kids from the neighborhood showed up, but it was a really small event. I don't think more than 60 people attended.

The main inspiration came from one rather active evening when a member dragged a discarded pink Jeep from the back alley into PS: One. We shoved larger batteries in it and drove on the roof of our space until somebody suggested that having more of these around would be fun. Then I said something about racing them, and a few drinks later we pretty much wrote the basic rules.

How many races have there been so far and how have they evolved?

We've been adding more races to our calendar since 2010, and we completed 2012 with six races total (four sanctioned and two non-points exhibitions). You could say that it really started expanding in 2011 when we added Kansas City to the calendar and the "championship" races finally meant attending more than one race weekend.

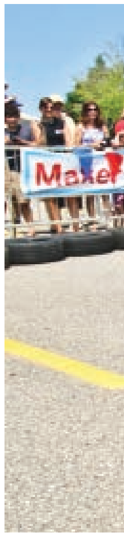
The one thing that has really changed is the level of creativity the teams are reaching. The cars are getting really interesting. We have wheelie-popping, trailer-hitching, power-sliding, drink-dispensing, water-dousing $500 electric race cars, and every season some

Eric Stein (Jim Burke, Banana Car)

666

GRAVE DIGGER

CAR#: 666
HACKERSPACE: Milwaukee Makerspace (Milwaukee)
ACTIVE: 2 seasons
WINS: 2
BASE: Power Wheels Grave Digger
FEATURES: Doors opened to fit driver Royce Pipkins' legs. Had no real brakes to speak of aside from a wooden plank with tire tread stapled to it. Earned namesake because it kept running over its own driver.



PPPRS TIMELINE +NOTABLES

- PPPRS founded.

POWER RACING SERIES

- First race had only one round. All cars were from the same team (Pumping Station: One).
- Cars were virtually stock, aside from reinforcements to accommodate larger batteries.

2009

hackerspace ups the ante.

On the organizational end, the biggest changes we've seen have come from improving how we run the event. I'm a graphic designer, so event management is probably the farthest I could be from any level of expertise. After a few years of trial and error, I'd like to think we have things sort of, mostly under control. Mostly.

PPPRS WISDOM #1:
"Don't worry about not knowing what you're doing, because you're not alone; we don't either."

Any memorable moments you can share from this season?
First was Sector67 towing their secondary car in the endurance race for 50-something laps. The crowd got a kick out of that. The fact that OmniCorpDetroit returned to Detroit in 2012 by converting their Banana Car into a rolling tiki bar was pretty fantastic as well. The T-shirt cannon that fired denim cut-offs was a nice touch. Finally, having our first night race in Chicago was also a highlight. The qualifying session for that race was actually intense, with cars coming within mere tenths of a second between each other. Ambassador Carol Moseley Braun presented the trophies.

Besides driving fast, what else gets points on the track?
Ah, the moxie points! Those are literally the crowd favorite. Basically we have an Arduino-

313

BANANA CAR

CAR#: 313
HACKERSPACE: OmniCorpDetroit (Detroit)
ACTIVE: 2 seasons
WINS: 0
BASE: Little Tikes Hummer
FEATURES: Only car with more than two car audio systems. Equipped with bar capable of banana mixed drinks. Armed with T-shirt cannons and rear pedestal for "hop-on" riders. Stands 6' tall, not including disco ball.

Anne Petersen (Grave Digger, Little Pink Trike, Americar, man down)

- First race involving multiple (five) hackerspaces at Maker Faire Detroit.
- First wheelie performed by Milwaukee Makerspace's Little Pink Trike, which split in half upon landing.

- First Endurance Race, shockingly won by OmniCorp-Detroit, who never pitted for batteries.
- First electrical fire: Americar goes ablaze in demonstration run while piloted by Bre Pettis.

KEEP RIGHT

2010

controlled board of buttons that gets sent out into the crowd, and next to each button is a team. When the crowd pushes a button, that team is rewarded actual race points for doing whatever the crowd finds entertaining. It's up to the teams to find ways to entertain

PPPRS WISDOM #2:
"Teams are also given some hefty limitations so you masochistic engineers can pleasurably cry yourselves to sleep at night."

everyone. This can be comprised of acting silly, popping wheelies, epic passes, or simply catching on fire. The goal is to encourage social engineering; you want teams to not only work the mechanical end of this series, you want them to figure out how to read a crowd. I think that social engineering is just as essential to a hacker-space competition as physical engineering.

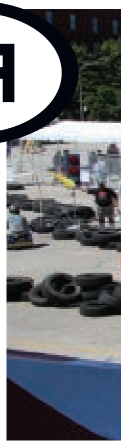
What are some favorite cheap but awesome mods you've seen?
J-Squad, one of the first teams, built their car around a $200 starter motor off a semi truck. There isn't really much logic to this; the car is an automatic drifting machine. The crowd really gets riled up when they see a kid's toy power slide through turns.

Sector67 started water-cooling their brush-less motors last season. Now several teams are equipped with similar systems. In 2011 they debuted the first wireless telemetry system that reported motor temperatures and other data to their pit crew. I think it was also equipped with GPS, but since that was over budget it was disabled during the race.

Why hack an existing platform instead of building a machine from scratch?
Well the easy answer is: you can't have a hackerspace motorsport without hacking! I really think there's massive value in building from scratch, but there's also another larger series of benefits that come from taking apart something and repurposing it. We could just have people make electric go-karts and dump as much money in them as possible and call it a day. To me, that's boring, and reserved for a

FAUXRARRI

CAR#: 67
HACKERSPACE: Sector67 (Madison, Wis.)
ACTIVE: 1 season
WINS: 7
BASE: Power Wheels Ferrari
FEATURES: Custom Arduino-based motor controller dubbed Paragon. First car to utilize water-cooling system. Relies heavily on regenerative braking. Acceleration from two unstoppably powerful 1970s electric lawn mower engines. Has trailer hitch for wheelie bar. Clocked 0-18mph in 50 feet.



Colin Parsons (Fauxrarri)

- First time PPPRS hosted two events in one year, with the opening round in Kansas City.
- Digital moxie point system.
- First year with over 20 entrants.
- First real pit stop for both batteries and tires.

- First rain-affected race. Cost Sector67 valuable lap time.
- First car flip by Royce Pipkins in Kansas City.

2011

PPPRS WISDOM #3:

"For every ounce of engineering there will be equal parts of tomfoolery."

Eric Stein (raceway shots); Alfredo Castil (The Cannon, timeline shots)

more legitimate racing series. I want people to take something that was never intended to be modified in this way and use a minimal budget to make it happen. Some of the best bouts of creativity come from constraints, and we live in a world full of constraints! We should just condition ourselves to try and fail and then learn. Hacking apart stuff is pretty much the easiest and cheapest way to do this. It's something we all need.

How did you get started making things and who are your inspirations?
I was raised in a home of making. My father is in the tech industry and a self-taught automotive engineer, and my mother was in the printing industry and an illustrator. Both of these backgrounds cultivated my love of art and science. I used to build things out of anything sitting around the house (mostly various types of paper and cardstock) and loved cars from a young age. I really admired the artistry in engineering early on.

03

THE CANNON

CAR#: 3
HACKERSPACE: i3 Detroit (Detroit)
ACTIVE: 3 seasons
WINS: 8
BASE: Power Wheels Jeep Wrangler
FEATURES: Odd camber setup catered to Karen "Cannonball" Corbeill's aggressive sitting stance. Built around low-hanging batteries and dual 1000-watt motors. Dual disc brakes work occasionally. Relies on shifting body weight to manage turns. One of the most difficult cars to drive.

- Timing and scoring become electronic.
- Closest drag race ever, won by under 3". Required video review.
- First full-on rain race at Maker Faire New York, with i3 Detroit victorious.

- Four races in one season (Kansas City, Detroit, Chicago, New York), plus two non-points exhibition races in Florida and Indiana.

2012

PPPRS WISDOM #4:

"OK, so you're taking these tiny little plastic cars and modding them with motors that push them near 20mph and you're asking me if this is safe? Methinks you need to wear the helmet outside of the track."

Having a mutual respect for both fields really shapes the kind of art projects you take on, and honestly, when it comes down to it, I've seen PPPRS as some sort of traveling hacker art exhibit. Makers and artists are cut from the same cloth as far as I'm concerned.

What do you think is the key factor in the recent growth of hackerspaces?

Community. You need to have a strong community. Variety is just as important. Hackerspaces are an exponential force of creativity and require a relatively healthy mix of tinkerers, hobbyists, and professionals to work. I also think the modern economic climate has really benefited from this growth. The lumbering state of our country, coupled with a growing resentment of apathy and pessimism in my generation has really helped too.

Makers my age seek the knowledge of the past to look toward the future. We ask our elders the long-forgotten trades and give these skills a renewed purpose. The economics of mass production has helped us scale things down to a world of affordable customization. Frankly, if things keep going the way they're headed, you'll see a rebirth of manufacturing in the U.S. the likes of which we've not seen previously. I honestly feel that we're on the verge of the next great cultural industrial revolution, and the seeds for this prosperity are right in our neighborhoods at our local hackerspaces.

How has hosting the event at Maker Faires affected the race?

MAKE magazine has literally helped make this

314

LITTLE PINK TRIKE

CAR#: 314
HACKERSPACE: Milwaukee Makerspace (Milwaukee)
ACTIVE: 2 seasons
WINS: 1
BASE: Fisher-Price Barbie Trike
FEATURES: First entry with battery meter and fast-change battery pack for quick pit stops. First to pop wheelies. Fastest in a straight line during seasons raced. Single most difficult vehicle to drive (mad props to the over-6'-tall Tom Gralewicz for nearly winning with it on several occasions).

Eric Stein (raceway shots); Anne Petersen (Little Pink Trike) sort of event even remotely possible. Between all the staff, such as Sherry [Huss], Dale [Dougherty], Louise [Glasgow], and Jonathan [Maginn], we've had help from day one. They're fantastic to work with! They showed us the ropes, gave us the advice and help we needed, and then delivered the track and logistics. We simply could not have done it on our own. They really made sure we could perform as we needed and taught us a great deal. I'm glad we reached out to them in Detroit 2010 because I feel every year we work with Maker Faire we become stronger and more prepared to put on a good show. After all, at the end of the day, it's about going out there and showing the crowd how fun making can be. What better way than to get a bunch of hackerspaces together at Maker Faire?

Where do you hope to take the series, literally and in essence?

I try to take things one year at a time, but I've certainly considered what it would mean to keep doing this for many years to come. If that is a real possibility, I want to make this event an arena for education.

With the help of sponsorships, I want to get high schools into the series and have hackerspaces mentor the development of their teams. I want to help foster inexpensive and fun education with real-world trial and error, all within the confines of a local hackerspace. I hope I can make that happen soon, as early as this coming season but as late as 2014.

Deep down, all I really want is for the hackerspace community to continue supplementing education, with my little series contributing toward a larger goal of having hackerspaces — these great bastions of learning — teach communities.

What's the most important thing you've learned about hosting an event of this magnitude?

That it's absolutely impossible to do this without friends or a community of people who believe in you. If I were to list all of those who have helped me over the years, it'd take up a few pages. Their enthusiasm keeps me going through the rough parts of organizing. I have to give a shout out to Patrick Callahan, though, who helps out tremendously.

Here's something else important I've learned: anyone can do this. Seriously, there's nothing stopping you from going out there and doing something like this. Yes, you. This is really for anyone out there who's swamped in the doubt and uncertainty that never stops bouncing around in your head — you just need to silence those thoughts and do it. Get an idea, talk to people, refine it, fail a ton, and make it happen. There's no time better than now. Go find a community, get involved, and be the person you've always wanted to be.

✚ Mod your own car and get in on the action at an upcoming race: powerracingseries.org.

DUCT TAPE + ZIPTIES

CAR#: 911
HACKERSPACE: CCCKC (Kansas City, Mo.)
ACTIVE: 2 seasons
WINS: 1
BASE: Power Wheels Cadillac Escalade
FEATURES: Uses bicycle frames and tires for chassis. Has unique "Flintstones" bottomless floor so you can push with the power off (during cautions in the Endurance Race) to conserve battery. Made by two hacker families and features several team members in high school (former FIRST robotics competitors).

Alfredo Castil (Duct Tape + Zipties)

PPPRS WISDOM #5:

"We will laugh at you. You'll get used to this or cry. Then we'll laugh more. That's actually written in the rules."

Going PRO

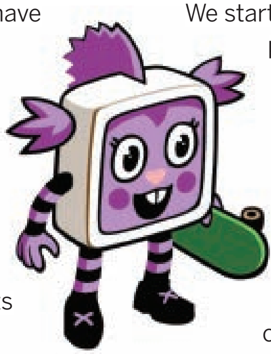
By ***David Merrill***

Makers are turning their hand-soldered prototypes into real consumer electronics.

Startups don't make mass-market consumer electronics products, only giant companies do. That's what I used to think. Despite a few celebrated exceptions with DIY beginnings like HP and Apple, it has historically been tough for small companies to succeed making hardware products. The main barrier is simple: it's expensive and complicated to manufacture physical things!

Components and materials have to be purchased in advance to guarantee availability, each unit requires labor to assemble, and transportation costs eat profit margins. This all makes the financial barrier to entry daunting. On the flip side, desktop software, mobile apps, and web services are much cheaper to build and deploy these days, so a lot more startups and venture investments have steered toward virtual products.

But recently something awesome has been happening: more startups, like the company that I co-founded, Sifteo (sifteo.com), are making hardware products. Makers are turning their hand-soldered prototypes into real consumer electronics (CE) products and selling them through retailers like Amazon and Best Buy.



Changes in manufacturing and distribution power this new breed of lean CE startups. In the last year and a half at Sifteo, we launched two generations of Sifteo Cubes, a hands-on game platform built around a very different (and fun) new interface, an expanding library of downloadable games, and a software development kit with an emulator for developers. Sifteo Cubes are "inch-scale computers": small, wireless tiles with color screens, accelerometers, adjacency sensors, and touch sensing that make classic play interactive — they're like programmable magic dominos that run brainy action-puzzle games.

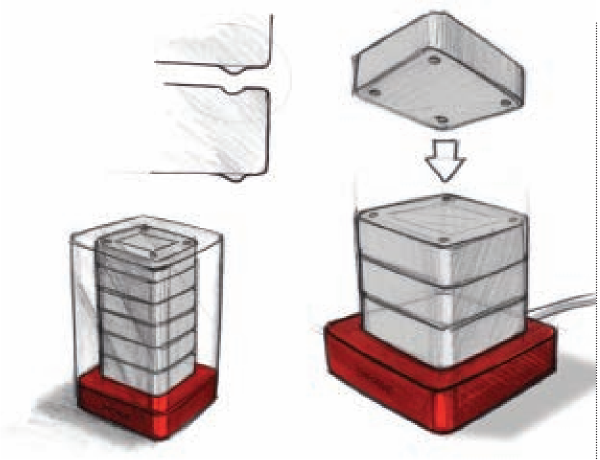
This article shares our founding story, the evolution of our products, what has changed in the market to make what we do possible, and my top five lessons for transitioning from hobbyist maker to entrepreneur.

Case Study: Sifteo Cubes

Jeevan Kalanithi and I didn't realize we were mapping out the next 6+ years of our lives when we spent an afternoon in 2006 sketching on printer paper in the kitchen. Longtime friends and then-graduate students at the MIT Media Lab, we were thinking about how computer interfaces should be more hands-on, more like a pile of Legos than a glass slate and a keyboard. I love building useful physical things and am fascinated by how tools and other objects augment creativity and help us think. The more we sketched, the more Jeevan and I became obsessed with the idea of a computer interface made up of a bunch of little interactive pieces that would let hands and minds move in unison.

We started with a simple idea: small physical objects that could each represent a digital thing, like a photo or an email. Arrange the objects and you arrange their virtual counterparts! There were a lot of open questions, like: what capabilities should these devices have? What will the "killer app" be? How "real" do our prototypes need to be to learn if this is a good idea? First, we made non-functional prototypes using wood and acrylic, to try different sizes for the devices and ideas for applications. We asked others what they thought they'd be good for. We called our idea "the Siftable Computer," or "Siftables," for short, and learned that they should have screens about an inch square and should be able to talk to each other when placed side-by-side.

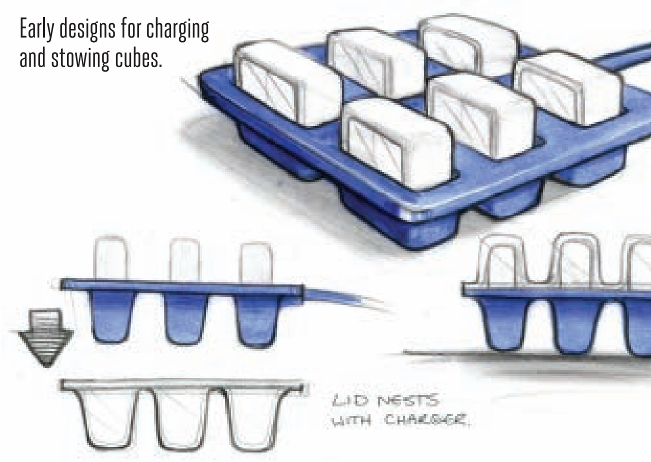
We bought color LCDs, infrared transceivers, accelerometers, and microcontrollers from online electronics hobbyist shops and sent a circuit board design off for barebones, low-cost fabrication. When the first circuit boards arrived, we assembled a handful of barely functional Siftables that kicked off two full years of trial and error. We made three generations of working prototypes, each generation fixing the bugs of the previous and



allowing us to try new application ideas more easily. We let people use them a lot along the way, and noticed something surprising and exciting: our testers were having a lot of fun. Rather than using them for work, they wanted to play with Siftables.

By the third-gen prototype, we had gotten it mostly right. The color display, Bluetooth radio, neighbor sensing, 3-axis accelerometer, and battery-charging circuits were all working well. The downside? Each block cost more than $200 in materials, and it took me four hours to build a single one, soldering all the components by hand.

By 2008, Siftables was a great research platform, but it didn't seem like it was destined to be a commercial product. They were too expensive to manufacture, and although people who used them thought they were neat, we still weren't confident in their mass appeal. Then an unexpected breakthrough happened: I was invited to give a short "tech demo" talk at the TED Conference. I almost turned down the offer, thinking that we'd have better demos to show a year later — but decided that the opportunity might not exist then! The audience loved the simple, brainy, playful apps that I showed, like the physical equation editor and the word game that I likened to an interactive form of Scrabble. When my talk appeared online it went viral, and has now been viewed more than a million times.



Early designs for charging and stowing cubes.

What's Different About Now?

So why can a young startup make a CE product these days?

Costs are down, and quality is up. Components are cheaper than ever and manufacturing capacity in Asia (where Sifteo cubes are now built) is plentiful, thanks mostly to the rise of the mobile phone industry and other mass-market CE products.

Prototyping is easier. Basic circuit boards can be fabricated cheap and quick, facilities like TechShop provide affordable access to expensive tools, and online suppliers of DIY materials are more comprehensive and helpful than in the past.

CE startup founders are helping each other. The web-entrepreneur culture of sharing information is spreading to CE startups – you'll be surprised at who will meet you for coffee to hear you out and give some feedback. There are a number of new hardware incubator programs, and the Bay Area now has several Meetup groups focused on commercializing hardware products.

The mature internet. Products can connect to the internet, meaning CE businesses like Sifteo can have a second revenue stream based on virtual goods (e.g. our game store). I call this Connected CE, and it's relatively new. Companies can also spread the word about their product using web video, enabling customers to get comfortable enough to buy without experiencing it firsthand. Kickstarter is a fantastic tool that allows entrepreneurs to gauge demand before they commit to building a product. The new revenue streams and message-spreading capabilities allow CE startups to enjoy the kind of steep growth potential that attracts (or someday obsoletes?) investors.

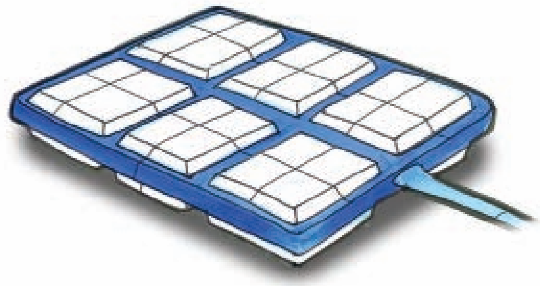
New Deal Designs (illustrations)

The response to my TED talk showed us that Siftables resonated with a wide audience. People were excited by their tactile nature — unlike any technology they'd previously experienced, and they wanted to play. We started Sifteo Inc. and were awarded a Small Business Innovation Research (SBIR) grant from the National Science Foundation. Funded by this initial grant, we met venture capital firms True Ventures and Foundry Group and raised more than $10 million in two rounds. One takeaway from fundraising (which required serious time and effort) is that it's better to find an investor who already believes in your vision rather than trying to convince one who doesn't.

With a funded startup, there was still a ton of work to do before we could release a product to consumers. The game system would have to be robust, affordable, and user-friendly. We rewrote the code and rebuilt the hardware from the ground up. The finished product, Sifteo Cubes, did not inherit a single line of code or any hardware design from our earlier MIT prototypes. The Original Sifteo Cubes launched for the holidays in 2011 with a growing library of games focused on intelligent play. Users loved the tactile play experience, but the system was not user-friendly enough! Since games ran from the computer, they had to stick close to their PC — people really wanted it to be portable so they could take it anywhere. Jeevan and I work with a team of 25 extremely talented makers, and we hunkered down together immediately to create the solution: a new Sifteo Cubes platform that is portable, developed in just under a year and with a brand new SDK and cycle-accurate emulator that's already released. We're getting faster. You can read more about how we did it at tech.sifteo.com, and download the SDK and emulator for free at sifteo.com/developers.

Have a question about your CE startup or idea that I might be able to help with? Send me an email at dave@sifteo.com.

Dave Merrill (dave@sifteo.com) builds hand tools for the digital age with a bunch of smart makers at Sifteo. He is an entrepreneur, programmer, self-taught electrical engineer, and geek dad.



Takeaways for Makers

We have learned a lot over the past few years. Here are some of the most useful tidbits:

A neat idea is not the same as a good product, and a good product is not the same as a great business. Don't fall so deeply in love with your idea that you can't evaluate whether a successful business can actually be built around it.

Find out who your market is. You might think you already know who will buy your product, but entrepreneurs are often surprised. Get feedback early and often, and learn to relish being proven wrong.

Know what kind of company you want to build. Do you want to build an exponential-growth company, or not? It's OK to say "nope" and set your business up accordingly.

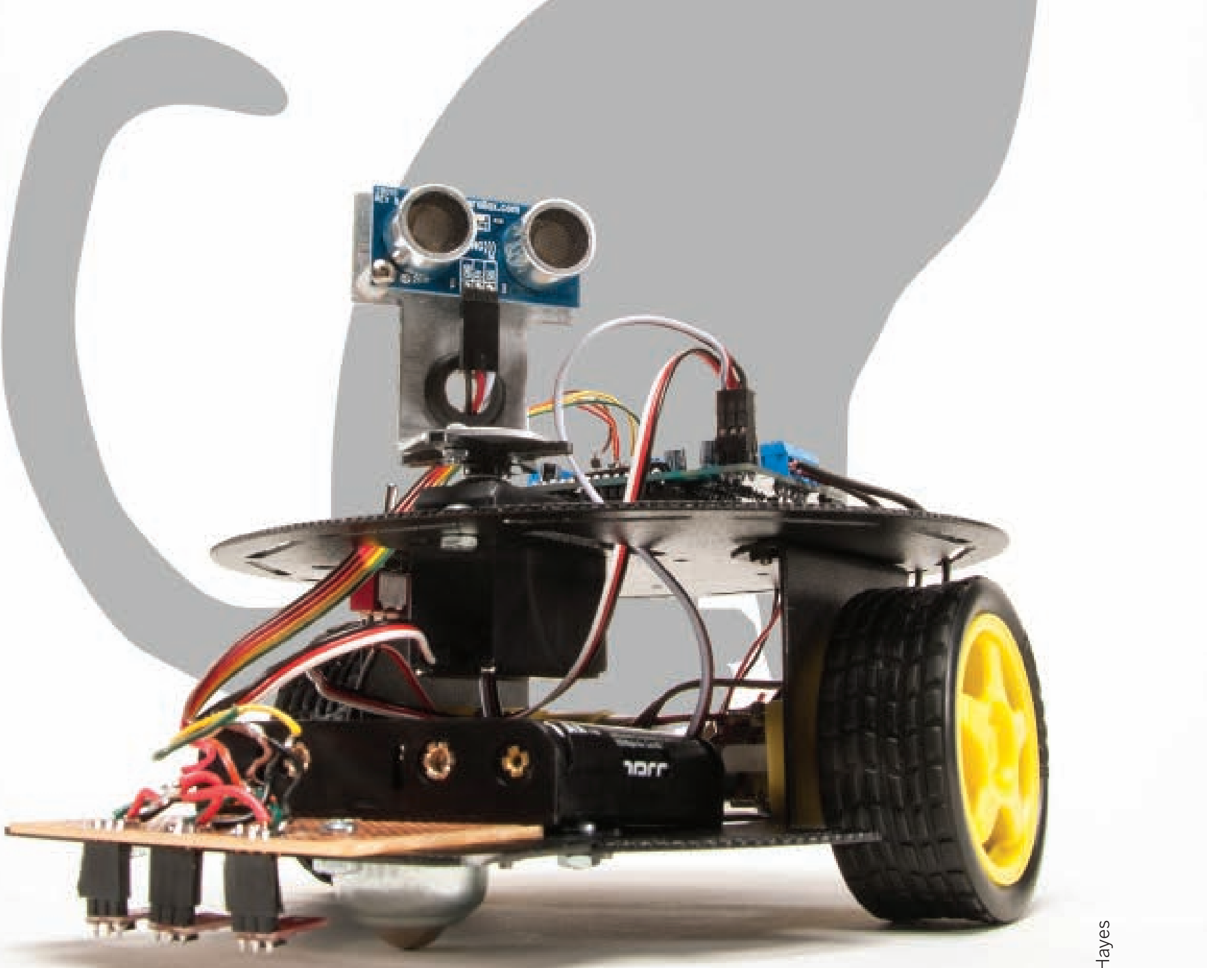
Keep it as lean as possible, but no leaner. Sifteo started in a basement where we paid $500 a month in rent. A good friend of mine regularly looks over new designs and offers feedback (thanks, Ivan!). Even after raising some money, finding ways to keep expenses down will increase your chances of success because you'll have more time to find your way there. At the same time, we do pay for outside help in areas where we need it, such as manufacturing, PR, and retail-channel relationships. Know what you can do well, and outsource the rest.

Nobody is more passionate than you about making your idea real. You really have to go for it, and you'll sacrifice other things along the way to building a successful company. Extraordinary outcomes require extraordinary efforts, and the startups that succeed are the extraordinary ones.

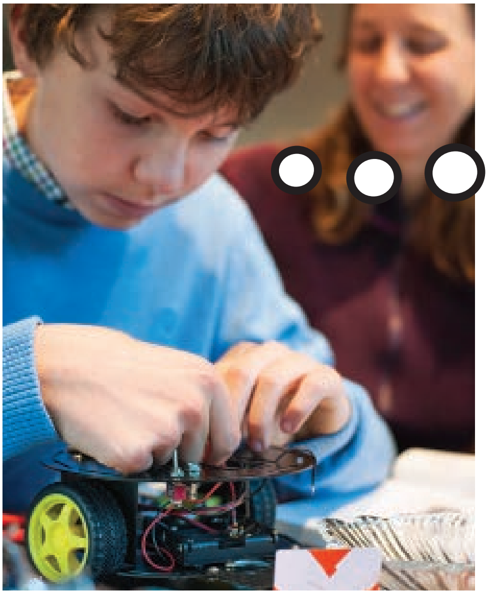
Learning TO BUILD A Bot

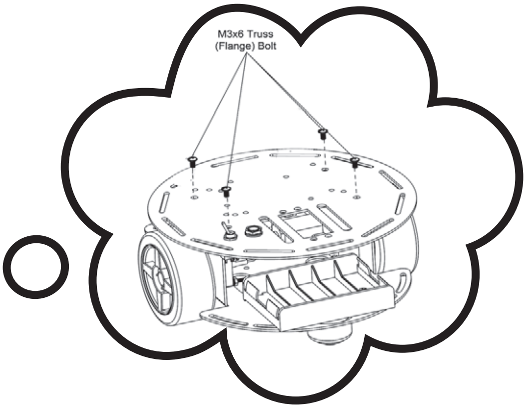
By **Benjamin Bonner** and **Kendra Markle**

Friends Ben, Kendra, and Monsieur Tux the cat tackle the Rovera Robot.



Gregory Hayes





Kendra: With great anticipation, my favorite 13-year-old, Benjamin Bonner, and I sat down to build MAKE's Rovera 2W Arduino Robot Kit. With Monsieur Tux the cat closely monitoring our efforts, we carefully unpacked the components and laid everything out. The size of the companion book (*Make an Arduino-Controlled Robot*) was daunting at first, but it has lots of color photos and illustrations, and moves you methodically through the build. It was easy to figure out what to do and in what order.

We quickly had the chassis and wheels together and the power switch and battery case soldered on (you supply the batteries). The instructions then show connecting the completed motor shield (a board that's added to the Arduino to provide motor control). After a moment of confusion, we discovered that this was a separate kit (included with the Rovera) with its own instructions. We found and followed those online.

Benjamin had never soldered before and he got some really good practice on the motor shield and Rovera's printed circuit board, which has just enough components to be challenging but not too many to be overly intimidating.

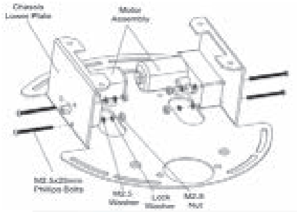
I highly recommend keeping all of the components together in groups. We organized ours in different bowls. With lots of similar-looking parts, pretty soon your desk will be covered with tools, parts, wire clippings, and solder bits, and that one lost component can take forever to track down.

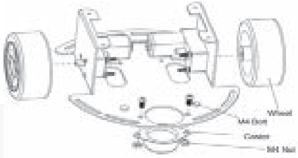
The Rovera Arduino library code was easy to download from the Maker Shed and the instructions were clear and helpful. Loading and understanding the code wasn't quite interesting enough to hold Monsieur Tux's attention. He preferred to distract Benjamin while I set up the software environment.

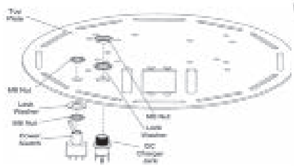
The fun really begins after the robot is fully assembled. The included code is just the beginning of the features and personality you can program for your bot. You're only limited by your imagination and patience for working through issues that come up. Monsieur Tux apparently has some great ideas for future additions and improvements.

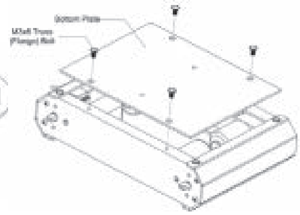
While it's possible for an intelligent eighth grader to build this bot alone, it's complex enough that having a little help makes it more enjoyable. We worked on it together for about an hour every day after school for almost two weeks before it really came together. It took longer than we thought, mostly because we had to troubleshoot a few problems, which are bound to happen with a project of this size (you're building a robot, after all). We also had to re-buy parts that we managed to ruin, since no extras are provided.

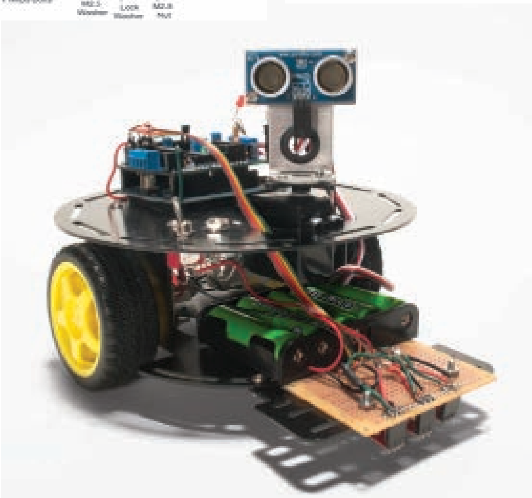
Benjamin: The Rovera is *way* better than Lego! This was my first big electronics project — my only experience before this was making the robot cockroach kits [RoboRoach from Backyard Brains]. It started to be really fun once I knew how to solder well. My favorite











part was soldering up the motor shield. The board looks like a city, and adding components feels like adding buildings to your city.

Unfortunately, the biggest skill I ended up needing for this project was de-soldering. I installed one of the 16-pin IC chips on the motor shield backwards and it was so trying on my nerves to de-solder all of it. But I learned my lesson. In the future, I'll always make sure to install the chip as marked!

You might need more time than you think to get all the way through this project. The instructions say that you can build Rovera in a weekend. That would be true for someone who's experienced in soldering and basic robot construction, and may be true if you don't make any mistakes.

Monsieur Tux was a helpful member of our team. He has a keen eye for detail and kept our spirits up. I want to program the robot to play with him. He's a black cat so I think we can program Rovera to follow him around, which will, of course, annoy and confuse him. He will be our test kitty. We'll see if he and Rovera become friends or enemies.

Besides being an eighth grader, Benjamin Bonner is an avid sci-fi reader and has read the entire *Doctor Who* series. He loves model trains, building worlds in Minecraft, and sleeping in.

Kendra Markle builds tools for behavior change in the healthcare industry (alteractions.org). She also makes wearable electronics, shoots portrait photography, and spends much time letting the cat in and out.

Monsieur Tux the cat is a keen artificer and excellent project manager with an interest in robotics and opening the front door by himself. He loves to solder and is the author of *Making Things Meow*. He is a relentless napper.

THE MAKE ROVERA ROBOT KIT is available in two models: two-wheel drive (2W) and four-wheel drive (4W). Both kits come with all the basic parts you need to build the bot and include Michael Margolis' companion book, *Make an Arduino-Controlled Robot*. The book provides assembly instructions for the two robots, how to program them, and has additional ideas for what you can do with your new bots. Rovera 2W and Rovera 4W are both available in the Maker Shed (makershed.com).

Written and photographed by
Tim Hunkin

Victorian MICROTECH

Adventures in vintage watch restoration.

I didn't know much about watches until my aunt died and I inherited an astonishingly beautiful pocketwatch from her. Looking online, I found it was made in Switzerland around 1800. It didn't run, and when I opened the case I thought a small worm had gotten trapped inside. On closer inspection it wasn't a worm but the tiniest chain I had ever seen, a perfect microscopic bicycle chain with links smaller than half a millimeter (above right).

I really wanted to take the watch apart to see how it worked but I was nervous because it was obviously worth a lot. So I emailed the local branch of the British Horological Institute with photos of the watch, inquiring if any of their members would be willing to tutor me. I had several replies saying a beginner should definitely not start with such a valuable piece (I think worth roughly £1,000/$1,608) but one member, Ian Coote, offered to take me on.

The first surprise was the height of his workbench, almost at neck level. You rest your wrists on the edge of the bench, and the watch movement is clamped in a holding block.

The screwdrivers are much more precise than cheap jeweler's drivers — they're color-coded and it's important to hold them the right way and use exactly the right size for each screw.

Once a screw is free, you remove it with tweezers. But these aren't ordinary tweezers; they have super fine points made of super hard steel (the best ones are made by a company called Dumont and cost about £30/$48). I never realized tweezers could do

Ian Coote

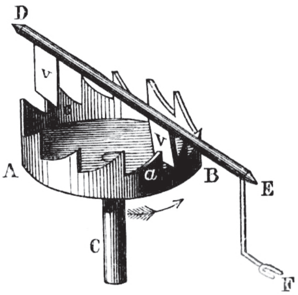
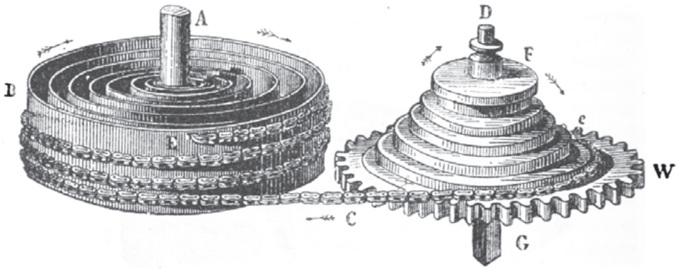


Fig. 58.



TIME PIECES: (Left) The verge escapement and (right) the fusee of old.

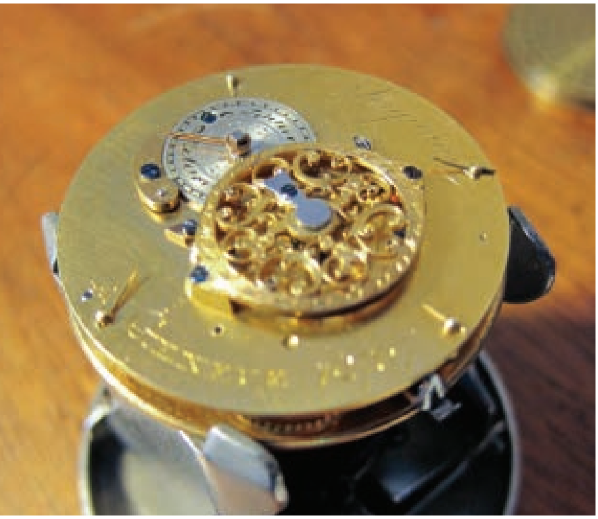
so much — they make picking up something tiny, like a human hair, really easy. The danger is that because they're so hard, it's easy to scratch the watch — I scratched a few parts, maybe decreasing the value of my heirloom.

You aren't supposed to touch anything with your fingers. Ian says I'm a good pupil apart from this failing — my fingerprints are now on almost every part.

I Lose a Part and Search for It

With Ian's encouragement I stripped the watch down to a mass of gears, plates, screws, and springs. Amazingly, nothing was seriously damaged, so it looked as if it might be mendable. Every screw looked different to me, so I couldn't see how we could possibly ever put it back together, but I had taken a few photos.

Once stripped down, everything had to be put in the cleaning machine. This involved putting all the parts in little wire baskets. Any sense of order I had as to where all the parts fit was lost at this stage. The cleaning machine immersed the parts and agitated them in a series of different fluids. The process took nearly an hour.



I then started reassembling the watch with Ian's guidance. With the help of the photos, working out where everything went wasn't quite as hard as I had thought. It gradually struck me that all these tiny parts had been made by hand. I can't imagine how the delicate minute hand could have been filed, or how any of the parts were made so precisely.

We then realized we had lost a part — the catch that locks the movement in the case. Ian's workshop is full of stuff, not an easy place to find anything. We spent hours searching and had just given up when it reappeared in a corner of a dark blue tray where I had put some parts. By this time we were both exhausted so I returned to finish the job another day.

I Give My Watch a Lube Job

I hadn't realized that the escapement was a *verge escapement* (pictured above). This is the escapement that was used on the very first clocks. Verge escapements have a very irregular "tick" and are never good timekeepers. They were gradually abandoned in clocks after the pendulum was invented in the early 17th century. As it was impossible to mount a pendulum in a watch, the verge remained for another 200 years.

The tiny chain I found when I first opened the watch was part of a mechanism to make it a bit more accurate, called the *fusee* (above).

Google Books (etchings) from Oxford University (verge), and Harvard University (fusee)

The more you wind a watch, the stronger the "pull" of the spring on the escapement. To even out the spring tension, the chain goes from the spring barrel onto a wheel with a spiral track. The chain was bent from being squashed against the watchcase, so I thought it was no good, but Ian confidently pulled it straight. Fitting it back in place was fiddly.

The other fiddly bit was replacing the top plate. All the gear shafts have reduced ends, called *pivots*, which fit into holes in the plate. I could fit two, but while trying to get the last one in, the others would pop out again. This was a relatively simple watch — some chiming watches have 13 pivots to locate. I did eventually succeed.

The top plate is fixed by four tiny tapered pins, pushed through holes in locating pillars. One pin had snapped off, so the pillar (1.5mm diameter) had to be drilled out. Ian set up a 0.5mm spade bit in his watchmaker's lathe, made a center mark on the pillar with the tweezers, and told me to drill by pushing the pillar against the spade bit. I never thought it would work, but it was surprisingly controllable and my hole went perfectly through the center of the pillar.

Then all the bearing holes had to be oiled. Too much oil gums up the works and can suck the oil out of the vital places by capillary action. Watchmaker's oilers ingeniously dispense one tiny drop at a time.

I Put It Together and It Works! ... Sort Of

When we finally got the balance wheel back in place, the escapement showed no inclination to tick, but tweaking two adjuster screws eventually got it going. At the end of the second day it felt very satisfying to replace the dial and case and hear the escapement merrily ticking.

Sadly, having adjusted everything possible, it still runs wildly fast, gaining 3 minutes an hour. Ian thinks the balance spring may have broken and been shortened at some point.

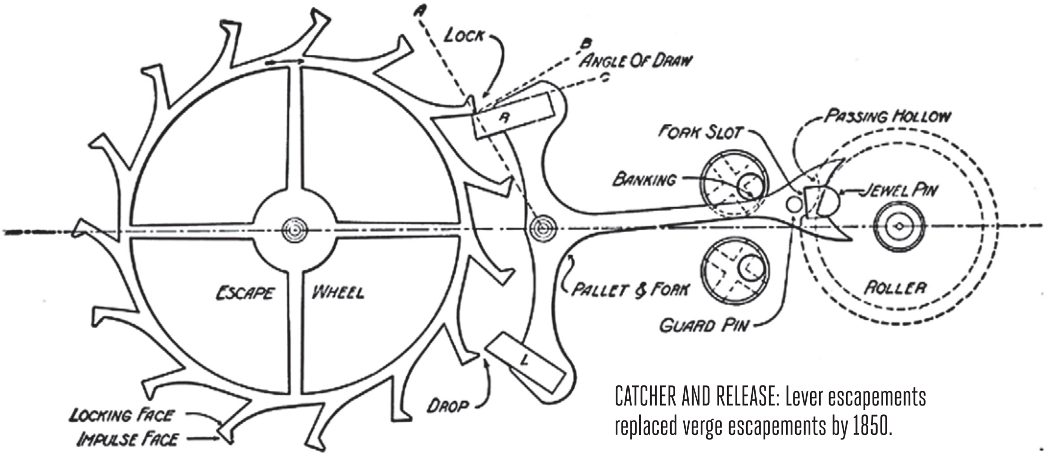
It was still a great experience. Rather than owning a valuable watch that doesn't do anything and that I don't understand, I now own a slightly less valuable scratched watch, but I know what makes it tick. I'm sure my aunt would have approved.

The Genius of the Lever Escapement

While I was working on my aunt's pocketwatch, Ian showed me some of his other watches. The very first watches appeared in the 1500s and apart from the addition of the balance spring, their basic design didn't change much until the 19th century. Then they went through a revolution — by 1850 the verge escapement was obsolete, replaced by the *lever escapement*.

The lever escapement solved a major problem. In a verge escapement the balance wheel is always in contact with the watch gearing, so any slight change in the friction of anything in the watch influences the balance wheel. The genius of the lever escapement is that the balance wheel (omitted from the shaft on the right of the drawing on the following page) is completely detached from the rest of the watch, except at the midpoint of its swing when it releases the "lever" and moves the *escape wheel* to the next position (making the tick sound). It's so much better that it doesn't need a fusee like the one inside my aunt's watch — a lever escapement will keep time whatever the spring tension.

Shortly after the lever escapement was introduced, an American engineer named Aaron Dennison developed the first machines



CATCHER AND RELEASE: Lever escapements replaced verge escapements by 1850.

to mass-produce watch parts. At first his companies kept going bankrupt, but somehow the same machines would reappear in the next company. Eventually named the Waltham Watch Company, it became well established and continued in operation until the 1950s. The Waltham Watch Company was really proud of its achievements, and felt that machine-made watches with interchangeable parts were "scientific" and greatly superior to European handmade ones. Its pride is very evident in the elaborate decoration of its watch movements.

Round Two: Dissecting a Waltham Railway Watch

I bought a beautiful Waltham pocketwatch (below) on eBay for about £100/$161 (a model 645, made in 1908) to take to bits. I thought it was a hopeless case because I couldn't pull out the winder to change the time. Ian immediately solved this problem. It was classed as a railway watch, and one of the railway specifications was that it must be impossible to change the time accidentally. So, instead of pulling out the winder, the dial cover had to be unscrewed and a tiny lever pulled out. Then the winder moved the

Rather than owning a valuable watch that doesn't do anything and that I don't understand, I now own a slightly less valuable scratched watch, but I know what makes it tick.

hands perfectly.

Instead of two thin "watch plates," Waltham watches are made of thick nickel-alloy plates, with spaces milled out to accommodate the gears. All the screws go in much further and it feels satisfyingly solid. It's a joy discovering how carefully every detail is designed.

My watch had 21 jewel bearings, pale pink rubies. Most of them could stay in place, but the balance wheel and escape wheel had a double jewel on each end — one with a hole as the bearing and one plain disk as an end plate, or thrust bearing — and these had to be taken out, as dirt gets in the gap between the two. After cleaning everything, we realized we had lost track of which jewel went where, a bad case of divided responsibility. It took hours inspecting them all under a microscope and trying them in different places.

Eventually we got the jewels in the right positions. The satisfying thing about a lever escapement is that it starts ticking instantly after the balance wheel is in place. Sadly my watch doesn't keep ticking for a full day, and is only accurate if kept flat. Ian is confident he could get it to work properly with effort, but still, not bad for a 100-year-old watch.

The End of the Pocketwatch

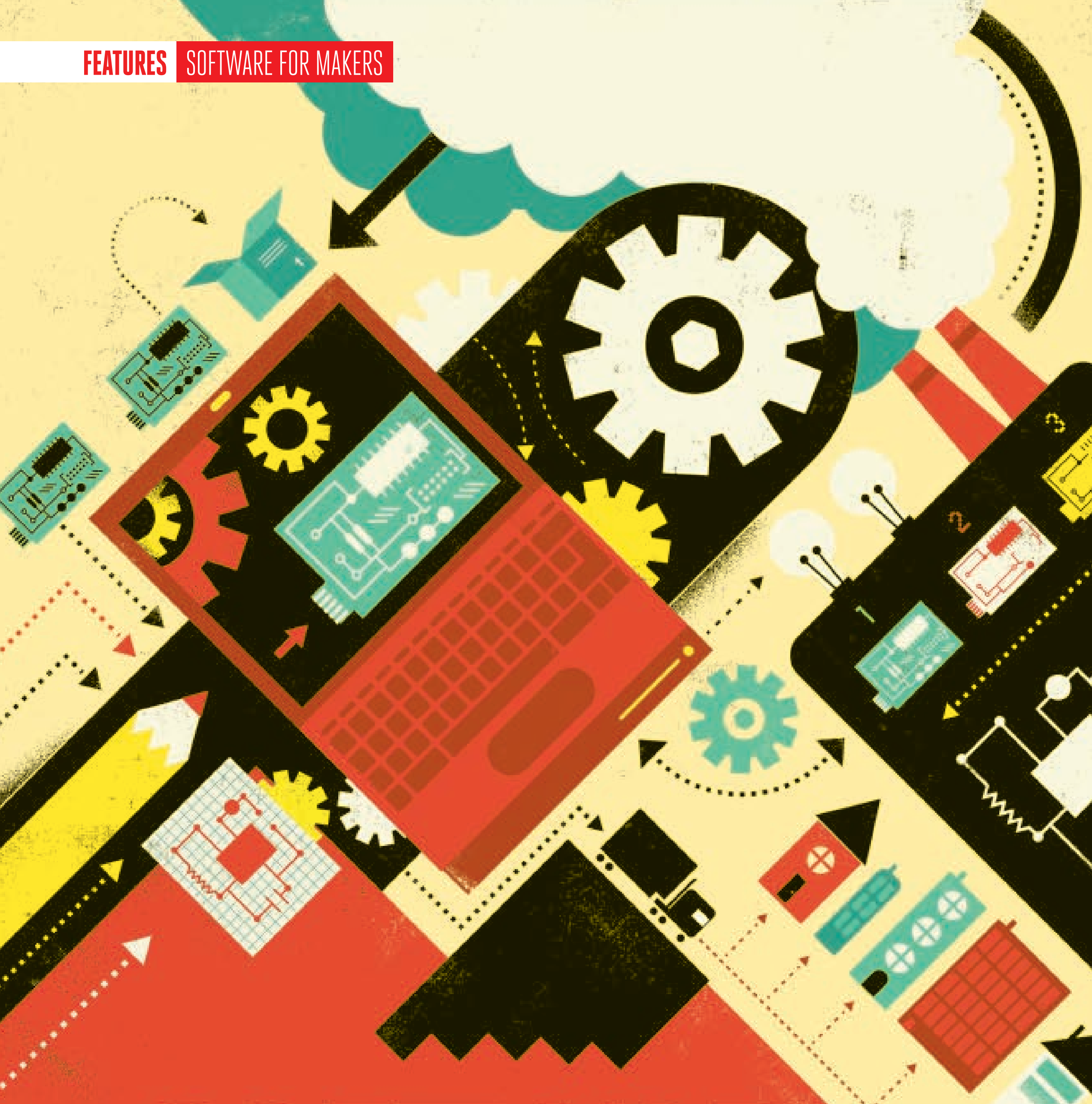
Pocketwatches were gradually superseded by wristwatches in the early 20th century. The movements were exactly the same, but half the size. The first digital electronic watch was developed by the Hamilton Watch Company and marketed in 1972 as the Pulsar. It had an LED display that lit only when a button was pressed for a few seconds, to avoid draining the batteries. The enthusiasm for digital displays didn't last.

Today's dial watches are electronic and battery powered (the first watch of this type was introduced by Seiko in 1969). The hands are driven by a stepper motor, and the timing is controlled by a quartz crystal oscillator. Quartz watches are typically accurate to within half a second a day, about 10 times more accurate than any mechanical one.

Now almost everyone has a mobile phone and there's no need to have a watch at all, so today's watches are basically jewelry. Simple quartz watches are now amazingly cheap.

Mechanical watches are also still made, but it's a strange business. At one end of the scale the Chinese mechanical watches on eBay cost less than £10 ($16). I bought one and it keeps good time. The Swiss watches that feature in glossy magazine adverts (often costing over £10,000/$16,080) also have traditional lever escapements. They're beautifully made and every part is hand polished — but it's weird that people spend that much on a watch that is less accurate than a simple quartz watch.

Tim Hunkin trained as an engineer but became a cartoonist for a U.K. Sunday newspaper. He next made *The Secret Life of Machines* TV series and now runs an arcade of homemade coin-operated machines in Southwold, England. He wrote "Building with PLCs" in MAKE Volume 23.

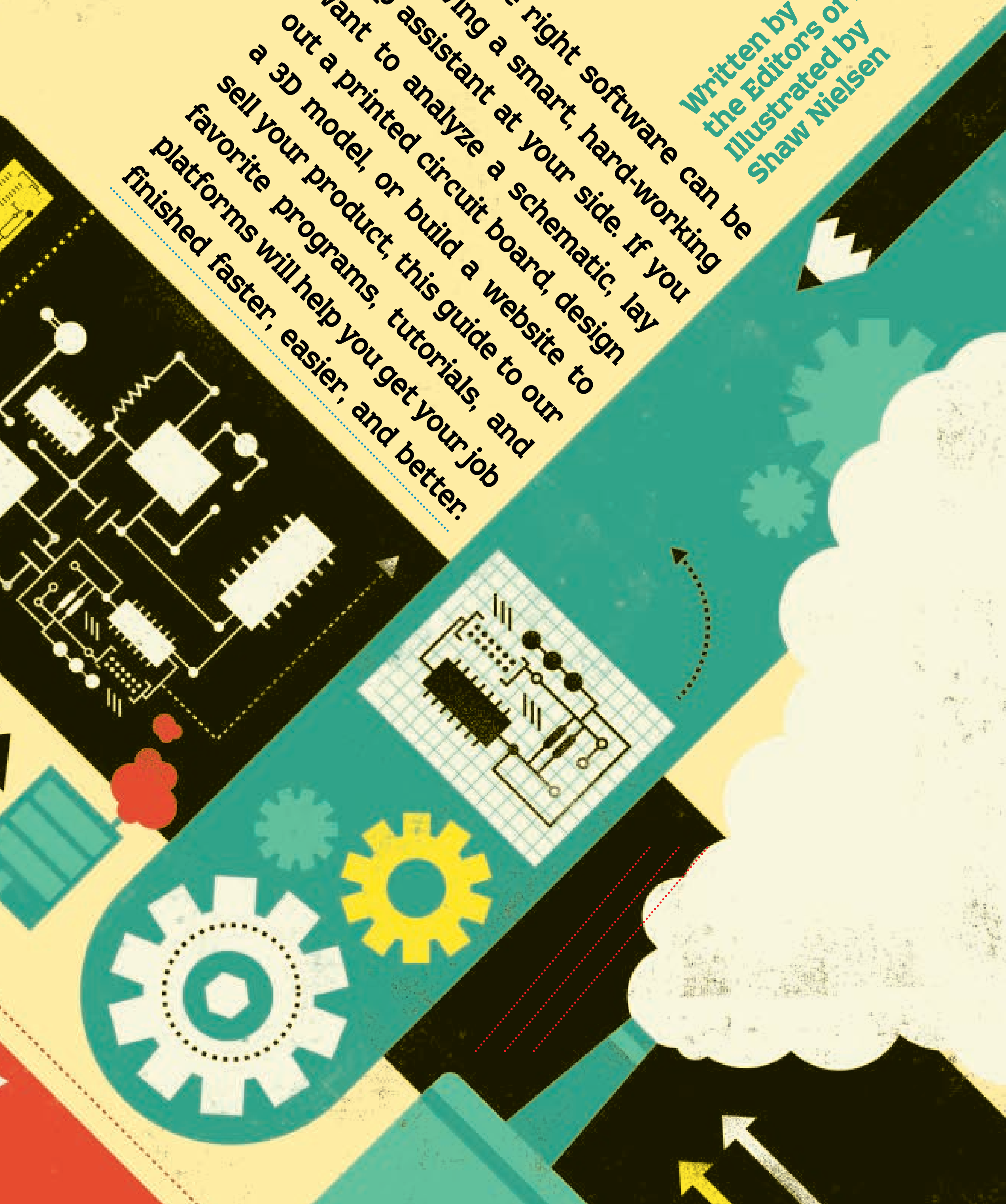


SOFTWARE FOR MAKERS:

CREATING THINGS FROM ATOMS IS BETTER WITH BITS

Having the right software can be like having a smart, hard-working shop assistant at your side. If you want to analyze a schematic, lay out a printed circuit board, design a 3D model, or build a website to sell your product, this guide to our favorite programs, tutorials, and platforms will help you get your job finished faster, easier, and better.

Written by the Editors of MAKE
Illustrated by Shaw Nielsen



ELECTRONICS DESIGN

Software tools to help you design, simulate, and analyze circuits, as well as draw schematics and lay out printed circuit boards.

EAGLE

$69+ \\ cadsoftusa.com

If you're creating a printed circuit board (PCB) that's more complex than an LED blinker, you'll need a CAD program to create the Gerber files that PCB manufacturers expect. EAGLE is currently the common coin of the open hardware crowd, even though there's a (small) price to entry for commercial use. EAGLE offers a modular CAD tool, but you'll really just need the schematic and board editors to get started laying out your own PCBs.

FRITZING

FREE \\ fritzing.org

Fritzing is the name both of an open source initiative to help create electronics and of a software package for designing projects. The program includes many common electronic components, as well as micro-controllers, popular shields, and accessory boards you can drag and drop into your designs. Fritzing lets you switch between three views of your project: breadboard, schematic, and printed circuit board.

CIRCUITS.IO

FREE \\ circuits.io

Circuits.io is a web-based electronics design tool, but it's also an online marketplace. You can design your board using their free editor, order copies of the board from them, or share your project for others to order. Circuits.io includes design verification, so it's very unlikely that you'll design something that can't actually be manufactured.

CIRCUITLAB

FREE \\ circuitlab.com

CircuitLab is both a circuit design tool/schematic editor and a circuit simulator. After you lay out your circuit, you can set the parameters of each component and run a variety of simulations and visualizations right in your browser. When your design is complete, you can easily share it with other users.

KICAD

FREE \\ kicad-pcb.org

If you want a truly open source CAD program for laying out printed circuit boards, KiCad may be your answer. It comes close to providing the workflow and functionality of closed-source CAD tools like EAGLE, but without the restrictions and cost. You may invest a little more in the learning curve, but that could easily change in the near future.

CREATIVE CODING

Languages and libraries for artists, designers, and musicians.

PROCESSING

FREE \\ processing.org

This open source programming language is ideal for working with graphics and for creating animations, interactive programs, and other visual software. Although Processing is based on the Java programming language, it's much easier to learn, and a large number of artists, students, hobbyists, and designers have already mastered it.

OPENFRAMEWORKS

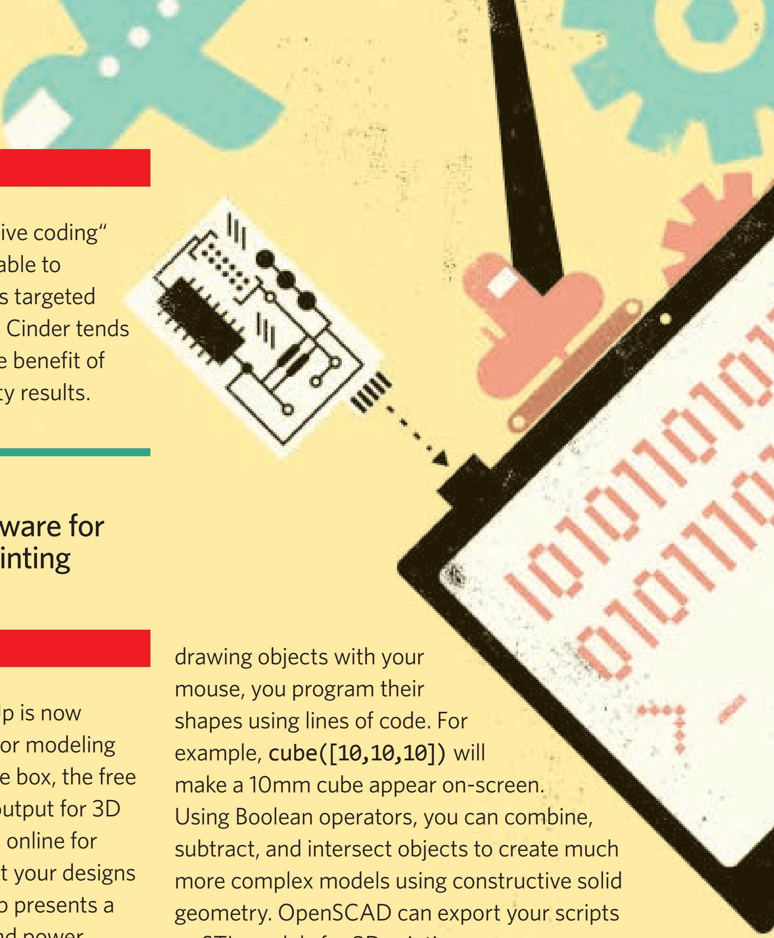
FREE \\ openframeworks.cc

OpenFrameworks is a collection of C++ libraries for "creative coding" that work on all computer platforms and mobile devices. It presents a fairly unified interface for doing multimedia, computer vision, Arduino, and more. Think Processing for production.

PURE DATA

FREE \\ puredata.info

Pure Data (or Pd) is a visual programming environment for musicians who want to synthesize sounds to create new interactive instruments and environments. Pd "patches" are programs created by linking audio inputs and outputs to graphical blocks that perform digital signal processing functions on the sounds flowing through them. Pd is an open source work-alike to the Max/MSP environment.



CINDER

FREE \\ libcinder.org

Cinder is a C++ framework for "creative coding" by artists and designers. It's comparable to Processing or openFrameworks but is targeted at a professional audience. Coding in Cinder tends to be a bit more complicated with the benefit of better performance and higher quality results.

3D CAD

Useful and inexpensive software for designing 3D models, for printing or otherwise.

SKETCHUP

FREE to $495 \\ sketchup.com

Previously a Google project, SketchUp is now owned by Trimble. It's a design tool for modeling and presenting 3D objects. Out of the box, the free version isn't suitable for generating output for 3D printers, but there are many tutorials online for installing a plugin that lets you export your designs to the required STL format. SketchUp presents a nice balance between ease-of-use and power.

123D DESIGN

FREE \\ 123dapp.com

This is part of the free 123D suite of tools from Autodesk. You can model objects using its easy-to-learn interface, prepare your models for printing, export them to STL files, or send them directly to many popular fabrication companies.

TINKERCAD

$20+/month \\ tinkercad.com

Tinkercad is a web-based modeling program. With a WebGL-enabled browser such as Google Chrome or Firefox, you can run Tinkercad's 3D user interface directly in your browser. Build up your design, save it online, and share it with others. You can also send files directly to popular 3D printing services or download STL files for printing yourself.

OPENSCAD

FREE \\ openscad.org

If you like programming languages more than dragging and dropping, you might prefer OpenSCAD to the other modeling tools out there. Instead of drawing objects with your mouse, you program their shapes using lines of code. For example, `cube([10,10,10])` will make a 10mm cube appear on-screen. Using Boolean operators, you can combine, subtract, and intersect objects to create much more complex models using constructive solid geometry. OpenSCAD can export your scripts as STL models for 3D printing.

3D PRINTER FRONT-ENDS

Utilities to control your 3D printer and to prepare your 3D models for fabrication.

REPLICATORG

FREE \\ replicat.org

ReplicatorG is a front-end for RepRap-based 3D printers such as the MakerBot Cupcake CNC, Thing-O-Matic, and Replicator. It was originally created to support MakerBot printers, but can also be used with other RepRap-based printers. You can use ReplicatorG to load an STL model, then rotate, move, and/or resize it before "slicing," which prepares the model for printing. Once you've sliced the file, you can send it directly to the printer or save it to an SD card for printing later.

MAKERWARE

FREE \\ makerbot.com/makerware

MakerWare is the latest front-end printing software from MakerBot. It's specifically designed for their newer models: the Replicator and Replicator 2. However, MakerBot has indicated that it may support the older Thing-O-Matic in a future upgrade. Unlike ReplicatorG, MakerWare is not fully open source, but the parts that do the heavy lifting (the mathematical calculations needed to "slice" the model) — the slicers Miracle Grue and Skeinforge — are. Unlike ReplicatorG, MakerWare can load more than one STL at a time.

REPETIER-HOST

FREE \\ repetier.com

This is a unique front-end for RepRap printers. Like the others, you can load STLs and arrange them as you'd like, and then slice and print an entire "build plate" all at once. Repetier-Host can slice models using either Skeinforge or Slic3r. Unlike other front-ends, Repetier-Host gives you three visualizations of your model: the 3D STL view, the layer-by-layer view of the G-code instructions that comprise the sliced model, and the real-time build view of each line of material as it's laid down. If you want to explain how 3D printing works, give the demo using Repetier-Host.

PRINTRUN/PRONTERFACE

FREE \\ reprap.org/wiki/printrun

Easy to use and very fast, Printrun is a front-end for RepRap 3D printers. It doesn't have all the bells and whistles of Repetier-Host, but its simplicity is quite appealing. You use Printrun to slice your model (by invoking Slic3r or Skeinforge), then send your model to the printer. In addition to a graphical user interface, Printrun includes command-line tools for working with print jobs.

WEBSITE DESIGN

Slick tools and tutorials to create attractive and highly functional websites.

TREEHOUSE

$25-$49/month \\ teamtreehouse.com

Earn achievement badges as you take interactive lessons in web and iOS design and development. Treehouse offers 700 instructional videos along with accompanying quizzes and code challenges, with the goal of bringing affordable tech education to the masses.

POPCORN MAKER

FREE \\ popcorn.webmaker.org

The goal of Mozilla's Webmaker platform is to turn web consumers into web makers. They're working on several tools to make this happen, but Popcorn Maker really hits the spot; it's a tool for remixing and remashing web video. If you think about how much learning and skill sharing is moving into video form, you'll quickly realize the value of Popcorn Maker.

PAPER.JS & PROCESSING.JS

FREE \\ paperjs.org, processingjs.org

If you want to draw animated graphics on a web page, you've got quite a few options. If you want to avoid Flash and have your animations work on mobile devices, the field narrows considerably: the JavaScript frameworks Paper.js and Processing.js are good options. Use Paper.js if you want interactivity; use Processing.js if you already know how to program in Processing.

ZEN CART

FREE \\ zen-cart.com

Zen Cart is one of the world's most popular open source online store programs. A 2003 fork from osCommerce, it's PHP-based, uses a MySQL database, and is readily hacked and customized to meet your particular needs, with a wide variety of features available either natively or through free adds-on. Google its name, and the first three hits are from big commercial shopping cart providers who are trying to persuade you not to use it. What better endorsement could you ask for? Our pals at Adafruit have been using it since 2005, and are a great resource to help you get started.

WORDPRESS

FREE \\ wordpress.org

WordPress (WP) is the most popular blogging and online content management platform in the world today. It's free, open source software, written in PHP, and using a MySQL backend, which allows it to be installed on almost any web server. Overall, WP achieves an amazing balance between user-friendliness and advanced customizability. Themes control how content is visually presented on a page, plugins offer extended functionality like search engine optimization and rich commenting, and widgets allow for easy custom page layout. And WP's extremely active user community is constantly working to tweak and develop them all. Great mobile apps are available for WP, as well, so you can take your blogging on the go.

MICRO-CONTROLLERS

Software to get the most out of your Arduino or other microcontroller.

ARDUINO

FREE \\ arduino.cc

This is the software package you need to get your Arduino to do something other than run the pre-installed "Blink" sketch. You use the Arduino IDE (integrated development environment) to write programs (known as sketches among Arduino users), and load them onto your Arduino board. Within the Arduino IDE, you'll use a prettied-up variant of C++ that was inspired and informed by the Processing language. If Processing took Java's graphical power and made it easy for kids, artists, and designers, Arduino did the same thing with C++'s power to make cool stuff with embedded devices.

PROPELLER

FREE \\ parallax.com/tabid/832/Default.aspx

The Propeller is a microcontroller unlike any other; it has eight cores (called cogs) running independently, in parallel, sharing memory and other resources. For quite a while you could only program the Propeller in Assembly or in a higher-level language called Spin. More recently Parallax has provided tools for programming the Propeller using the open source C toolchain.

VISUAL STUDIO EXPRESS/NETDUINO

FREE \\ netduino.com/downloads

Despite the -duino suffix, Netduino is not Arduino. You can't grab the Arduino IDE, plug in a Netduino, and expect anything interesting to happen. The "Net" in Netduino refers to .NET, Microsoft's development platform. Many years ago, Microsoft tried an experiment called SPOT (Smart Personal Object Technology) that was probably a bit ahead of its time. Instead of being crushed up and spit out, Microsoft decided to put the whole thing out under the Apache 2.0 open source license — compilers, runtime, and tools — as the .NET Micro Framework. Even though it's open source, you still need a development environment, which is where the closed-source Visual Studio IDE comes in. While it's possible to develop Netduino programs with a 100% open source toolchain (using the Mono Project), it's painful. Visual Studio Express gives you an easy way to develop and deploy Netduino programs.

ENERGIA (MSP430)

FREE \\ energia.nu

This is a port of the Arduino development environment (everything from the IDE to the compiler tools that run under its hood) to the Texas Instruments MSP430 microcontroller family. It feels just like Arduino, and you can pretty much use the same code you use on Arduino (though you'll need to change your pin assignments to match the board you're using). This is a great development environment for exploring the inexpensive MSP430 LaunchPad from Texas Instruments.

PROGRAMMING FOR KIDS

Entertaining and useful programs to pique kids' interest in software and make programming accessible.

PYTHON

FREE \\ python.org

Python is a great first programming language (or scripting language). It's clear, easy to get up and running, and the Python community has created lots of libraries that will do what you need. Python is an interpreted language, which means that you can write a program (or script) and execute it directly rather than compiling it into machine code.

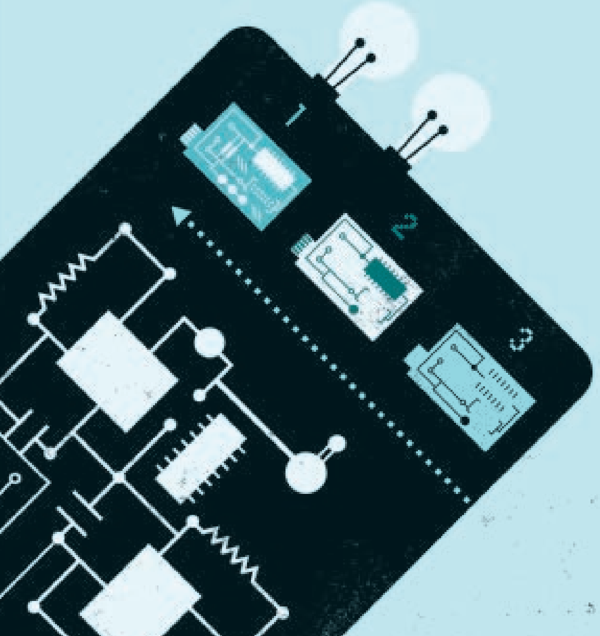
SCRATCH

FREE \\ scratch.mit.edu

This graphical programming language was developed at MIT to teach kids how to program and think creatively. By dragging, dropping, and connecting colored blocks, you can create games with animation and sound effects.

"It is our responsibility to equip children with the knowledge necessary to understand our world and to have a host of options in it and I believe that programming can play an integral part in this."

–Michael Kohl



MIT APP INVENTOR

FREE \\ appinventor.mit.edu

Inspired by Scratch, App Inventor is a project that was originally created at Google to bring Scratch-like programming to Android phones. Kids can drag and drop blocks together to create working programs, and then deploy them to Android devices. When the App Inventor project lead, Hal Abelson, finished his sabbatical at Google and returned to MIT, he brought it back with him.

MODKIT

FREE \\ modk.it

Intended to be intuitive enough for kids to use, Modkit is a browser-based Scratch-like programming platform for the Arduino. Once you write a program by dragging and dropping colored blocks, you can examine the Processing code it generates, and edit it directly in Processing.

ALICE

FREE \\ alice.org

Not just for kids (but perfectly suited to them), this educational software from Carnegie Mellon University is aimed at teaching object-oriented programming in a 3D environment. Using the drag-and-drop interface, students visually learn to animate 3D objects and become engaged in programming through storytelling.

HAPPY NERDS

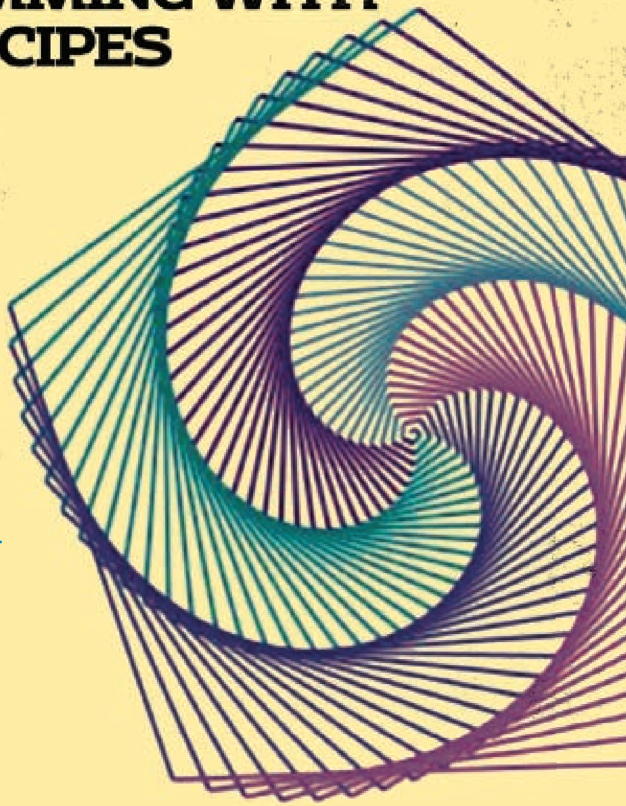
FREE \\ happynerds.net

Austrian software engineer Michael Kohl has put together this site as a resource dedicated solely to programming for kids. Under each category (Windows, Mac, Linux, Browser, and Books), Kohl provides healthy lists and links to learning resources. He writes, "It is our responsibility to equip children with the knowledge necessary to understand our world and to have a host of options in it and I believe that programming can play an integral part in this."

CODE KIDS:

START PROGRAMMING WITH SMALLBASIC RECIPES

By Lynn Langit



"Thinking like a programmer" is a great way to interact with your computer. Programming itself is satisfying because you can make whatever you can imagine.

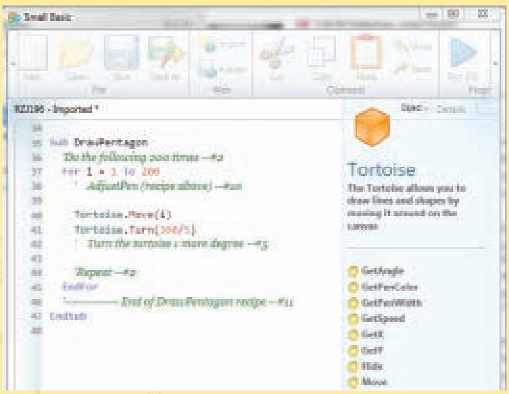
Breaking a problem down into concrete steps that you can then test out one at a time is part of the maker mentality. Thinking like a programmer will help you in other places too; for example, when you're trying to solve math problems.

SmallBasic is an introductory programming language, based on Microsoft .NET. The language and its editor (also known as an integrated development environment, or IDE for short) is a free download. SmallBasic recipes are free, fun lessons you can use to teach yourself how to program computer graphics, make simple games, and do other things. Recipes are designed for kids ages 10 and up who have basic keyboarding skills.

In the screen shot (right), you can see an example recipe called Pentagon Crazy.

To use recipes, you'll also need to download the SmallBasicFun extensions and follow the instructions for installing them inside SmallBasic. These extensions add objects, examples, and more to SmallBasic itself, making programming easier and even more fun. Get them here: extendsmallbasic.codeplex.com.

SmallBasic recipes are part of the "Learn to Program Courseware" found at TeachingKidsProgramming.org (TKP). You'll find links to all of the software downloads, recipes, tips, and answer keys there. We also have videos of each recipe being coded line-by-line in the Teachers section of the TKP website.



HOW DO I GET STARTED?

All the steps are listed on the TKP website, but we'll also list them here:

1. Grab a PC with Windows XP, Vista, or 7 and .NET 3.5 SP1 or greater.

2. Download and install SmallBasic and the extensions on your PC, or download our SmallBasicOnUSB zip file (makezine.com/go/smallbasiczip) onto a flash drive, unzip it and plug it in to your PC. Then click the *SB.exe* file to get started (no install required).

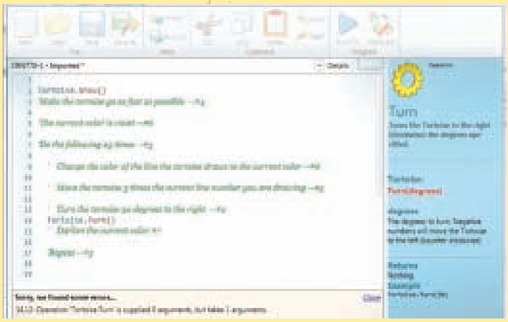
3. Browse the SmallBasic recipe library and pick a recipe to start with. Import the ID# into SmallBasic and start translating the English comments into SmallBasic code. We suggest you start with the SQUARE recipe and then work your way down the recipes page (recipes are listed from easy to hard on that page).

TIP Code with a friend: this process of working is called "pair programming." To do pair programming, just take turns on the keyboard. One kid types while the other kid talks (that is, tells the kid who is typing what to type). Make sure you swap roles regularly — we suggest every 5 minutes or so. It's best if you actually stand up and switch places as you go along.

4. After you've translated each (single) line of English into SmallBasic code, RUN the code (using the F5 key) to make sure that your translation was correct.

5. Delete the English comment after you've got your code right.

6. Pick your next line to translate. Pick a line you can test by running your program. For example translate "Move the Tortoise 50 pixels" before "Make the Tortoise move as fast as possible." You can also watch a short video on coding up a mini-recipe (called the Giant Tortoise) to see coding with SmallBasic in action: makezine.com/go/tortoise.



I'M STUCK

When you get stuck, we've got many tips for you to try out. What to do depends on how you're stuck.

Error Message

One kind of stuck is that you get some error message at the bottom of the IDE. For example, you see that the error says "14,12: Operation 'Tortoise.Turn' is supplied 0 arguments, but takes 1 arguments."

For this kind of stuck we suggest you double click on the error message text (read it first!) and then click on the line of SmallBasic code that is causing the error. Take a look at the example (right side highlighted) and update as needed. You can even copy and paste the example from the documentation if need be. We call this "fake it 'till you make it." Your goal here is to get your code to run.

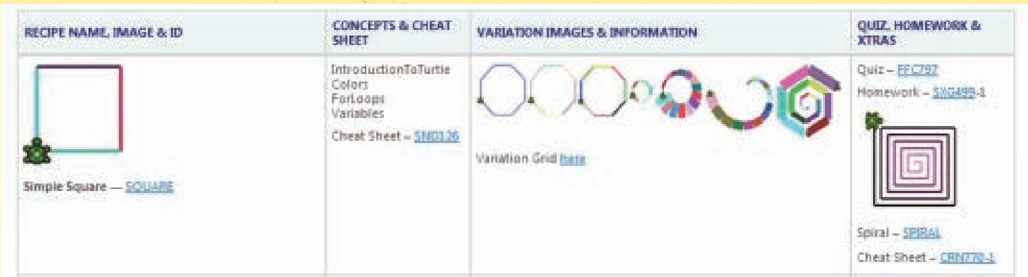
You can always also just "Undo" until you get back into a state that will run and then try another SmallBasic word.

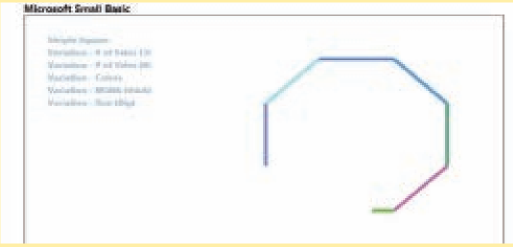
Unsure of What to Do

Another kind of stuck is that you don't know the SmallBasic word(s) to use to translate one or more of the English comments. Here we suggest using the Ctrl+Spacebar keys to get a list of all possible words. If you know the Object (noun), but can't find the Operation (verb), try looking at other Objects to see if a more appropriate Operation is listed with that object. For example, if you need to center a shape at a given x,y location, you would want to use the ShapeMaker object (rather than the Shapes object) as ShapeMaker includes an operation named CenterShapeAt().

Weird Results

Yet another kind of stuck is code that will run (meaning there are no errors shown when you try to





Here's an example of what you can turn a square into with just a few changes to your code.

run it), but runs in a weird way, such as an all-white program window where you had expected to see the Tortoise or Turtle objects drawing something. This can be caused by a number of errors, the most common of which are incorrect End statements for Loops, Conditionals, or Subroutines. Check the position of your EndFor, EndIf, and EndSub statements. (Again, you may want to use the Undo feature to get back to a runnable state.)

You can also use the Cheat Sheet provided for each recipe, which shows you the SmallBasic code. It also indicates which lines of English should be translated into code first, so you can actually see the results as you go along.

```
'Show the tortoise --#1
Tortoise.Show()
'Make the tortoise move as fast as possible --#6
Tortoise.SetSpeed(10)
'Do the following 4 times --#5
For i = 1 To 4
  'Change the color of the line the tortoise draws to blue --#3
  Tortoise.SetPenColor(Colors.Blue)
  'Move the tortoise 50 pixels --#2
  Tortoise.Move(50)
  'Turn the tortoise 90 degrees to the right --#4
  Tortoise.Turn(90)
  'Repeat --#5
EndFor
```

ON MY OWN

After you finish translating a particular recipe, you can tinker with the code to make it into something slightly (or even very) different than what you started with, e.g., change a square into a spiral. Look at the "Variation Images and Information" section for each recipe for suggestions, cheat sheets, and more.

BEYOND SMALLBASIC

If you click the "Graduate" button in the IDE it will translate your code to VisualBasic.NET. To edit VB.NET you'll need the Visual Studio IDE. Download either VB Express (free), or sign up for DreamSpark to get a full version of Visual Studio to work with.

At the TKP site there are also recipes for other programming languages (such as Java, T-SQL for databases, and more). There are lessons for Microsoft Kodu as well — a programming language designed for children as young as 6 to get started creating worlds and games via visual programming.

Enjoy working with SmallBasic Recipes!

We know that you'll be making cool stuff with SmallBasic, and we want to see and share what you've done. You can publish your variations by clicking the Publish button in SmallBasic. Then you'll get an ID number. You can share that ID with your friends and they can see your variation and work together with you on making your program even cooler.

Lynn Langit is a professional programmer and technical educator, and is also co-founder of TKP, a U.S. nonprofit. She authors and teaches courseware for data solutions. Lynn blogs at LynnLangit.com and TeachingKidsProgramming.org.

THE BANANA INTERFACE:

THE ONLY LIMIT TO WHAT YOU CAN CREATE WITH SCRATCH AND MAKEY MAKEY IS YOUR IMAGINATION

By Eric Rosenbaum and Amos Blanton

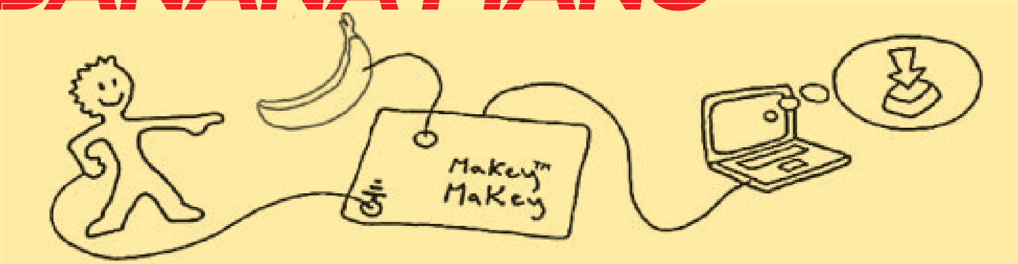
Kids get wide-eyed when they realize they can make music just by tapping on a row of bananas. Adults start jamming out on classic tunes, and then inevitably somebody discovers that they can play a sound by connecting two people: a high-five, or even a kiss, can trigger a cymbal crash.

It's all possible thanks to MaKey MaKey, a new invention kit developed by Jay Silver and Eric Rosenbaum. First you alligator clip everyday materials like bananas, Play-Doh, or your grandma to the MaKey MaKey circuit board. Then you plug it into your computer, which thinks MaKey MaKey is a USB keyboard. Now, when you complete a circuit through the bananas (or anything even a tiny bit electrically conductive), the computer thinks a key has been pressed.

MaKey MaKey works with just about any software you've already got, because it works like a keyboard that lets you make your own keys (it can click and move the mouse cursor, too). You can play games on a controller drawn in pencil, make music with fruit, advance your PowerPoint slides by taking bites from a pastry, take a picture of your cat when it takes a drink, or navigate Google Earth with your bare feet (check out the video at makeymakey.com to see lots of fun examples).

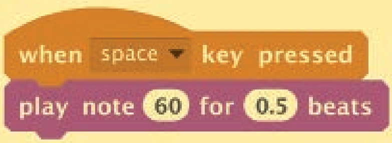
One of the most powerful ways to use MaKey MaKey is to combine it with Scratch, a free and easy-to-use graphical programming language we helped create as part of the Lifelong Kindergarten group at MIT Media Lab (see scratch.mit.edu). Scratch lets you make stories, games, and animations just by snapping blocks together on the screen. It's easy to make things happen when a key is pressed. There are few limits to what you can create with Scratch and MaKey MaKey. Here are a few projects we made to get you started.

BANANA PIANO



How do you make a banana into a piano key? First we'll set up MaKey MaKey so you can complete a circuit by touching a banana.

Connect yourself to ground, and a banana to "space" on the MaKey MaKey. Now, when you touch the banana, the computer thinks the space key was pressed.



Next we'll set up Scratch to play a sound when you press the space key (or touch a banana).

Just put these blocks (above) together in Scratch, and when you press the space key, it will play a piano note.

Now that you've got one banana working, we can set up some more keys and play some tunes!

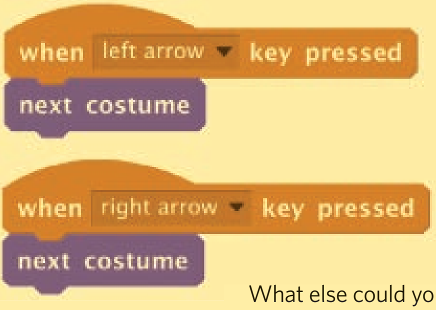
We made a piano in Scratch, with different notes triggered by the up, down, left, and right arrow keys, by the space bar, and by a mouse click. Each banana is plugged into one of those inputs on the MaKey MaKey. To connect the person to ground so they can complete the circuit, we like to use a lime.

What other musical instruments could you make? Lots of different types of fruit, vegetables, and other food will work for making pianos. You can play with other sounds, too. Can you make a drum kit out of cheese? How about a squishy sound effects machine made out of a few marshmallows?

Each time the horse rocks to the back or the front, Scratch steps the animation forward by one frame.

ROCK-AND-ROLL ROCKING HORSE

Tired of the usual game controllers? We decided to make a wooden rocking horse into a whole new kind of controller using MaKey MaKey and Scratch. First we made two simple switches that close when pressure is applied — we made ours out of clothespins and foil. We attached one to the front and one to the back of the rocking horse's rail. When the horse rocks, the clothespins press together, completing a circuit so that MaKey MaKey presses a key.



For our Scratch animation, we used an animated GIF of a horse running made from photographs created by Eadweard Muybridge back in the 1870s.

We imported the GIF into Scratch, creating a separate costume for each frame. (In Scratch, objects that perform functions are called *sprites*, and each frame of a sprite is a *costume*.) Then we used Scratch blocks to advance to the next costume at each rock, creating the illusion of movement — just as Muybridge discovered. The faster you rock, the faster the horse runs.

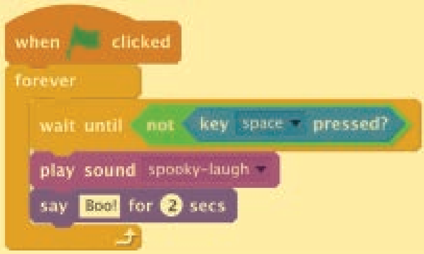
What else could you control with your own rocking horse? Maybe it needs a carrot you can feed to it, or some head-mounted lasers.

What other toys can you turn into controllers for your own games in Scratch?

Door Knocker of Doom

We wanted to create an interactive Halloween scare at the front door, using a MaKey MaKey and a computer running Scratch showing in the window. We experimented with the brass door knocker and found that it was conductive. Then we connected two clips to it: one on the base, connected to ground on the MaKey MaKey, and the other on the handle of the knocker, connected to "space." The knocker normally sits touching the base, so Scratch will think you're holding down the space key until you lift the knocker. Our little Scratch program waits until you lift the knocker, and then plays sound and animation.

Our example just makes the Scratch cat say "boo." What terrifying animations and sounds will you create? You can draw scary scenes using Scratch's built-in paint editor, or import other photos and graphics, then make them come to life using the motion and graphic effects blocks. You can record your own horrifying sounds, or find sounds online. You can also try connecting your computer to a projector or speaker system for bigger, louder effects. And of course, it's not just about door knockers: you can use anything that makes or breaks a circuit.



Other Ways to Connect Scratch to the Physical World

MaKey MaKey isn't the only way to create cool physical-digital projects with Scratch. Here are two other Scratch-compatible tools.

PICOBOARD

The PicoBoard (aka Scratch Board) is an open source sensor board available from SparkFun. It can sense levels of light and sound, the position of its built-in slider knob, the state of its button, and the resistance between each of its four electrical inputs (which come with wires and alligator clips). Scratchers have used PicoBoards to make everything from controllers for interactive games to sophisticated alarm systems.

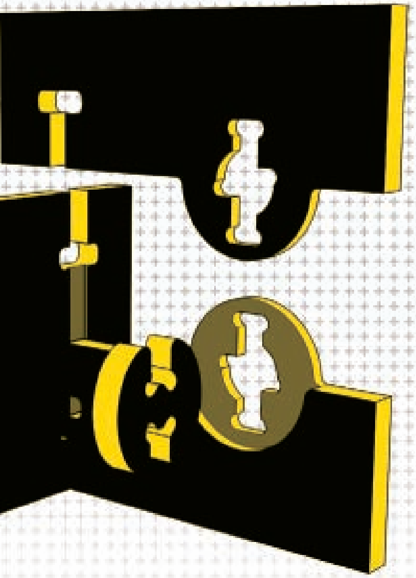
LEGO WEDO

The WeDo is a robotics kit developed by Lego for kids ages 7 and up. You can control your Scratch projects with the WeDo's distance and tilt sensors, and activate the WeDo's motor to create moving mechanisms. The WeDo is available online through the Lego education website.

Eric Rosenbaum is a Ph.D. student in the Lifelong Kindergarten Group at MIT Media Lab. He's a member of the Scratch team and co-creator of MaKey MaKey. Amos Blanton is the online community coordinator for Scratch. He designs and sustains supportive learning environments for people with agency.

SKILL BUILDER

INTERMEDIATE



CNC Panel Joinery

A guide to making interlocking, self-aligning, and demountable joints in flat stock. By *Sean Michael Ragan*

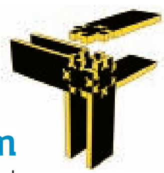
I'VE BEEN COLLECTING CLEVER WAYS OF SLOTTING flat stock together since I first read Victor Papanek and James Hennessey's *Nomadic Furniture* back in 1999, well before the advent of the accessible hobby-class CNC tools that make manufacturing parts like these pretty easy today. Now the world is full of people designing models, project enclosures, sculpture, furniture, and all kinds of other cool stuff to be assembled from parts made on laser cutters and CNC routers.

I keep expecting a definitive book or website to emerge that covers the "bag of tricks" in an organized way. So far, I haven't found it. Perhaps this article can serve as a jumping-off point.

In presenting this material, I want to first acknowledge my respect for the world's established and ancient traditions of joinery. I do not for a moment imagine that any of this is fundamentally new. But I do see a need to organize this information to address the needs of the small CNC tool operator who wants to make interlocking, self-aligning, and/or demountable joints in flat stock, for instance plywood or sheet plastic.

I may abuse some terms without meaning to. Generally, I've tried to use descriptive terms instead of "proper" names to avoid confusion, but here and there I may have slipped up and called a rose by some other name.

To simplify things, I'm only considering joints between two panels, using all-the-way-through cuts, orthogonal to the plane of the stock. For a taste of how complex this subject can become without these limitations, check out Jochen Gros' "50 Digital Wood Joints" project at flexiblestream.org/project/50-digital-wood-joints.

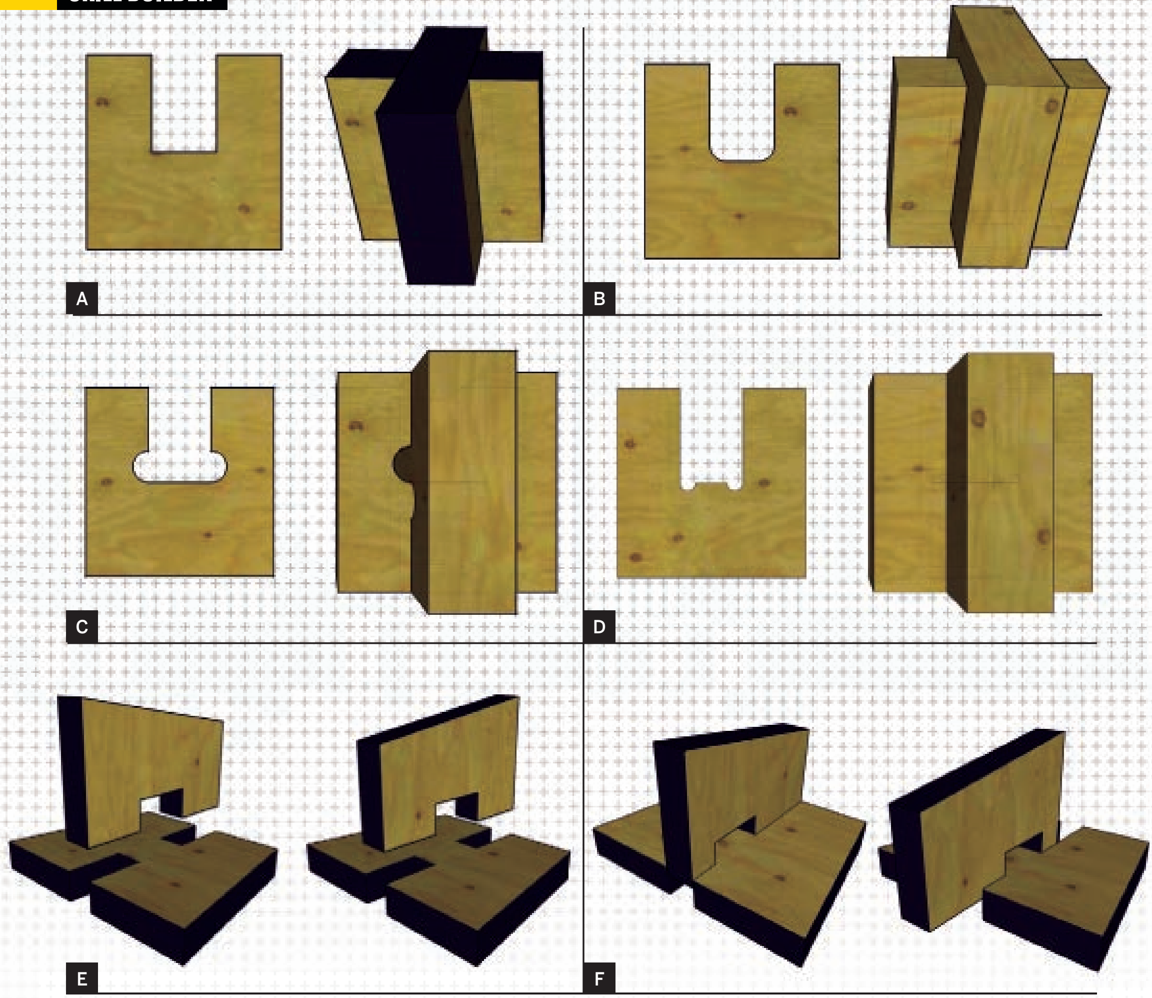


Laser vs. Rotary Cutters: The Inside Corner Problem

Hobby-class laser cutters and CNC routers each have advantages and disadvantages. Laser cutters can cut much finer details because they have very small *kerf*, or width of cut. On the other hand, they're more expensive and can't do partial-depth cutting or "pocketing" like a CNC router can. They also use heat, which can burn the substrate and/or generate nasty off-gassing. However, the burning effect can be used decoratively.

A CNC router can change bits and cut complex relieved surfaces, or make cuts with

Gregory Hayes



mitered or otherwise profiled edges. I don't think either tool can be described as simply "better," and with one minor caveat, all of the techniques presented here can be used equally well with either a laser cutter or a router.

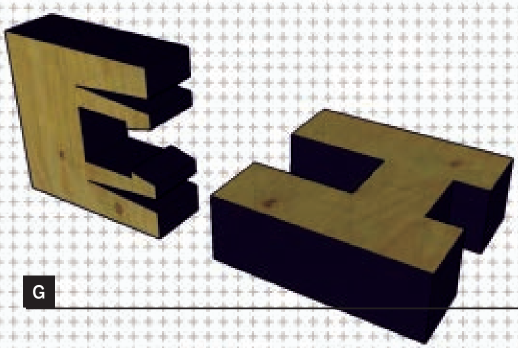
Because of its very small cutting channel, a laser cutter can produce an inside corner with a sharp angle, whereas a rotary cutter using a physical tool is limited to inside corners rounded at the cutting tool's radius. The laser-cut version, with its sharp 90° corners, is suitable for use in a simple edge-lap joint (**Figure A**).

The router-cut version, however, just doesn't work. The radiused corners bump into each other and the part edges don't line up (**Figure B**). You can cut each slot a bit deeper, of course, and in some applications this may be OK, but doing so leaves a void in the center of the joint and concentrates stress on the radiused corners.

A better solution is shown in **Figure C**. Now the inside faces of the edge laps mate cleanly. On the other hand, the round divots are visible in the assembled joint. If that bothers you, of course, you can also do it as shown in **Figure D**, if your cutter is narrow enough. On average, this method offers the best compromise; the flat areas between the divots seat against each other firmly and the divots themselves are concealed inside the joint.

To simplify presentation, the joints in the rest of this article are presented with ideal "laser cut" inside corners. But all of them should be readily adapted to rotary cutting by using the divot method.

Sean Michael Ragan



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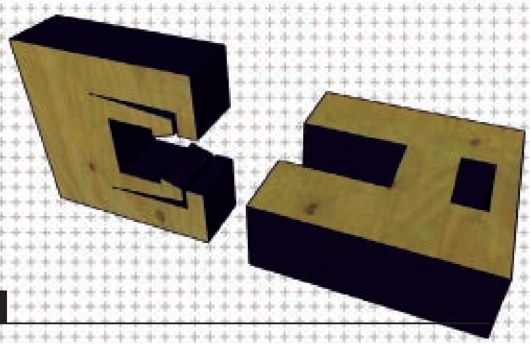

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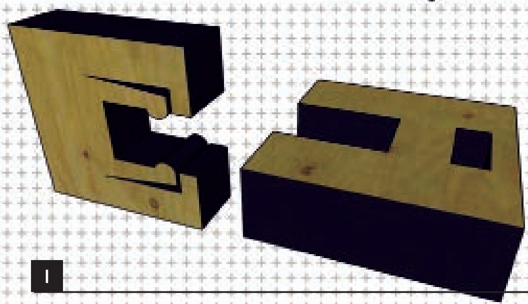

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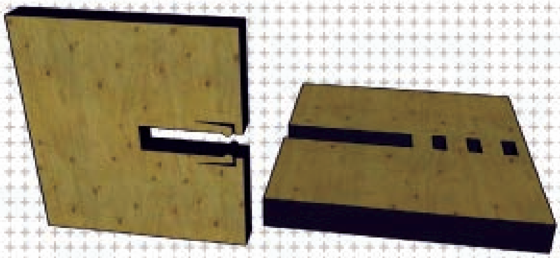

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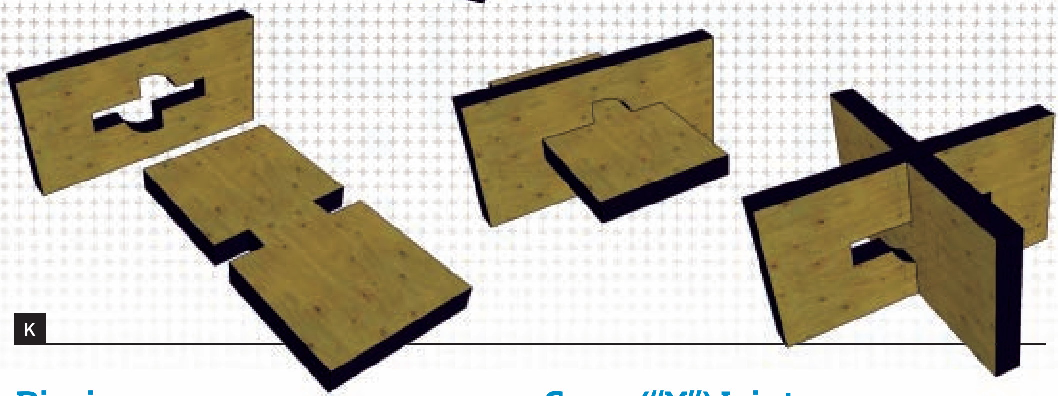


K

Biasing

Many of these joints are symmetrical, and can be assembled in more than one way. The joint in **Figure E**, for instance, can be assembled in two different ways (four, if approaches from below are allowed). Which is correct?

Often it's possible to deliberately break this symmetry so that the parts can only be assembled in one way, or in fewer or more obviously correct ways. For instance, the joint in **Figure F** can still be assembled, but the disfavored orientations are more clearly wrong because the part edges no longer align.

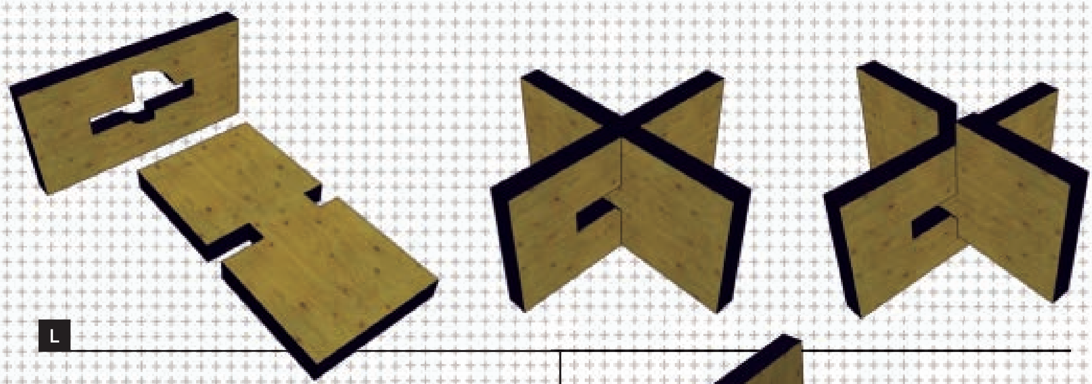
This trick can be very handy in complex structures, particularly for kit parts, to keep end users from putting the joint together backwards. I call a joint that has its symmetry deliberately broken in this way *biased*.

Cross ("X") Joints

Figure G shows a version of the basic slotted *edge lap joint*, in which one side has an integral snap-lock feature. The snap hooks are accessible from the end of the joint. Insert a small, flat-blade screwdriver, pry a bit, and they can be popped loose and the joint opened again.

But move the hook and the catch away from the edges of the stock, and the snap-lock action becomes irreversible (**Figure H**). Note that both pieces of stock could include both hooks and catches. I'm only showing "one-sided" snapping joints for clarity.

Replace the hook with a bulge, and the snap becomes a *detent*, meaning the part will stick in place but can be removed with sufficient force (**Figure I**). The detent could catch in one position, or many (**Figure J**).



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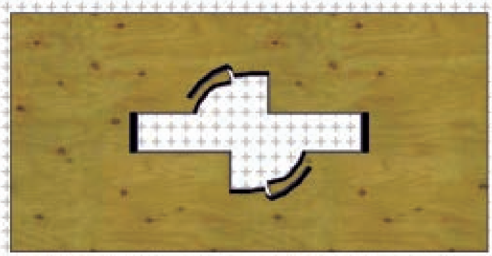

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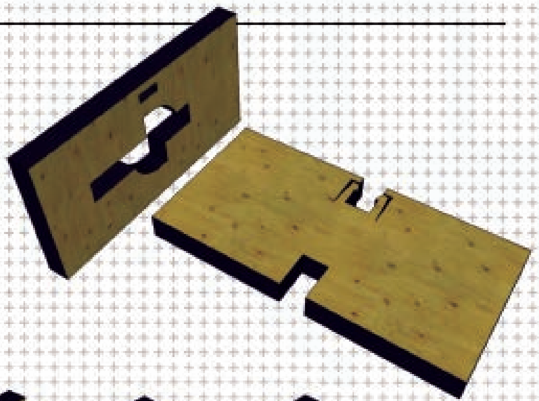
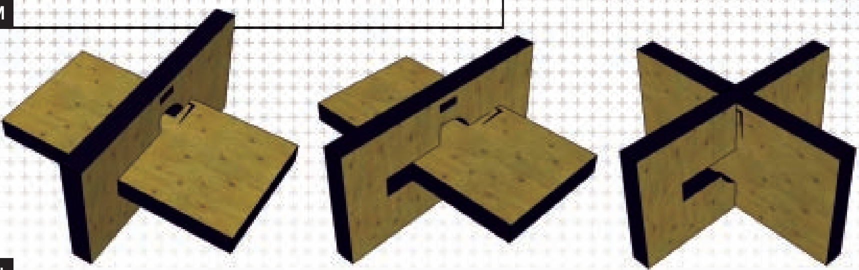




N

Figure K (previous page) shows an unusual *X joint* that uses a radial interlocking motion.

A biased version is also possible. **Figure L** shows an X joint with the symmetry broken: shown disassembled (left), assembled in its "favored" orientation (middle), and in its "disfavored" orientation (right).

Locks or detents can be added to the stationary member (**Figure M**) and/or to the rotated member (**Figure N**). Note, in this case, that it doesn't matter if the profile of the catch is hooked or rounded; once the catch pops into the slot, it'll be very hard to get out.

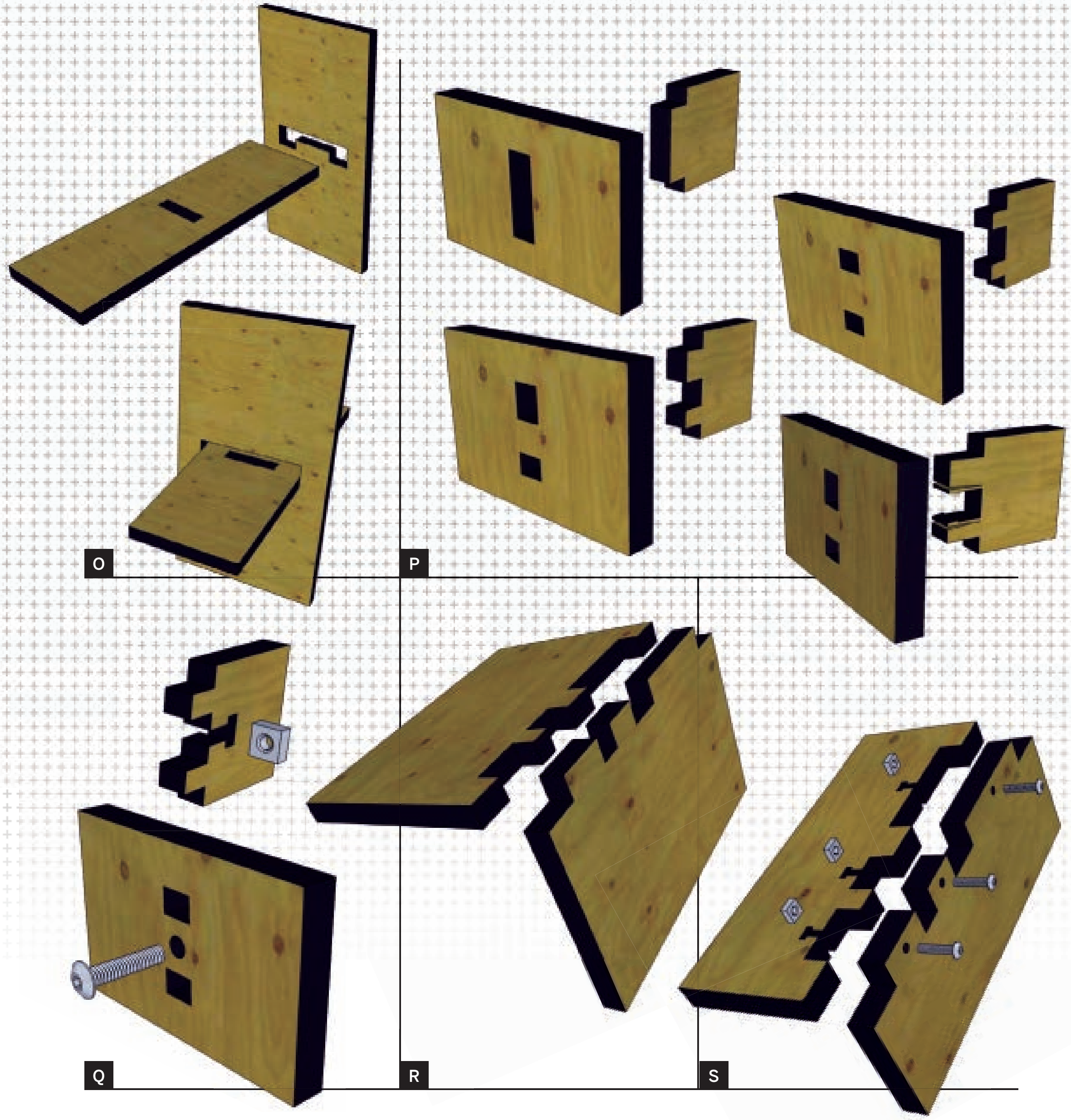
Finally, in the case of X joints, if one member is narrower than the other, a full-width slotted arrangement becomes possible (**Figure O**).

Such joints may be useful especially for shelves or other upright applications where gravity can help keep the pieces engaged, and may be biased or otherwise modified like the *T joints* described below.

Tee ("T") Joints

Figure P shows examples of simple *mortise and tenon* type joints, or T joints. We can split the mortise and tenon into two slots and tabs (or as many slots and tabs as we like). If we break the symmetry of the slots and tabs, the joint becomes biased. And if we extend the tab a small distance past the thickness of the stock, we can easily add snaps or detents that catch on the far side of the slotted part.

Fasteners in the plane of one of the pieces can also be introduced. The *captive square nut joint* (**Figure Q**) is seen on a number of commercial products featuring CNC-cut parts,



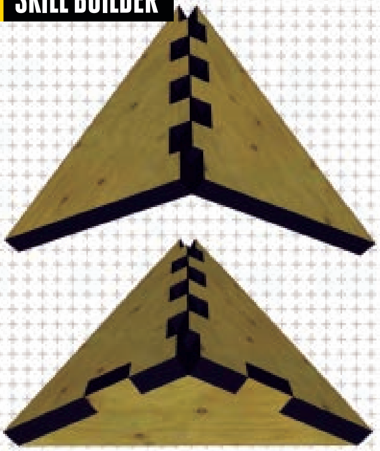
such as the Phlatformer vacuum former kit and several popular 3D printer kits.

This particular configuration was the subject of a nomenclature debate on the MAKE site, though no consensus was achieved. Interesting possibilities include "captive nut joint," "bedframe joint," and "Pettis joint" (my personal favorite, because it observes Stigler's Law*). There are almost certainly other clever ways to incorporate metal fasteners or other bits of common hardware in this type of joinery that I haven't seen, or that have not yet been invented.

Corner ("L") Joints

The arrangement of interlocking tabs and slots at a 90° angle is ancient and rudimentary (**Figure R**). Most people call it a *box joint*. It, too, can be biased by breaking symmetry, and it's just as amenable to the bolted captive-nut arrangement (**Figure S**).

* Stigler's Law of eponymy states that no scientific discovery is named after its original discoverer. Allegedly discovered by Robert K. Merton, making Stigler's Law exemplify itself.



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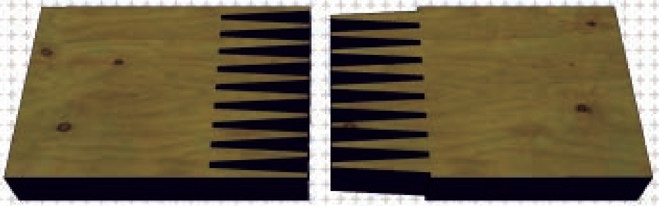
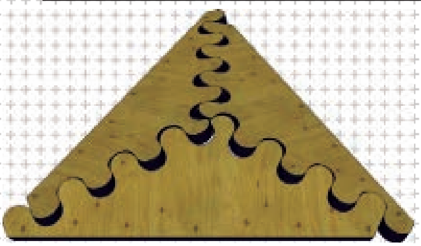


V

W



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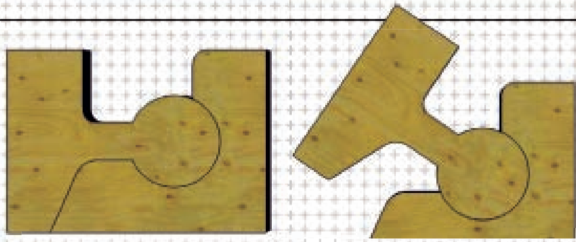
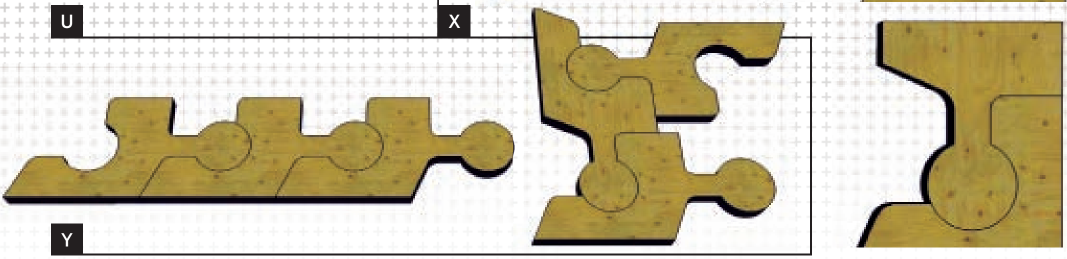


X



Y

Oblique ("V") Joints

Though the captive-nut joint doesn't really work unless its two parts are at right angles to one another, generally L joints can be pressed into service for acute or obtuse angles, as well (**Figure T**), making *V joints*.

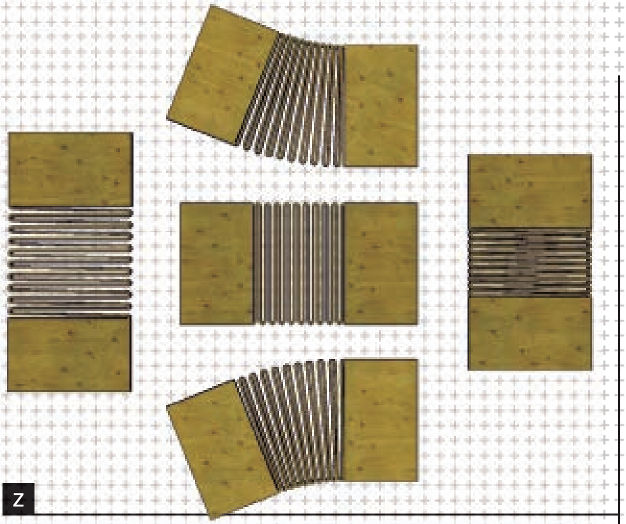
The bottoms of the slots no longer index closely against the surface of the stock, but if the members are held in alignment by some other means, for example by glue or the introduction of a third panel, it may not matter.

An interesting variation on this method, in which the fingers are rounded (**Figure U**), has been used by Belgian designer Sebastien Wierinck. Though rounded fingers may look better, it should be mentioned, they will limit the surface area available to any adhesive that might be used to glue the joint.

Coplanar ("I") Joints

The classic *finger joint* is used to join members in the same plane for gluing (**Figure V**). The interlocking bulbed version in **Figure W** doesn't depend on glue for its strength in tension. If left unglued, of course, these flat joints require some means to keep the two pieces in the same plane when the joint is in use.

Figure X shows a variation of the bulb joint that allows for in-plane hinging action. I want to call this a "Kanelba hinge," for George S. Kanelba of New York, whose Cube Desk project in the 1984 Popular Science book *67 Prizewinning Plywood Projects* is the only place I've ever seen it. Kanelba hinges can be daisy-chained to make "snakes" (**Figure Y**). The individual hinges, of course, can be set to stop at angles other than 90°.



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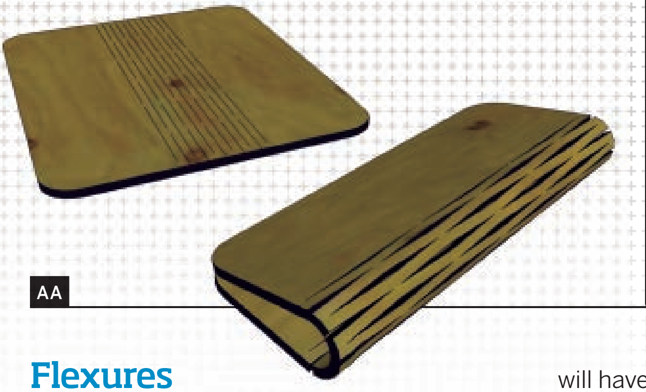
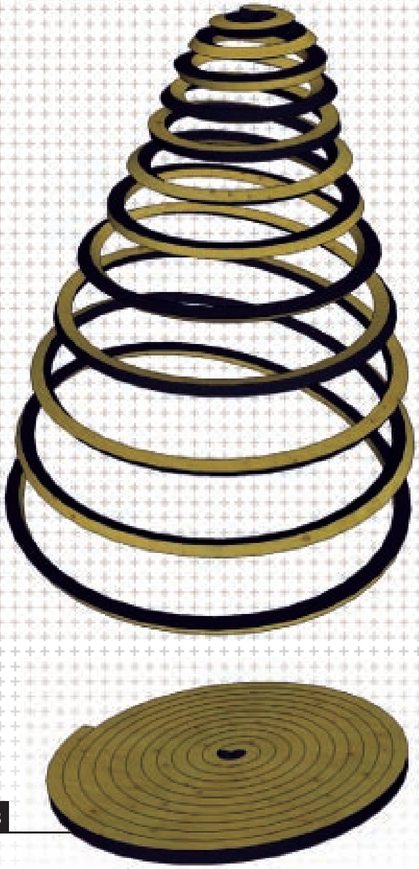


AA



BB

Flexures

Though not strictly joints, there is a class of clever CNC tricks that meet the rules of our game, and that are designed to exploit the natural elasticity of the panel material itself to create living hinges, springs, and other dynamic flexing elements. We have already broached the subject of integral flexures with our discussion of catches and detents.

Figure Z is an in-plane spring or living hinge element that is kind of like kerf-bending, but with "thru" cuts. If not constrained to motion in the plane, such a feature will be pretty unstable.

Figure AA shows a version more suitable for out-of-plane bending. This is the somewhat famous Snijlab living hinge technique (which I believe should be called a *sninge*), an accordion-cut pattern that allows for stable out-of-plane flexing (see *Laser-Cut Book Covers*, page 66). It's most commonly executed in laser-cut plywood, but there's no reason it couldn't be cut with a CNC mill and/or in other materials. A router-cut sninge, however, will have to be longer to achieve the same degree of flexibility, because the router slots will have to be considerably wider.

Finally, **Figure BB** shows an oddball spiral technique, courtesy of PlasmaCAM. Originally cut out from sheet steel using a CNC plasma cutter, a similar idea could work with a laser cutter or a mill, in some other material.

Final Thoughts

This is a huge area, and this article only just scratches the surface. While compiling it, new variations and ideas kept occurring to me, as I suspect they will to you, reading it. The rules of the game, again, are simple: all-the-way-through cuts, 90° to the surface of the stock, only one or two cut parts involved. What clever tricks have I missed? Let me know, in the comments of the original post at makezine.com/go/cncpanel.

Sean Michael Ragan is technical editor of MAKE magazine. His work has appeared in *ReadyMade*, *c't – Magazin für Computertechnik*, and *The Wall Street Journal*.

Use this neat technique to make plywood flexible.

By ***Christian Waber and Jiskar Schmitz***

TIME: 1 HOUR **COMPLEXITY: EASY**

Laser-Cut Book Covers

By making a pattern of laser cuts in a flat piece of wood, you can easily create hinges, clamps, and other features.

We made wooden booklets, each with a hinge and a notepad holder. The hinge can be fully bent in both directions repeatedly without breaking. How is that possible? First, wood has the strength to withstand repetitive bending and twisting. It won't break as long as the stresses stay under a certain limit.

The trick to making the wood flexible is to break it up in a lot of small pieces that can all twist a little. All these tiny twists add up so you can bend the sheet without stressing the material too much.

Imagine it like this: when you twist a matchstick with your hands, you can twist it maybe ⅛ of a turn before it breaks. Imagine now you have a matchstick 10 times longer. You can twist it 10 times as far, more than a full turn. That's how the hinge we use here works. When you look closely you can see that the cuts leave a pattern of interconnected small "sticks." When you bend the cover, you'll see them all twisting a little bit.

There are several patterns that will allow bending. The simplest one is a set of shifted cuts, as shown in **Figure A**. The longer or wider you make the piece, the softer it gets. This pattern yields a very springy hinge that you can move in all directions.

To make the hinge stronger, you can add some tabs in each line (**Figure B**). This gives the hinge a lot more strength while still allowing you to bend it.

Inside the cover is a clamp that holds the notepad with two flexible "arms," cut so they're slightly smaller than the notepad (**Figure C**). When you insert the notepad, the arms press on the sides, keeping it firmly in place.

Jiskar Schmitz

MATERIALS & TOOLS

» **Plywood, approx. 4mm** Birch works best.
» **Notepad, A7 size**
» **Rubber band**
» **Clear varnish**
» **Wood glue**
» **Sandpaper, 180 grit**
» **Laser cutter** If you don't own one, check your local fab lab, hackerspace, TechShop, or a commercial laser-cutting service.

1. Download the DXF files from Thingiverse (thingiverse.com/thing:12707). Load up your plywood, then send the files to the laser cutter.

2. When the pieces are ready, sand them to get rid of the laser-cutting marks.

3. Varnish both pieces to protect them from dirt. Set aside to dry.

4. When dry, apply wood glue to the back of the clamp's middle section and position it on the inside of the cover. Take care not to put glue under the ribbed "arms" of the clamp because these need to move freely. Put some weight on the clamp and wait 2 hours for the glue to dry.

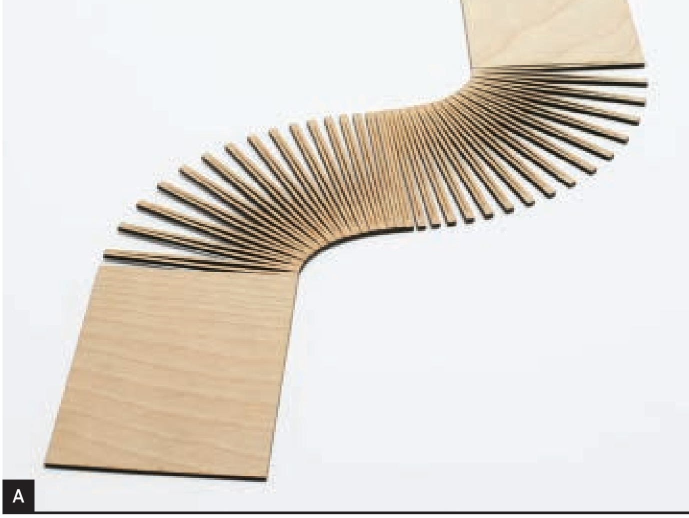
5. Carefully insert the notepad in the clamp, insert the rubber band in the 2 slots at the bottom, and you're done!

Mod It!

Once you've downloaded the DXF files, there's nothing stopping you from altering them to fit your own needs. Go ahead and change the shape to your liking, or laser cut your name onto it. You can also extract the hinge and use it in other projects that need some bent wood. Happy making and don't forget to share your work!

Christian Waber and Jiskar Schmitz are from the Netherlands. They founded the digital manufacturing company Snijlab (snijlab.nl) to make the full power of digital fabrication accessible for everyone. They love to design, make, and engineer.

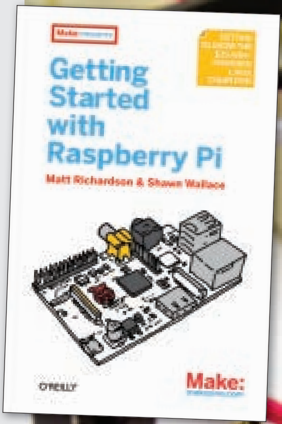
Gregory Hayes

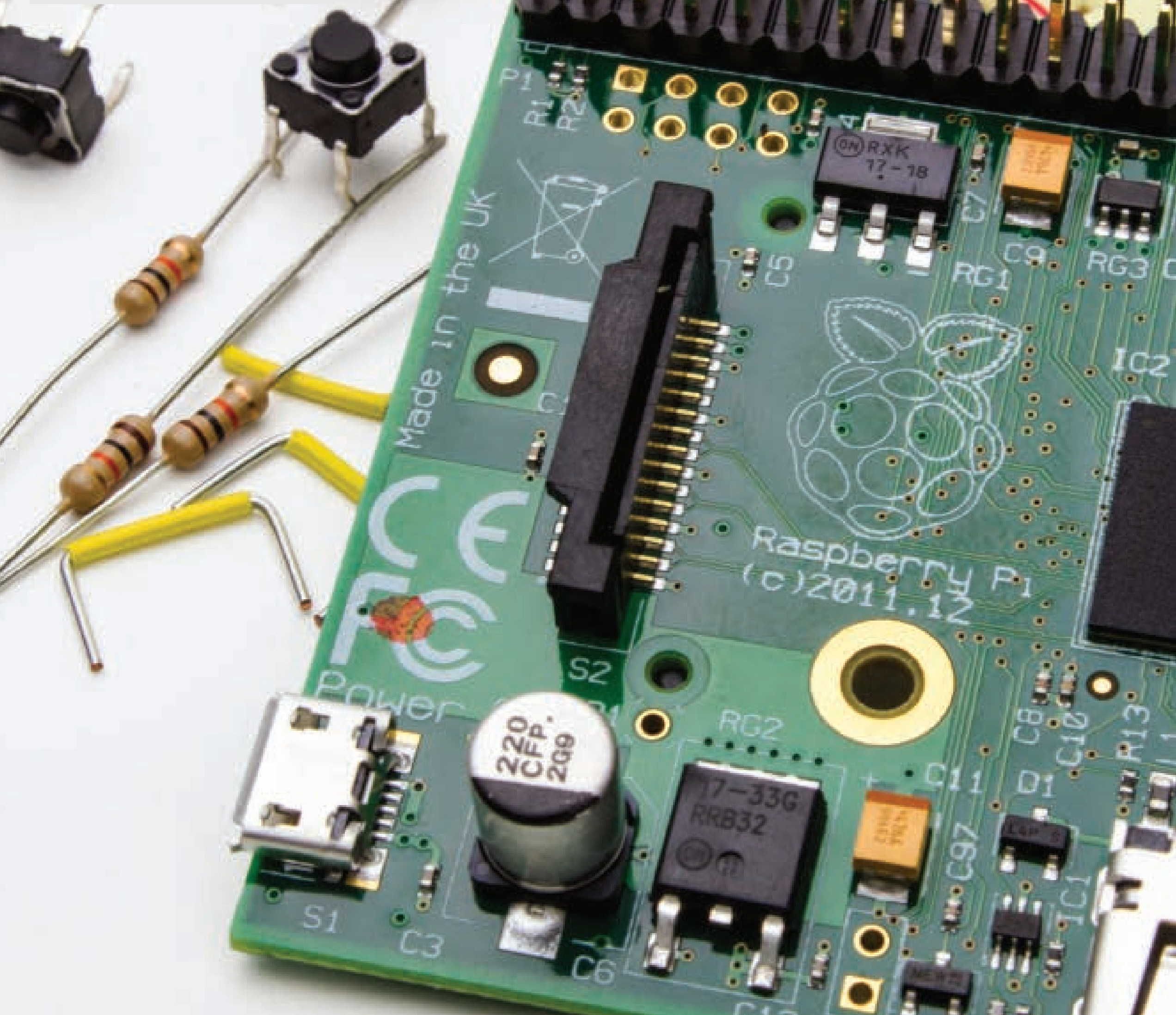

A


B


C

This project is from *Getting Started with Raspberry Pi* by Matt Richardson and Shawn Wallace. It assumes that you already know how to set up and operate the Raspberry Pi platform, and that you know the basics of the Python programming language. If you want to get up to speed quickly, you can find all of the above (and much more) in Richardson and Wallace's book, available in the Maker Shed (makershed.com).





Simple Soundboard

An introductory exercise for Raspberry Pi.

By ***Matt Richardson and Shawn Wallace***

TIME: 1 HOUR **COMPLEXITY: INTERMEDIATE**

In this simple breadboard build, we'll use a Raspberry Pi and the sound functions of the Pygame module in the Python programming language to make a soundboard. A soundboard lets you trigger the playback of sounds when you push its buttons.

You'll also need a few uncompressed sound files, in WAV format. You can record or download your own, and there are a few sound files preloaded onto the Raspberry Pi in */usr/share/sounds/alsa/* that you can use for testing. We even collected a few public domain sound effects from The Internet Archive that you can download at makeprojects.com/v/33. These will give you some fun files to play with right away.

1. Breadboard the circuit.

Using a female-to-male jumper wire, connect the Raspberry Pi's ground pin to the negative rail on your breadboard.

With another female-to-male jumper wire, connect the Raspberry Pi's 3.3V pin to the positive rail on your breadboard. Insert the 3 pushbutton switches into the breadboard, all straddling the center trench.

Now with standard jumper wires or small pieces of hookup wire, connect the positive rail of the breadboard to the top pin of each button. Next, add the pulldown resistors. Connect the bottom pin of each button to ground with a 10K resistor.

Connect each button's bottom pin (the one with the 10K resistor) to the Raspberry Pi's GPIO pins using female-to-male jumper wires. For this project, we use pins 23, 24, and 25.

About Python

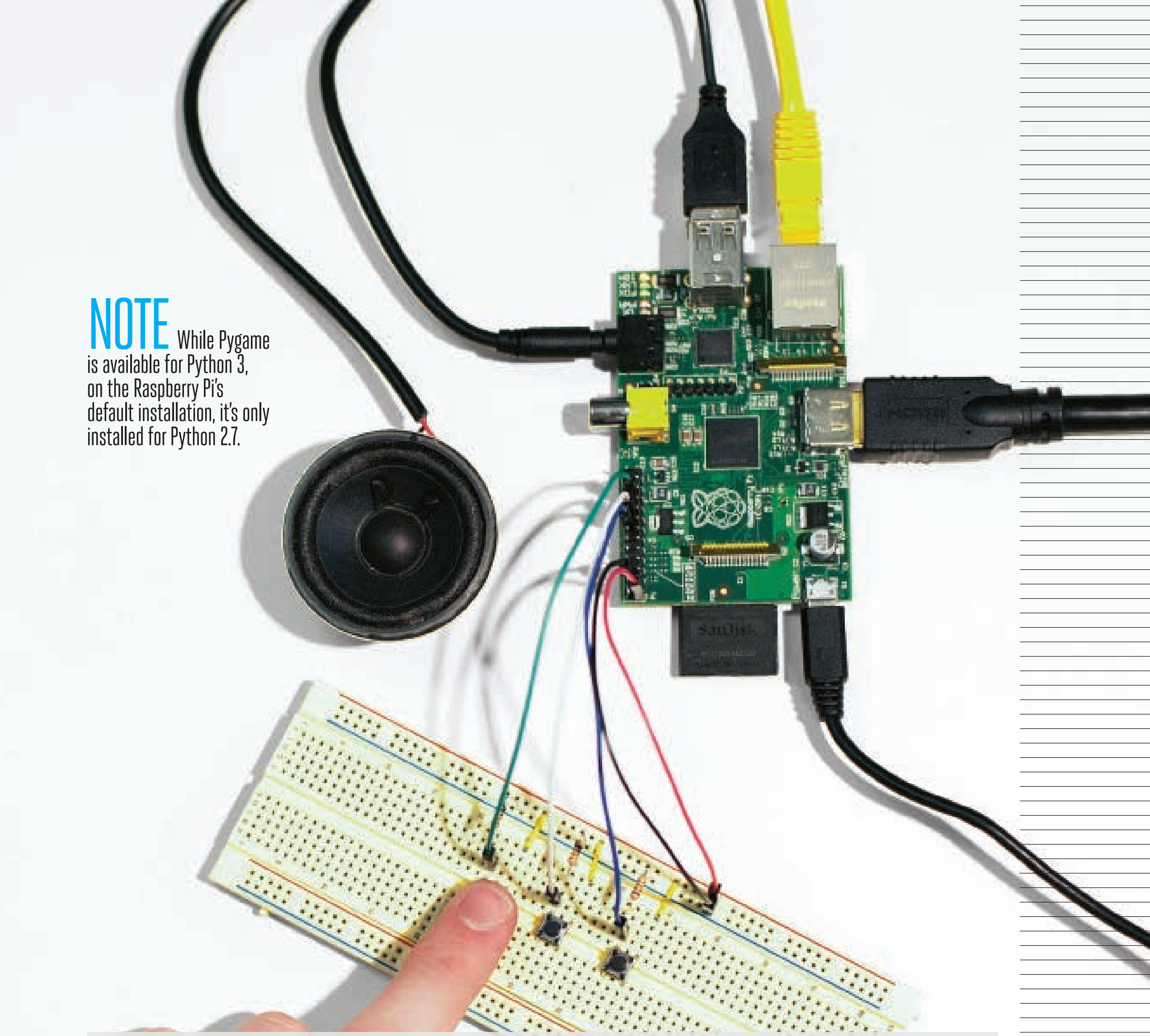
» Python (python.org) is a great first programming language; it's clear and easy to get up and running. More importantly, there are a lot of other users that you can share code with and hit up for questions.

» Guido Van Rossum created Python, and very early on recognized its use as an accessible first language for computing. In 1999 Van Rossum put together a widely read proposal called "Computer Programming for Everybody" that laid out a vision for an ambitious program to teach programming in the elementary and secondary grade schools using Python. More than a decade later, this is actually happening with the coming of the Raspberry Pi.

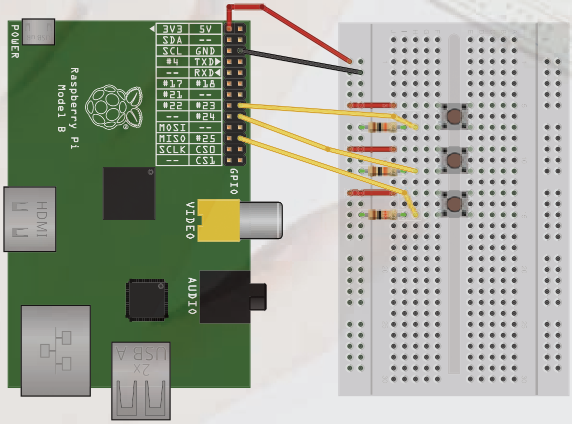
» Python is an interpreted language, which means that you can write a program or script and execute it directly rather than compiling it into machine code. Interpreted languages are a bit quicker to program and have a few side benefits. For example, in Python you don't have to explicitly tell the computer whether a variable is a number, a list, or a string; the interpreter figures out the data types when you execute the script.

» The Python interpreter can be run in 2 ways: as an interactive shell to execute individual commands, or as a command-line program to execute stand-alone scripts. The integrated development environment (IDE) bundled with Python and the Raspberry Pi is called IDLE.

Gunther Kirsch



NOTE While Pygame is available for Python 3, on the Raspberry Pi's default installation, it's only installed for Python 2.7.



MATERIALS

- **Raspberry Pi** with power, keyboard, monitor, and network connected
- **Pushbutton switches (3)**
- **Jumper wires, female-to-male (5)**
- **Standard jumper wires (3) or hookup wire** cut to size
- **Solderless breadboard**
- **Resistors, 10kΩ (3)**
- **Computer speakers** or an HDMI monitor that has built-in speakers

2. Work on the code.

Create a new directory in your home directory called *soundboard*. Open that folder and create a file there called *soundboard.py*. Open *soundboard.py* and type in the following code (or download it from makeprojects.com/v/33):

```
import pygame.mixer
from time import sleep
import RPi.GPIO as GPIO
from sys import exit

GPIO.setmode(GPIO.BCM)
GPIO.setup(23, GPIO.IN)
GPIO.setup(24, GPIO.IN)
GPIO.setup(25, GPIO.IN)

pygame.mixer.init(48000, -16, 1, 1024)

sndA = pygame.mixer.Sound("buzzer.wav")
sndB = pygame.mixer.Sound("clap.wav")
sndC = pygame.mixer.Sound("laugh.wav")

soundChannelA = pygame.mixer.Channel(1)
soundChannelB = pygame.mixer.Channel(2)
soundChannelC = pygame.mixer.Channel(3)

print "Soundboard Ready."

while True:
    try:
        if (GPIO.input(23) == True):
            soundChannelA.play(sndA)
        if (GPIO.input(24) == True):
            soundChannelB.play(sndB)
        if (GPIO.input(25) == True):
            soundChannelC.play(sndC)
        sleep(.01)
    except KeyboardInterrupt:
        exit()
```

Initialize Pygame's mixer.

Load the sounds.

Set up 3 channels, one for each sound, so that we can play different sounds concurrently.

Let the user know the soundboard is ready.

If the pin is high, execute the following line.

Play the sound.

Don't "peg" the processor by checking the buttons faster than we need to.

This will let us exit the script cleanly when the user hits CTRL+C, without showing the traceback message.

Go to the command line and navigate to the folder where you've saved *soundboard.py* and execute the script with Python:

```
$ sudo python soundboard.py
```

After you see "Soundboard Ready," start pushing buttons to play the sound samples. Depending on how your Raspberry Pi is set up, your sound might be sent via HDMI to your display, or it may be sent to the 3.5mm analog audio output jack on the board.

To change that, exit the script by typing CTRL+C and executing the following command to use the analog audio output:

```
$ sudo amixer cset numid=3 1
```

To send the audio through HDMI to the monitor, use:

```
$ sudo amixer cset numid=3 2
```

Of course, you aren't limited to just 3 sounds; you can add quite a few more. Just add the files to the soundboard directory and update the code accordingly.

Matt Richardson is a contributing editor of MAKE and a Brooklyn-based technophile, maker of things, photographer, and video producer. His work can be found at mattrichardson.com.

Shawn Wallace edits books for MAKE and lives in Providence, R.I. His work can be found at fluxly.com.

DIY Welding Rod

TIME: 1 HOUR COMPLEXITY: EASY

Prepare for the zombie apocalypse by rolling your own.

Written by ***Chris Hackett***

There are a bunch of DIY welder articles and how-tos out in the ether, ranging from the super simple, dumb, and brutally effective (3 car batteries wired in series) to the high-tech and fancy (TIG machines from microwave bits, oxyhydrogen torches from split water and plumbing supplies).

It's safe to say that experienced makers will be fusing metal even if an exceptionally biblical catastrophe were to strike the welding industry. If civilization and supply chains collapse, the anti-zombie fences will still get built, and the Thunderdome will be sturdy and made from steel.

However, all the DIY welders I've seen assume that you have access to welding rod. For the less weld-informed, a good, solid weld involves more than melting and fusing metals — the weld zone needs to be free of oxygen, otherwise the normal oxidation of metals that leads to rust, patinas, and discoloration happens at a dizzyingly rapid rate, accelerated by the high heat. This is not just an aesthetic issue — the oxidation happens inside the weld, so instead of a solid metal bond, you get a brittle foam filling.

Becky Stern

Rod Research

» My first step was to look up patents, which lay out the crucial core of a technology. Often, the making process is laid out as well, protecting the inventor's rights to the means, as well as the ends. This keeps patent attorneys employed, and provides a nice step-by-step for writers to rip off.

» I dug up the patent "Electrode for Arc Welding," filed in 1918 by Reuben Stanley Smith, a prolific inventor and resident of Milwaukee, Wis. Basically, a steel rod is wrapped in cellulose (paper) soaked in sodium silicate, and the wrapping is crimped to maintain close contact with the rod. The electrodes are then dried out.

» The rod is the electrode and filler; the paper/sodium silicate wrapper spews out shielding gas upon combustion and provides a path of plasma to guide the arc. The rod does not deposit a protective ceramic slag like modern welding rods, but, as Mr. Smith stated in the patent, "I have found, also, that the coating of slag produced by the use of known covered electrodes is not essential to the production of eminently satisfactory work." I tweaked the patent procedure a little to use commonly available materials.

MATERIALS

- **Silica gel packets (2–3)** usually labeled "Desiccant: Do Not Eat" and packaged with electronics, shoes, and other things that hate dampness
- **Lye, 100%** sold as drain cleaner
- **Steel wire or coat hanger, 2' or more** to cut into welding rods
- **Newspaper**
- **Plastic cups (3)**
- **Nitrile or latex gloves**
- **Stir sticks, plastic or wooden**

TOOLS

- **Digital pocket scale**
- **Hot plate** to cook the lye and silica gel into sodium silicate
- **Pliers**
- **Safety glasses or goggles**
- **Cooking vessel, tempered glass or nonreactive ceramic** don't use metal or Bad Things might happen
- **Toaster oven** to cook the rods. A rod oven, or some time in the sun, should do the trick as well.
- **Mortar and pestle, or scrap of metal round stock**

A

B

CAUTION Wear gloves and goggles, and weigh out the parts individually. A little lye in the eye or in a cut on your hand will ruin your day.

Removing the oxygen is usually achieved by flooding the weld area with inert gas — regulated, pressurized gas from a separate tank in the case of MIG and TIG welding, or gas created from vaporizing flux in oxy-fuel, stick, and flux-core welding. The standard, flux-coated arc-welding rod is the common currency of welding, used to hold the world together. You can get them everywhere. Until you can't.

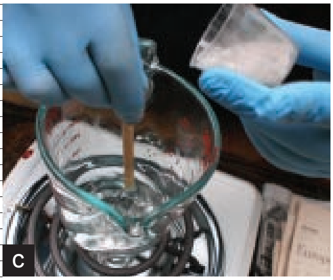
Even the finest DIY welder is useless without welding rod. I did a bunch of research, and as far as I can tell no one has made their own welding rod and documented it online. A minor but potentially crucial gap in the DIY world, solved here (and on the web at makeprojects.com/project/d/1712).

1. Make the sodium silicate.

If you have some lying around, you can skip this step. Empty out the silica gel packs until you have a pile of beads about the size of a large walnut.

Get smashy with the silica gel beads. A mortar and pestle work best here. I didn't have one, so I rolled the silica gel package with a metal rod (**Figure A**).

Time for some chemistry. Zero your scale. Sodium silicate is made from water, silica gel, and sodium hydroxide (lye). The proportions (by weight) are 6 parts silica gel (crushed as best you can), 4–8 parts lye (4 will work, 8 is stoichiometric, and anywhere in between is fine), and 10 parts water (**Figure B**).

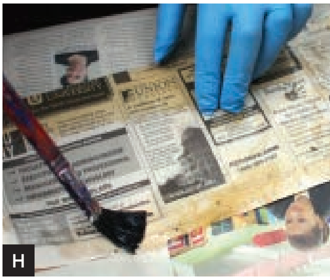

C


D


E


F


G


H


I


J


K

Heat the water, then slowly add the lye while stirring (**Figure C**). If you just dump the lye in, you'll get a solid, hard lump of a caustic base at the bottom of your heating vessel. The only way I found to remove it was neutralizing it with some decently strong hydrochloric acid. It totally looked like Science, but was an annoying waste of time.

Heat and stir until you get a clear but ominously thick solution. Be wary, but not too afraid — it can smell your fear.

This next part can be tricky — add the silica gel powder to the lye/water solution, but just a little bit at a time. Take the solution off the heat when you add the powder, then return it to the heat while you stir. If you leave it on the heat for too long it will boil over in an instant. If it gets too cool the silica gel won't go into solution, and will clump at the bottom.

Done right, the result will be a gummy gel, sodium silicate (**Figure D**)!

2. Prepare the rods.

Straighten the coat hanger, then cut pieces of welding-rod size: about 1' long will work.

Hangers are usually covered with paint or clear varnish, likely to avoid leaving your clothing stained with rust (I've never used a hanger for the intended purpose). Sand away the varnish or paint until you're left with a shiny rod of steel (**Figures E and F**).

Cut paper strips a little shorter than your rod. Each strip should be wide enough for 8–10 wraps around the steel (**Figure G**).

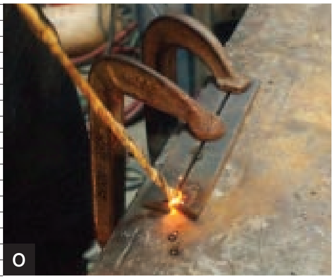
Paint a layer of sodium silicate onto the paper (**Figure H**). You want the paper to be as saturated as possible. I found that painting both sides allowed the sodium silicate to soak in nicely and evenly.

Roll the saturated paper around the steel rod; again, 8–10 layers will do. Try to get it as consistently tight as possible. It's harder than you'd think. Smooth the layers as you go, and smoosh the trailing edge into the rest of the


L


M


N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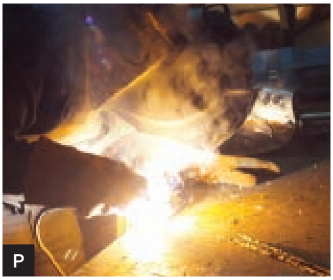

P


Q


R


S


T

wrap (**Figures I, J, and K**).

Use pliers to crimp the gooey paper tightly and uniformly onto the rod to prevent the coating from disintegrating faster on one side than another.

3. Bake the rods.

Cook the rods in a toaster oven at a low heat for about 15 minutes. This drives out moisture, and also makes a carbonized shell that keeps the rods intact when stored. You want them to be totally dry and golden (**Figures L and M**).

4. Weld.

You're ready to test. I guess for maximum punk-rock DIY points I should have tested them using a car-battery welder, but the arc welder was right there.

I used the recommended settings for a $3/32$" rod: DCEP, around 100 amps (**Figure N**). Striking an arc took a couple of tries, but once I figured out the correct distance and angle, the rod burned almost as well as an off-the-shelf rod (**Figure O**). Tons of smoke, though, and the arc was not super stable.

Then I welded with the homemade electrode (**Figure P**). It was splattery and ugly (you can partially blame user error and a bit of a learning curve), but it definitely looks like a weld (**Figure Q**). Notice the lack of ceramic slag — just some ash.

I then brushed it to see the glory of my weld. Looks OK, in parts. The weld side is not pretty, but the backside shows good penetration (**Figures R and S**).

I chopped the weld up for a closer look, and success! No pitting, no craters, and total fusion of the metal (**Figure T**). Welding, from home-rigged rods. Take that, zombies.

Hackett is a teacher (adjunct professor at New York University), artist, founder and director of the Madagascar Institute (madagascarinstitute.com), and television presenter (most recently on *Stuck with Hackett*).

The Panjolele Cake Pan Ukulele

Start your own ukulele craze with this great-sounding musical instrument built from simple household parts.

Written and photographed by ***Chester Winowiecki***

TIME: 2–3 DAYS **COMPLEXITY: MODERATE**

I love making my own musical instruments. Nothing beats the feeling of playing your own tunes on an instrument you made yourself. While the best instruments are made by skilled craftspeople with high-quality materials, it can be very rewarding to craft an instrument with simple components at hand.

A few years ago I got interested in the idea of making my own cigar box ukulele. I had a nice box and the wood to make the neck but I needed a lot of other parts, like frets and a slotted fretboard and tuners and strings, that I had to order and wait for them to arrive. But I wanted it done right then! So while I waited, I thought about how those parts functioned and what I could substitute.

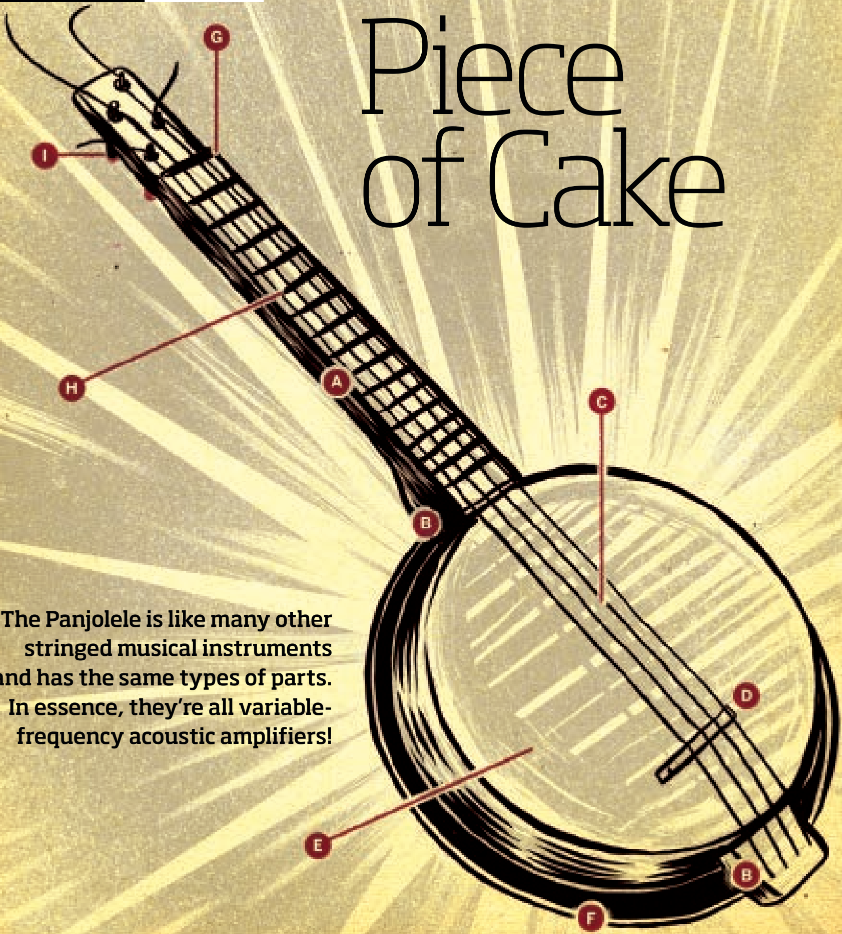
I remembered someone using toothpicks for frets on cigar box guitars, and while I was wary of steel strings cutting into the wooden frets, I thought a ukulele's nylon strings should be fine. Toothpicks for frets: check.

I'd also seen a lot of instruments built with cookie tins for the body, so I headed to the local resale shop to look for one. No tins, but what I did find was even better. Nice, rigid aluminum cake pans, in two sizes. "Resophonic instruments use aluminum cones, don't they?" I thought. Cake pans for the body: check.

I brought my treasures home and found a nice piece of hardwood for the neck. Luckily, I had a set of tuners and strings on hand. I got to work and a few days later, I had a cake pan uke!

The name? Early in ukulele history, Alvin D. Keech introduced a banjo ukulele that eventually got the name banjolele. Looking like it does, it seemed natural to call my instrument a Cake Pan-jolele, or Panjolele for short.

Piece of Cake



The Panjolele is like many other stringed musical instruments and has the same types of parts. In essence, they're all variable-frequency acoustic amplifiers!

Evan Hughes

COMPONENTS

A The neck is supported by your fretting hand and is the platform for other parts: the frets, the nut, and the tuners.

B The brace goes through the body and is attached to the neck. It supports the tension of the strings so the soundboard doesn't have to.

C The strings are the primary sound makers. When plucked, they vibrate at a certain frequency based on their thickness, tension, density, and length.

D The bridge takes the vibrations of the strings and transfers them to the soundboard.

E The soundboard acts as an amplifier that makes the vibrations louder with its bigger surface area.

F The resonator reflects some of the sound waves from the back of the soundboard and gives the overall sound more bass by creating a partial enclosure.

G The nut stops the string vibration at one end, holds the strings above the frets, and has notches to keep the strings spaced apart.

H The frets are stopping points for the strings. By pressing the string down to the fret, you make its vibrating length shorter and thus its pitch higher.

I The tuners tension the strings and allow them to be tuned to specific pitches.

MATERIALS

From a hardware store:

» **Hardwood lumber, 1×2 nominal, 36" length** Actual size is ¾"×1½". Choose oak, maple, poplar, or other hardwood, as straight and as knot-free as possible.

» **Wood screws, #6×1¼", Phillips head (3)**

» **Wood glue**

» **Spray lacquer or polyurethane, clear (1 can)**

» **Sheet metal screw, 2", pan head**

From a resale shop or department store:

» **Cake pans, aluminum or steel, 2" deep: 9" diameter (1) and 8" diameter (1)** Cake pans have sides at right angles to the bottom, and are deeper than pie pans. Steel is OK, but rigid aluminum pans are easier to cut and have a better sound.

From a music store:

» **Ukulele friction tuners (set of 4)** I'm using a basic $13 set, item #UP26 from Elderly Instruments (elderly.com), but for just $15 you can get better quality tuners, Elderly #GUKNW.

» **Ukulele strings, concert scale length (set of 4)** I'm using a basic $3 set of Hilo black nylon strings, Elderly #HCU. For $5, Aquila's Nylgut set, Elderly #ANCR, has the sound of old-fashioned gut strings.

From a grocery store:

» **Square wooden toothpicks (20)** You can also get these from Lego Education (legoeducation.us), item #W751742.

TOOLS

» **Pencil**

» **Ruler** with 1⁄32" marks

» **Marking pen, fine tip**

» **Square, adjustable**

» **Handsaw or power miter saw**

» **Sanding block and sandpaper** in various grits

» **Drill or drill press**

» **Drill bits: 1⁄16", 1⁄8", 3⁄16", 3⁄8", and #6 countersinking bit**

» **Screwdriver, Phillips head**

» **Spring clamps (2 or more)**

» **Hacksaw with fine-tooth blade**

» **Rotary tool with cut-off wheel** such as a Dremel

» **Needle files** including a triangular file

» **Rasp or Surform plane/rasp**

» **Flush nippers, end cutters, toenail clippers, or a utility knife**

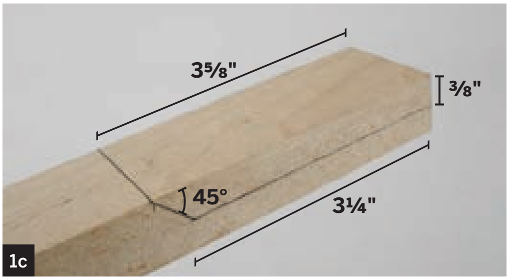
1. PREPARE THE NECK AND BRACE

1a. Using a power or hand miter saw, cut 2 lengths from the 1×2 board: 13¾" for the neck and 10½" for the brace. Save the leftover piece for other parts.


1a

1b. Decide which side will be the fretted (top) side of the neck, and use a sanding block to sand it flat and smooth. Start with coarser grits and work up to finer grits.

1c. At one end of the topside of the neck, mark out the cutout as shown. This is the Panjolele's headstock.



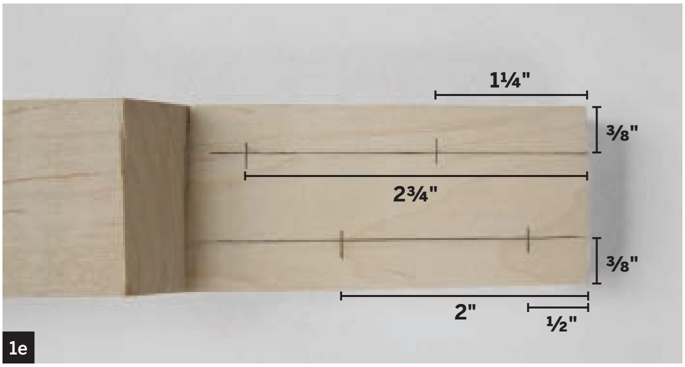
1c

1d. Carefully cut away the wood from this area using a handsaw and then sand away any saw marks.


1d

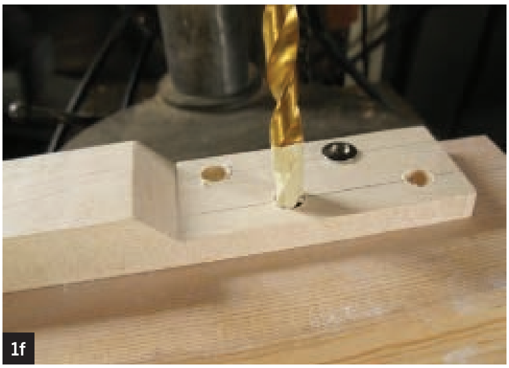

1d

1e. Mark out the placement of the tuner holes as shown. Drill the holes all the way through the headstock using a 3⁄16" drill bit.



1e

1f. Following the same holes, drill down ⅛" from the top of the headstock with a ⅜" bit. Test the fit with one of the tuners.


1f

TIP Mark the bit with a piece of tape to help you stop at the right depth.

NOTE These hole dimensions fit the UP26 tuners. Adjust if necessary to fit your tuner's shaft and bushing.

2. ATTACH THE NECK TO THE BRACE

2a. Mark out the areas where the neck and brace will join. Draw a line on the bottom of the neck 1½" from the uncut end. Make a similar mark 1½" from one end of the brace. This is now the top of the brace.

2b. On the bottom of the brace at this same end, mark out the 3 holes as shown.

Drill the holes all the way through with a #6 screw countersinking bit.

2c. Leaving one hole uncovered, clamp the neck and the brace together on a workbench with the 2 marked areas facing each other and each edge squared up to the marked lines.

Using the hole as a guide, use the #6 bit to drill ½" into the neck on the centerline, fret side down, being careful not to drill all the way through.

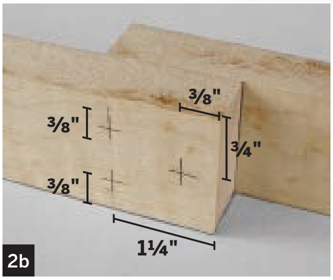
Install a #6 wood screw into this hole and tighten well.

2d. Remove the clamp, recheck the alignment of the 2 pieces, and drill the other 2 holes. Install the remaining wood screws to check for fit, then remove all the screws.

2e. At the other end of the brace, mark out the string holes as shown in the diagram. Using a 1⁄16" bit, drill the holes all the way through the brace.

2f. Measure 5" from this same end, and drill a ⅛" hole through the brace, centered from side to side.

2a



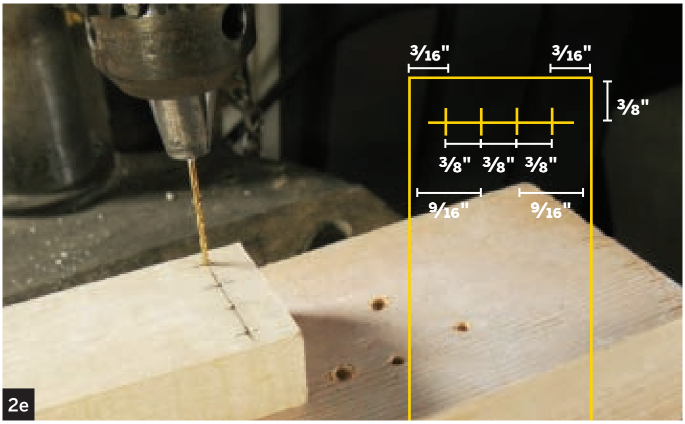
2b

2b

TIP Alternately, use a bit slightly larger than the unthreaded part of the screw's shaft, then use a larger bit to countersink the top of the hole.

2c

2d



2e

2f

3. LAY OUT AND GLUE THE FRETS

3a. Using a pencil, mark a line on the topside of the neck 3⅞" from the headstock end. This is where you'll glue the nut.

3b. Starting from this line, mark out the placement of each fret as shown in the chart (below).

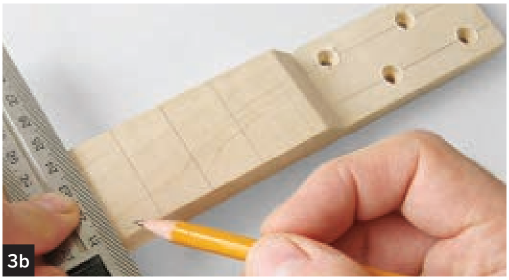
3c. With a very small amount of wood glue, glue one toothpick at the headstock side of each line, and clamp carefully with a pair of spring clamps. Allow the glue to set for a couple of minutes, remove the clamps, and carefully wipe away any excess glue with a damp rag.

Set aside to completely dry overnight.

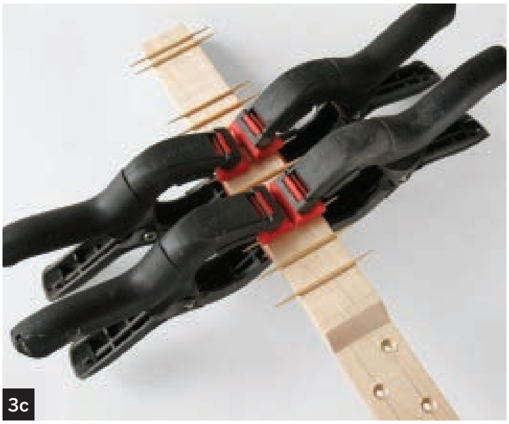
Fret Placement Chart
Scale length: 15½"

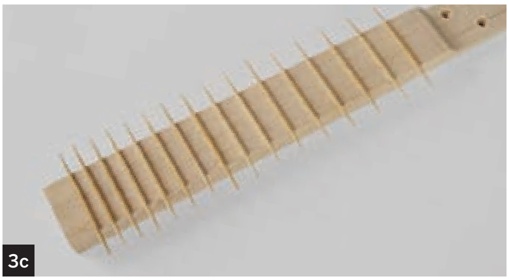
Fret #	Inches from nut (to nearest 1/32)
1	⅞
2	1 11/16
3	2 15/32
4	3 3/16
5	3 7/8
6	4 17/32
7	5 5/32
8	5 3/4
9	6 9/32
10	6 13/16
11	7 9/32
12	7 3/4
13	8 3/16
14	8 19/32
15	9
16	9 11/32


3a


3b


3c


3c


3c

NOTE Double-check your measurements and be sure the lines are square to one edge.

TIP To keep your fingers away from freshly glued frets and do the job faster, stagger the gluing order: #1, #7, #2, #8, #3, #9, etc.

4. PREPARE THE CAKE PANS

4a. On the back of the 9" cake pan, mark the center and drill a 3⁄16" hole.

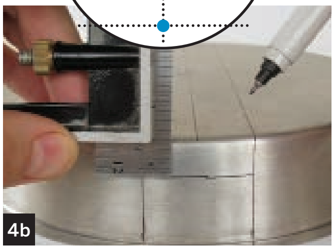
4b. On the back of the 8" cake pan, mark the center and draw a line through it, from edge to edge. Draw parallel lines ¾" on either side of this centerline.

Transfer these parallel lines down each side.

Between these lines, mark a base line on each side ½" from the back of the pan, using the adjustable square.

4b

4b



4b

4c. Using a hacksaw, cut a notch in the side of the pan along the parallel lines, from the rolled top edge to your base line.

Cut along the base line with the rotary tool's cutoff wheel. (You might also be able to score, bend, and snap the piece off.)

Repeat on the other end of the pan.

4c

4c

4d. File away any burrs and test-fit the brace into the notches. If necessary, file enough metal away for the brace to fit.

4d

4d

5. SAND THE FRETS

5a. Using a saw, pair of flush nippers, end cutters, toenail clippers, or utility knife, carefully trim the ends off of the toothpicks.

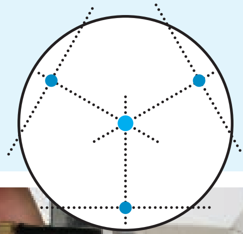
5a

TIP If you use a saw like I did, clamp the toothpicks and cut downward to avoid pulling off the frets.

How to Find the Center of a Circle

Draw a line across the circle, near the edge. Measure that line and divide it in half, then use your adjustable square to draw a second line from the midpoint, perpendicular to the first.

Do this 2 more times. The 3 perpendicular lines will intersect in the center of the circle.



5b. With medium-grit sandpaper and a sanding block, sand the edges of the toothpicks flush with the edges of the neck. You can also sand the ends of the frets at a 45° angle.

5c. With fine sandpaper and a block, sand the tops of the frets so that they're all level.

5d. Sand the top edges of each fret to make them nice and round.

6. FINISH THE NECK AND BRACE

6a. Using a rasp or Surform tool, ease over the corners of the neck, and round the back.

6b. From the leftover parts of the 1×2 (or other hardwood scrap), cut the nut and bridge pieces as shown. File the notches with a triangular file.

Glue the nut on the nut line on the fretboard side of the neck, the same way you glued the frets.

Set the bridge aside; you'll use it in the final assembly.

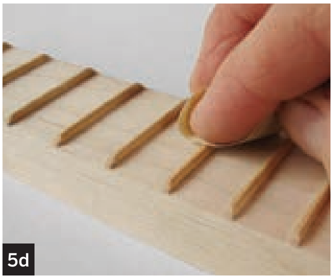
6c. Sand the entire neck smooth, removing all pencil lines and tool marks. Sand the brace.

6d. Attach the neck and brace with the 3 wood screws.

6e. Finish the entire neck/brace assembly and the bridge with spray lacquer or polyurethane and allow to dry completely.


5b

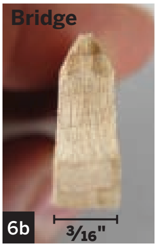

5c


5d

CAUTION Don't sand too much, as this will change the maximum height of the fret.


6a

NOTE Stay about 1/2" away from the headstock area and the area that will be screwed to the brace.



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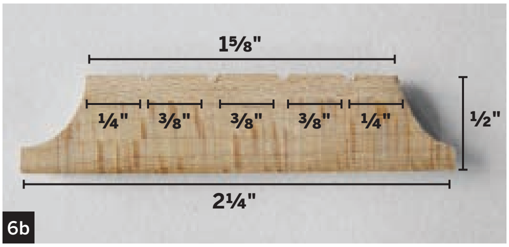

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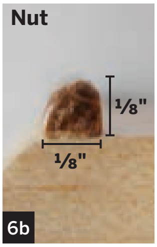

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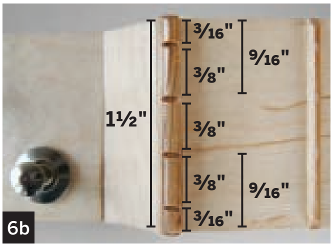

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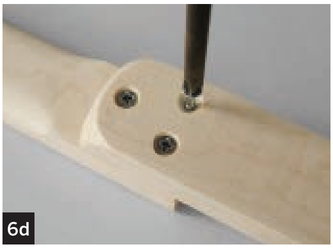
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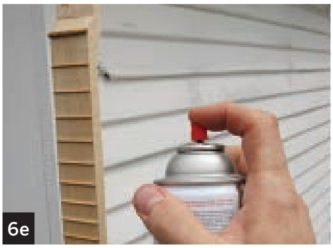

6e

7. FINAL ASSEMBLY

7a. Press-fit the bushings into the front of the headstock and install the tuners.

7b. Put the 8" cake pan over the brace, taking care not to scrape the wood finish.

7c. Tie a knot in the end of each ukulele string and thread them through the holes in the end of the brace. Check the diagram to get the placement just right.

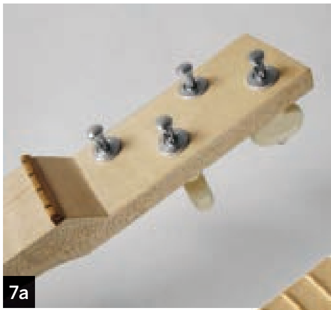
Thread the strings through the holes in the tuners and knot them. Turn the tuners to tighten the strings.

7d. Attach the 9" cake pan to the back of the brace with the 2" pan head screw.

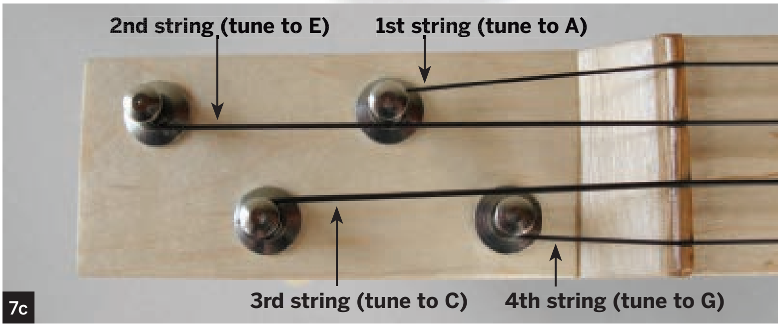
7e. Put the bridge under the strings and move it 15⅝" away from the nut. (The extra ⅛" compensates for any string stretch.)

TEST BUILDER: Josie Rushton, MAKE Labs


7a

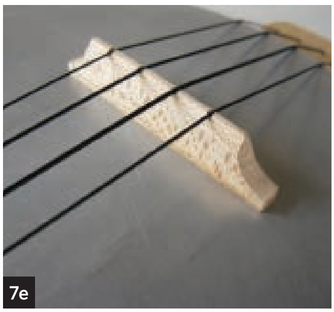

7a


7b



7c


7d


7e

When he's not diligently avoiding work, Chester Winowiecki makes functional pottery and musical instruments from clay and other fun junk. He lives a happy rural life with his artist wife, Cara O'Brien, and their cat, Gizmo, in Whitehall, Mich.

FINAL ADJUSTMENTS, TUNING & PLAYING

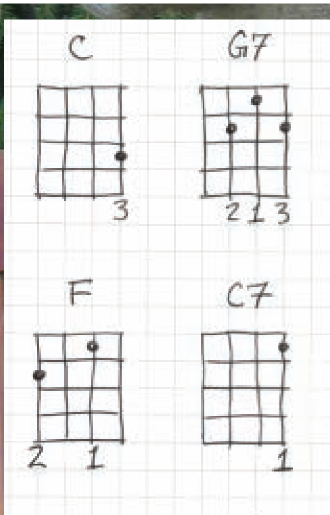
Resonation Nation

Cara O'Brien

Tuning up: Tune up your ukulele with an electronic or online tuner, tuning the strings G-C-E-A (most popular) or A-D-F#-B. Ukulele strings take a long time to stop stretching, so you'll need to keep retuning for a couple days, but it's good practice! If the tuners turn back after you let them go, tighten the screw at the end of the tuner.

Fine-tuning the action: If the strings feel really hard to push down to the frets, you can lower the "action" at the nut and the bridge. The bottom of the strings should be about 1/32" from the top of the first fret and 3/32" from the top of the twelfth fret. Deepen the notches in the nut first and then sand the bottom of the bridge. Do a little at a time, and check frequently so you don't overdo it. If you find that the strings pop out of the nut or bridge, use a precision knife to cut deeper slots.

Playing tunes: Here are few chords to get you started. For right-handers: use the fingers of your left hand to press the strings down to the frets in the spots shown in the diagrams. The numbers under each string show which finger to use. Strum all 4 strings with the first finger or thumb of your right hand. Lefties: reverse!



Going further: Use this same method to make instruments with longer scale lengths, more or fewer strings, metal frets and steel strings, or different sound boxes. One of my favorite instruments right now is a tenor banjo with 4 steel strings, metal frets, a 21" scale, and a cake-pan soundboard and resonator.

1.2.3. Dice Popper

By **Gus Dassios** Illustrations by **Julie West**

THIS IS MY VERSION OF A CLASSIC WAY to "roll" the die for a board game. The key to making this special die agitator is the clear plastic capsule. I found the right size, 2" diameter and 1⅞" tall, in a vending machine — it's the kind that holds inexpensive toys or trinkets.

YOU WILL NEED: **Plastic capsule, 2" diameter** » Die » **Compression spring, ⅜" diameter, 2"-long, .035" wire diameter** » Wood, ¼"-thick and ¾"-thick » **Flathead wood screws, #8×¾" (4)** » Finishing nails, 1¾"-long, small (4) » **Electric drill and drill bits** » Hole saw » **Saw** » Hammer » **Screwdriver**

1. Cut the wood.

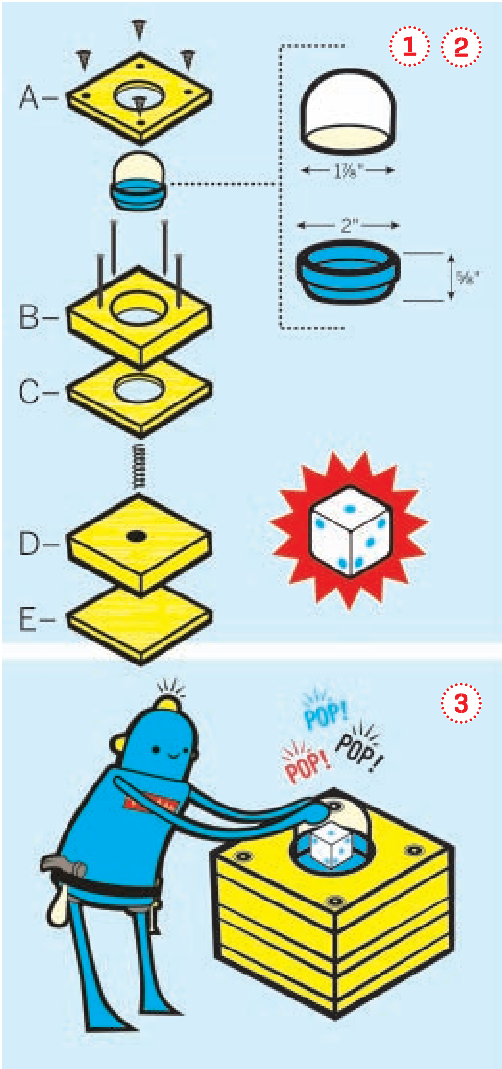
Parts A, C, and E are cut of ¼"-thick wood, while parts B and D are ¾" thick. Cut all 5 pieces to 3½"×3½".

2. Drill the holes.

Holes have to be drilled in all pieces except part E. » For part A, cut a large hole in the center, anywhere from 1⅞" to 2" in diameter, depending on the size of the domed half of your capsule. Then drill 4 countersink holes about ½" in from each corner, for the wood screws. » For parts B and C, cut a 2⅛"-diameter hole in each center. These holes will house the bottom part of the capsule. For part D, drill a ⅜"-diameter hole in the center, which provides a guide for the spring.

3. Assemble.

Nail together parts B through E with the finishing nails, avoiding the corners where the screws will go. After this bottom block is assembled, insert the spring. Place a die into the capsule, snap it, and lower it into the wood block. Part A will cap everything. It requires a slight push to keep it in place as you screw in the wood screws. » After that, you're ready to go. Good luck!



Gus Dassios lives, designs, and builds in Toronto, Ontario.

The Bhut Jolokia pepper is 125 times hotter than a jalapeño.

Written and photographed by ***Gabriel Nagmay***

Illustrated by ***Evan Hughes***

Growing the Ghost

TIME: SEVERAL MONTHS **COMPLEXITY: EASY**

Right now, under some lights in my basement, sit several dozen pots of soil. Out of each sprouts a small seedling, only a few millimeters high – a humble beginning for plants that will grow to produce one of the hottest peppers on the face of the Earth: the Bhut Jolokia, commonly known as the ghost chili.

THE BHUT JOLOKIA FIRST CAME TO MY ATTENTION IN 2007, when Guinness World Records crowned it "world's hottest chili pepper" (though it's since been deposed by another). Certified at well over 1,000,000 Scoville heat units, the fruit from this plant is 125 times hotter than the spiciest jalapeño.

At the time, tracking down seed stock for the pepper was a challenge. I was lucky enough to have a friend of a friend who worked for New Mexico State University's Chile Pepper Institute (chilepepperinstitute.org).

These days, seeds can be purchased from online retailers or from private growers on Amazon and eBay. There are even "just add water" kits. Skip these. Chili peppers are easy to grow — once you know a few tips.

MATERIALS & TOOLS

» **Bhut Jolokia chili pepper seeds** available online
» **Seed starting tray** with soil
» **Pots, 3" or 4" (one per seedling)**
» **Fertilizer, nitrogen rich, such as 10-5-5** or composted manure
» **Fertilizer, 5-10-10**
» **Heating pad**
» **Grow lights**
» **Digital oven thermometer**

1. Start your seeds.

Chili peppers require a long growing season to produce mature fruit. In northern climates, it's best to start your seeds indoors up to 3 months before the last frost date, allowing the plants plenty of time to germinate and grow a few sets of leaves before they're transplanted outside. For me, this means getting my seeds and setup ready by mid-February.

My indoor setup is simple. On a table in the basement, I have a seed starting tray, a heating pad, and lights. The tray is divided into 72 cells, each holding a few cubic inches of soil.

Fill the cells with soil and place a single seed on top of each. No need to cover them; all they require for germination are the proper moisture and temperature. Thoroughly water the seeds and set the tray on the heating pad.

Keep the soil moist and warm, between 75°F–90°F. You can use a digital oven thermometer to track the temperature. With luck, roots should emerge from each seed in 7–14 days. (Bhut Jolokia seeds will germinate at temperatures as cool as 65°F, but it'll take 30+ days, and many seeds may fail.)

Once they emerge, your tiny plants will require a good source of light. Since you're doing this in the winter, indoor lighting is your best option. Fluorescent tubes are inexpensive and efficient, and they work well. Hang them above the plants with wire so you can adjust the height. It's important to keep them only a few inches above the top of the peppers; any higher, and the plants will grow spindly. Leave the lights on 24 hours a day to give your peppers a jump-start on the season.

The first set of leaves will be tiny and round. As each seedling establishes its root system, a second set of leaves will appear. When these "true leaves" emerge, transplant the peppers into 3"–4" pots. Over the next couple months, your plants will have room to grow a healthy root system and several more sets of dark green leaves.

2. Move the plants outdoors.

Peppers require full sun and well-drained soil. I've found that raised beds or 2gal pots both work well. After the last chance of frost, you can move your plants outside. Just be careful — a single cold night (below 50°F) will decimate your chilies.

The most important tip to remember when gardening: try to mimic the environment where your plants would thrive naturally. These peppers are from the Assam region of India, where summer temperatures can reach

When transplanting your ghost chilies outside, keep them cozy with mini greenhouses made of 2-liter soda bottles.

Use a nitrogen-rich fertilizer for the first month to promote rapid foliage growth, giving your peppers their best chance of producing a bumper crop of extreme hotness.

100°F. They also do well with high humidity. If you live in a northern part of the United States (like me), you might have to improvise.

If you don't have row covers to keep the temperature up, you can make a mini greenhouse for each plant. Cut the bottom off a clear, 2-liter soda bottle and place it over each start. This has the added benefit of keeping out slugs, cutworms, and other pests. Just keep an eye on the temperature inside the bottle; too much heat will turn the mini greenhouse into a solar oven. The cap can be removed to provide ventilation.

During the first few weeks outdoors, a nitrogen-rich fertilizer will help the plant grow tall and strong. At the time of planting, apply either composted manure or a slow-release fertilizer such as 10-5-5. These numbers correspond to the nitrogen (N), phosphorus (P), and potassium (K) available in the fertilizer. The higher levels of nitrogen will promote rapid foliage growth, giving the plant a chance to thrive. You may soon need to add a stake or cage to support the plant.

Ghost Sauce

This delicious Belizean-style hot sauce will highlight your home-grown Bhut Jolokia chilies. Adjust the peppers to taste: 2.5oz gives good heat without overpowering the flavor. Any more, and you may want a warning label.

1. Sauté ½c white onion.

2. Add 1c water, 2tbsp fresh lime juice, 2tbsp white vinegar, ½tsp salt, 1 chopped garlic clove, and ½c shredded carrot. Bring to a simmer, then turn off the stove.

3. Add 2.5oz chilies, chopped. Wear gloves when handling them.

4. Blend and enjoy!

Each pepper is so potent that even minimal contact can numb your fingertips.

Regular watering and proper fertilization throughout the hot summer months will ensure that your pepper plants continue to thrive. However, after the first month in the ground, consider switching to a 5-10-10 fertilizer. This mixture contains half as much nitrogen as phosphate and potassium. High nitrogen promotes foliage growth, but it may do so at the cost of flower and fruit production. You could easily end up with a huge green plant that never produces a single pepper.

As summer comes to an end, you should have a mature Bhut Jolokia plant covered in 2"–3"-long, distinctly wrinkled, green peppers. Your goal is to let the peppers ripen on the vine, giving them time to produce the most capsaicin — the chemical compound that makes peppers taste hot — but two things can easily ruin your crop: frost and birds.

Any temperature below 50°F may cause the plant to drop fruit prematurely. On cool nights, cover your peppers with a row cover or a thin sheet to trap warm air around the plant. If extended cold weather is in the forecast, you might even dig it up and bring it indoors.

The other enemy: birds. In India, people use these blazing-hot peppers to ward off elephants, but unfortunately birds seem to be immune to capsaicin. Crows, ravens, and others will be attracted to the bright red fruit and will happily steal it as it begins to ripen. Try bird netting or other measures to deter them.

3. Harvest your peppers.

Pick individual peppers as they ripen. A fully ripe Bhut Jolokia pod is completely red and has a glossy, wrinkled texture.

At this point, your peppers have developed the maximum amount of capsaicin, so be careful when handling them. Most of this heat chemical is contained on the ridges inside the fruit where the seeds are held. However, it's a good idea to wear gloves when handling the fruit. Each pepper is so potent that even minimal contact can numb your fingertips.

Another advantage of picking the peppers fully ripe is seed saving. Each mature fruit contains about a dozen seeds. Carefully collect these. They'll stay viable for several years if stored in a cool, dry place.

4. Use your ghost chilies.

Armed with an arsenal of fully ripe ghost chilies, you now have many usage options to choose from. You can hang them around your home to protect from wild elephant attacks. You can extract the capsaicin to produce a potent, homemade pepper spray. Or, like me, you can use them as the key ingredient in my kick-ass Ghost Sauce recipe. Enjoy!

Gabriel Nagmay (gabriel.nagmay.com) is a web geek living in Portland, Ore., who loves building tall bikes, brewing beer, and growing unusual edibles.

Key-Card Door Lock

Pick-proof, programmable security without a microcontroller.

Written and illustrated by ***Charles Platt***

TIME: 2 HOURS—2 DAYS
COMPLEXITY: MODERATE TO HIGH

Almost anyone can learn to pick a typical door lock. The most common method is to jiggle the tumblers by inserting a tool known as a "rake," while applying turning force with a tension wrench. When the tumblers are aligned, the cylinder rotates and you can walk right in.

When I first started thinking about a pick-proof electronic lock, I imagined a totally automated system using a key card and a motor that would pull a deadbolt aside. However, a motor that was powerful enough to overcome the likely friction would require either 115V AC (vulnerable to power outages) or a substantial battery.

It would be cheaper and simpler to use an off-the-shelf deadbolt that's moved manually by turning an external knob. I could block or unblock the movement of the deadbolt using a small, low-power DC gearmotor to turn a lever, as shown in **Figure A**.

For the key card, I imagined a plastic rectangle punched with a unique pattern of holes. The card would slide into a slot with a light source to shine through the holes to phototransistors beneath. Additional electronics would decide whether the pattern was correct. If I needed to rekey the lock, I could make a new card with a different pattern, and reprogram the electronics to match.

The word "reprogram" suggested I'd need a microcontroller to complete this project. Or would I? Maybe a set of switches could do the job more simply and cheaply. The first step toward figuring this out was to review the way in which phototransistors generally behave.

MATERIALS

- **Phototransistors, visible spectrum (6)** Everlight part #PT334-6C or RadioShack #55053303
- **LEDs, white, water-clear (3)** typical 3.3V forward voltage, minimum, 5,000mcd with 30° dispersion; Kingbright #WP7104VW1C or RadioShack #55050632
- **Slide switches, subminiature DPDT (6)** C&K #OS202013 MT5QN1
- **Toggle switch, DPDT, center-off momentary, minimum 3A** Mountain Switch #108-0005-EVX
- **Resistor arrays, bussed, 5.6K (2)** Xicon #265-5.6K-RC
- **Logic chip, triple 3-input AND gates, type 74HC11** Texas Instruments #SN74HC11N
- **Darlington transistor, 8A, type 2N6043** On Semiconductor #2N6043G
- **Mini lever snap switches, SPDT, 5A (4)** maximum 20g operating force, Mountain Switch #101-1206-EV
- **Diodes, general purpose, 3A (2)** Vishay #SRP300G-E3/54
- **Voltage regulator, 5V, type LM7805** Fairchild Semiconductor #LM7805CT or RadioShack #276-1770
- **Capacitors, multilayer ceramic: 1μF (1), 0.1μF (1)** for smoothing the 5V output
- **Gearmotor, 9V or 12V DC, minimum 10rpm** ServoCity #RZ12-300-10RPM or check eBay for substitutes
- **9V battery**

Optional, recommended for testing:

- **Breadboard**
- **Jumper wires**

For the finished project:

- **Keyless deadbolt**
- **Opaque plastic** to make key cards and mounting panel for switches
- **Plywood, plastic, or aluminum sheet** to fabricate card slot

TOOLS

- **Multimeter and test leads**
- **Soldering iron and solder**
- **Wire cutters and strippers**

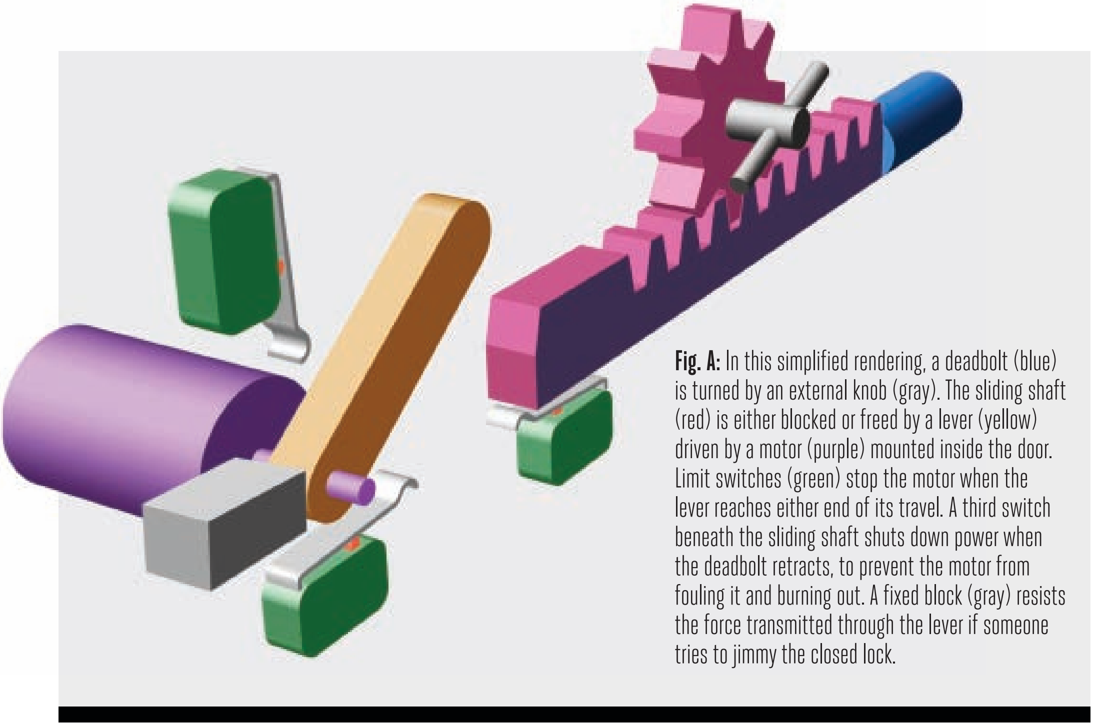


Fig. A: In this simplified rendering, a deadbolt (blue) is turned by an external knob (gray). The sliding shaft (red) is either blocked or freed by a lever (yellow) driven by a motor (purple) mounted inside the door. Limit switches (green) stop the motor when the lever reaches either end of its travel. A third switch beneath the sliding shaft shuts down power when the deadbolt retracts, to prevent the motor from fouling it and burning out. A fixed block (gray) resists the force transmitted through the lever if someone tries to jimmy the closed lock.

Phototransistors Basics

In **Figure B** (following page), the phototransistor is the circle with arrows suggesting incoming light. When the light is off, the phototransistor allows only a tiny leakage current between emitter and collector, and the voltage between point X and ground is almost zero. As the light increases, the phototransistor junction becomes saturated, just like an NPN transistor when the base is highly biased. The effective internal resistance drops, and the voltage at point X rises close to the supply voltage (assuming any electronics attached to X have high impedance). I found a 5.6K resistor worked well with the phototransistor I chose for this project.

If the positions of the phototransistor and the resistor are reversed, the outcome is too. In **Figure C**, when the phototransistor is dark and blocks current, the voltage at X is high. When light shines on the phototransistor, the voltage at X goes low.

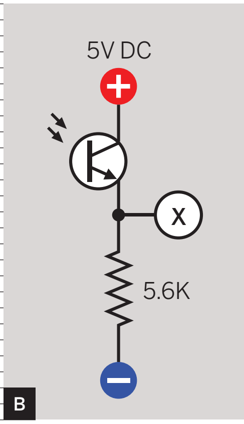
So, depending on wiring, a phototransistor can give a high output either in the light (Figure B) or in the dark (Figure C). Thus, if phototransistors are wired as in Figure B to match the holes in a key card, and as in Figure C to match the blocked areas of the card, all their outputs will go high when the card's pattern is correct. This can be verified by ANDing all the phototransistor states via a logic chip, because an AND gate only outputs high if all its inputs are high.

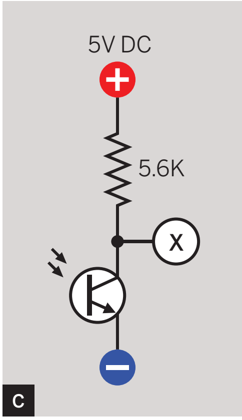
A hardwired array of phototransistors is not reprogrammable, but I saw that a DPDT switch could solve the problem, as shown in **Figure D**. In its "up" position the switch emulates the circuit in Figure B. In its "down" position the switch emulates the circuit in Figure C. If the key card pattern is changed, the switch positions are changed to match.

Phototransistors and subminiature slide switches are cheap, so the electronics for this project shouldn't cost more than $20. The motor and deadbolt are extra, but I found small DC motors on eBay for $5 or $6 each.

Combinations

Now to decide how many phototransistors to use. Sixteen in a 4×4 grid would allow 65,536 possible combinations, which sounded reasonably secure. But 16 phototransistors, 16 switches, and 32 resistors is a lot to wire. Then I realized most of the holes in the card could be dummies. Six phototransistors would still provide 64 possible combinations for the lock. I would be the only person who knew which holes were dummies, and which were not.





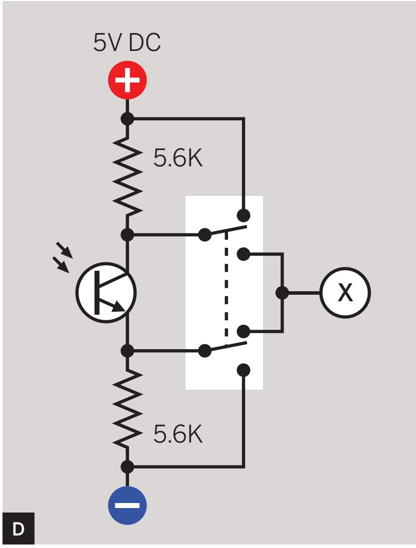


Fig. B: Voltage at point X is high when light falls on the phototransistor, and low when the phototransistor is dark.

Fig. C: Voltage at point X is low when light falls on the phototransistor, and high when the phototransistor is dark.

Fig. D: A DPDT switch enables a single circuit to emulate both of the configurations in Figure B and Figure C.

Next, how to AND 6 phototransistor outputs? This is easy using a 74HC11 chip with three 3-input AND gates. **Figure E** shows how they're chained to give a single output.

These phototransistors can be connected directly to the chip because they comply with its requirement for a high input no less than 3.5V and a low input no greater than 1V DC. Use a meter to verify your phototransistors also meet this requirement.

Additional Switches

The chip's output controls a Darlington transistor, which powers the motor (**Figure F**). The motor stops itself at each end of its travel by opening one of a pair of limit switches, marked S5 and S6. (If you're unclear about how limit switches work, you'll find a detailed explanation in my book *Make: Electronics*.)

S4 is a manual DPDT switch, spring-loaded to return to its center-off position. It starts the motor in one direction or the other by bypassing either S5 or S6 through a rectifier diode. If your motor doesn't respond appropriately, just swap the wires to its inputs.

The purpose of S7 is to minimize battery drain by keeping the circuit powered down until a key card is inserted. This switch should be positioned so the card closes it when slid fully in.

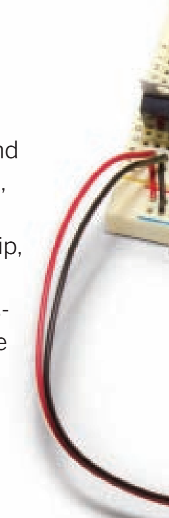
Because the motor will burn out if it tries to turn the lever to block the deadbolt when the deadbolt has already been retracted, I needed one more fail-safe switch. This is S8, which shuts off the power when the opening deadbolt rubs against it.

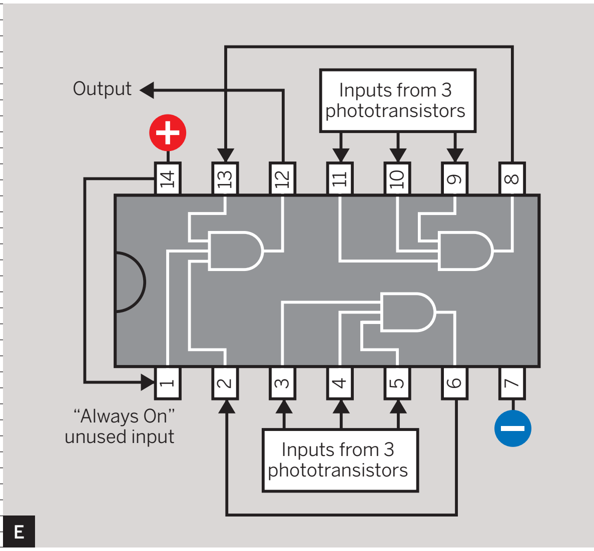
More Details

If you use a really small gearmotor rated for 9 or 12V DC, the whole lock can be powered by a 9V battery. An LM7805 voltage regulator (not shown) will reduce its output to the 5V required by the phototransistors and the chip. The LM7805 datasheet, online, will show you how it should be used in conjunction with a couple of bypass capacitors.

Because the motor is reversed by changing the polarity of the power, I couldn't add a protection diode to divert the surge that the motor takes when it starts or stops. If you find that the power spike disturbs your logic chip, try putting a 0.1 microfarad (μF) capacitor between the positive power supply to the chip, on pin 14, and the negative supply on pin 7.

The resistors in series with the phototransistors are all 5.6K. To simplify wiring and save space, I used a pair of resistor arrays. Check the datasheet online for the resistor array to





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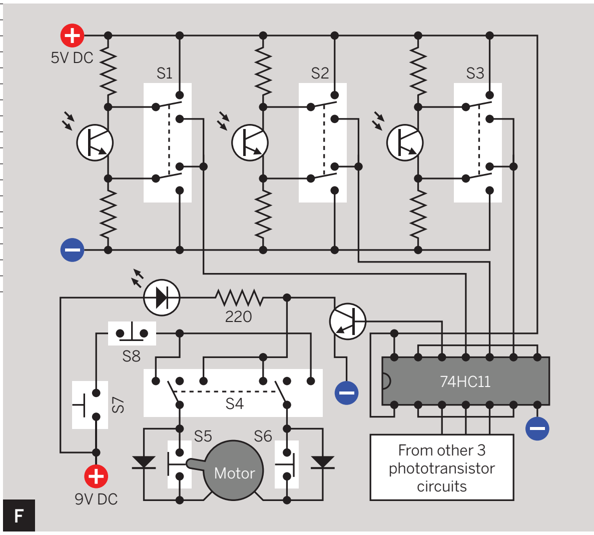

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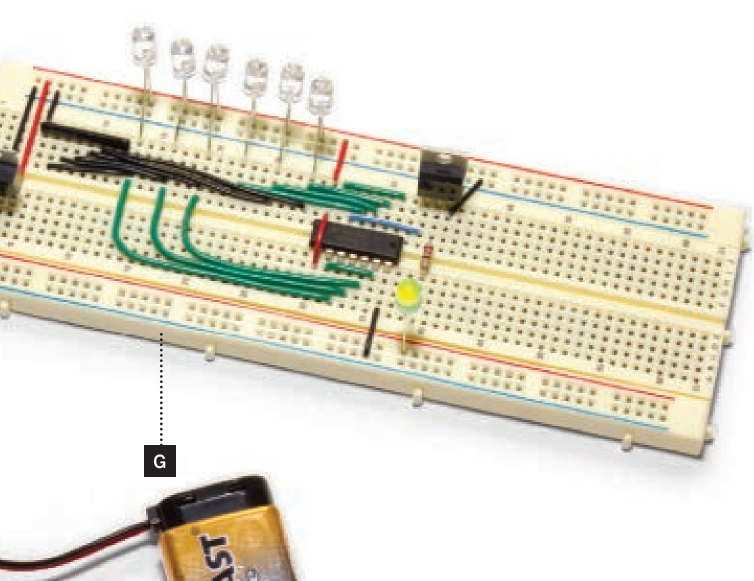

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Gunther Kirsch (G)

Fig. E: The internal arrangement of three 3-input AND gates in a 74HC11 chip, and how they can be chained to AND 6 inputs.

Fig. F: The complete schematic. Three of the phototransistors have been omitted to save space, but are wired just like the other three.

Fig. G: Breadboard proof-of-concept. Six phototransitors wired "light-high" are correctly ANDed, illuminating the LED.

see how the resistors are wired inside.

You may want to add an LED indicator outside the lock, tied to the output from the Darlington transistor, to let you know that the key has been accepted and the position of the deadbolt can now be changed.

Last but not least, you'll need a light source to activate the phototransistors. Many phototransistors are only sensitive to infrared, but the type I chose will respond to a very broad spectrum, so you should be able to use 3 bright white LEDs to shine down upon the key card. Wire them in series, and you can power them with 9V DC and no additional load resistor.

As for interfacing the motor with the deadbolt, this mechanical issue is outside the scope of this column, but the setup should look basically like Figure A. I leave it to you to determine the details of fabricating a card slot and mounting it in the door.

Can this lock be broken? Of course! If someone uses enough brute force, almost any door will yield. Still, the electronic lock will be considerably more secure than a traditional lock containing mechanical tumblers.

+ Get Charles' books, *Make: Electronics* and the *Encyclopedia of Electronic Components Vol. 1* from the Maker Shed: makershed.com.

An author and a contributing editor of MAKE, Charles Platt designs and builds medical equipment prototypes in Arizona.

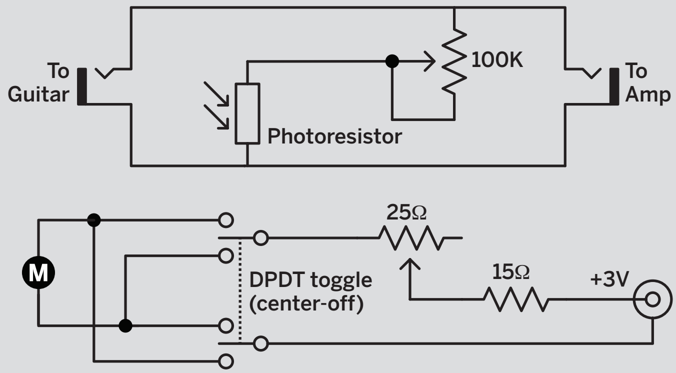
Optical Tremolo Box

Plug your guitar into light-programmable waveforms with this unique effects box.

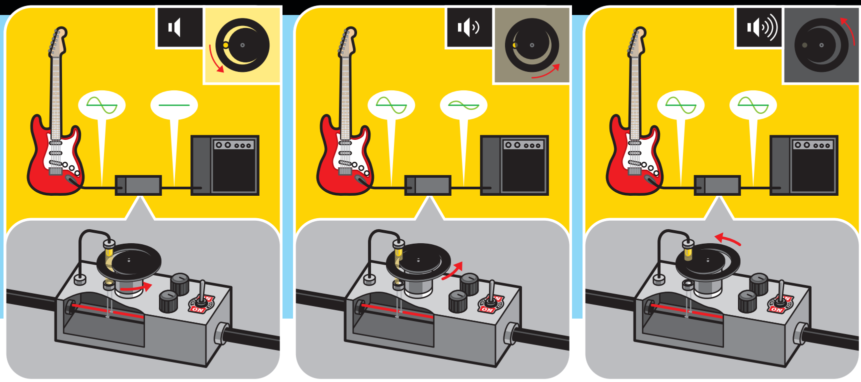
Written and photographed by ***Sean Michael Ragan***

TIME: 5 HOURS **COMPLEXITY: MODERATE**

MAKE contributing editor Charles Platt proposed a "Hypothetical Tremolo Wheel" in his article about online DIY guitar stomp-box communities (*MAKE Volume 15, page 82, "Stomp Box Basics: Tremolo and Fuzz"*). Well, it's hypothetical no more. I took Platt's cue and built this Optical Tremolo Box, which reads a patterned disk with a light sensor to create a warbling volume effect (tremolo) that you can custom-program with any pattern you like.



How It Works



How does tremolo work? So there's your electric guitar, the amplifier it's plugged into, and the cable that runs between them. Open up that cable and you'll find 2 wires – one "ground" and one held at a positive voltage relative to "ground." The changing electrical potential between the wires, over time, is what carries the sound signal.

What happens if you short-circuit those wires, bridging them with a third wire? The sound goes away. The charge can find its way home now, via the short, without ever bothering to go all the way through your amplifier. And so it does.

What if you bridge the 2 wires with a resistor instead? With a strong resistor, nothing happens – it's still easier for the charge to go through the amp. With a really weak resistor, the sound cuts out. With a resistor in the middle range, the sound will be quieted, but not completely muted, as the charge divides itself between short and signal pathways. Use a variable resistor, and you have a crude volume control: turn the resistance way up, the sound will be loud; turn it way down, and the sound will vanish.

And here's where Platt had a clever idea: use a resistor that responds to light. Wave your hand in front of the photoresistor, and the volume will respond to the shadow of your hand. Mount a spinning disk with alternating clear and opaque bands in front of it, and the volume will follow the pattern on the disk, repeating as it spins. That's tremolo – a repeating variation in volume over time.

Intrigued? Want to try building one? I thought you might. Let's get started.

Gregory Hayes; Rob Nance (illustration)

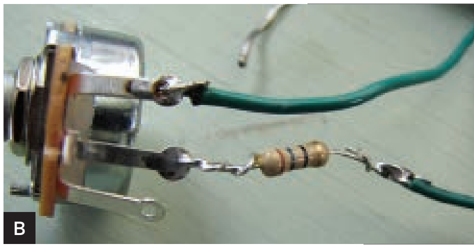
MATERIALS

- **Adhesive label, 8.5"×11", printable**
- **Project enclosure, plastic, 6"×3"×2"**
- **Rheostat, 25Ω**
- **Resistor, 15Ω**
- **Control knobs, for 1/4" shafts (2)**
- **Hookup wire**
- **Potentiometer, 10kΩ**
- **CdS photoresistors (5-pack), RadioShack #276-1657**
- **LED holder**
- **Switch, DPDT, with center off position**
- **Adhesive tape, double-sided, foam**
- **Jack, DC power, size M**
- **Jacks, 1/4", TS/mono (2)**
- **Motor, 1.5–3 V DC**
- **Plastic tubing, 3/8" long × 2mm ID × 3mm OD** I used the ink tube from a Bic Soft Feel retractable ballpoint pen, medium point.
- **Wood screws, #4 size, 1/4" length (2)**
- **Grommet, rubber, 3/8" ID × 5/8" OD × 1/2" mounting hole diameter**
- **Transparency film, printable, 8.5"×11"**
- **Terminal strip, 8-position, European-style**
- **Universal mounting hub for 3mm shafts, Pololu #1079**
- **Battery holder, 2×AA, enclosed, with leads**
- **DC power plug, coaxial, size M**
- **Heat-shrink tubing** multicolor assortment
- **Hook-and-loop fasteners, adhesive, coin shape, 5/8"** aka velcro dots
- **Power supply, wall adapter, 3V DC, with size M plug**
- **AA batteries (2)**
- **Cushion feet, jumbo, self-stick (3)**
- **Micro flex light** Coast model 7578 series

TOOLS

- **Computer and printer**
- **Drill and 1/8" drill bit**
- **File**
- **Hacksaw**
- **Lighter**
- **Multimeter**
- **Pliers, needlenose**
- **Scissors**
- **Screwdrivers: Phillips and 3/32" flat-blade**
- **Soldering iron and solder**
- **Unibit** aka step bit
- **Wire cutter/stripper**
- **Wrenches, box end: 10mm, 11mm, 12mm, 14mm**
- **X-Acto knife**

A


B

TIP A bit of rubbing alcohol can help if the templates don't come away cleanly.

1. DRILL THE ENCLOSURE

Download the drilling template from makeprojects.com/v/33 and print it onto a full-page adhesive-backed mailing label.

Cut out the 4 template sections, peel off the backing, and affix them to the front, top, and sides of the enclosure box.

Drill the holes where marked. Start each hole with a 1/8" brad-point bit, then switch to a unibit to drill the bigger holes (**Figure A**).

Peel off the templates and discard.

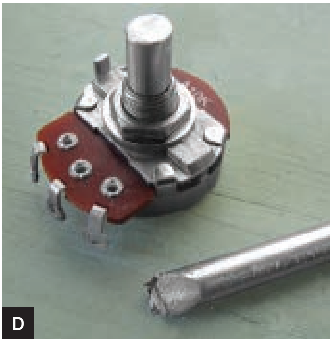
2. MOUNT THE RHEOSTAT

This knob controls the motor speed. First, bend all 3 contacts on the rheostat down 90°, parallel to the shaft. Then turn the rheostat all the way "down" (counterclockwise).

We add a 15Ω resistor, in series, to bias the range toward the slower speeds, which are more useful for tremolo effects. Solder one lead of the resistor to the rheostat center contact and the other to a 3" length of wire (**Figure B**).

Use your multimeter to check the resistance between the center wire and each of the other 2 rheostat contacts. One of them should read about 15Ω and the other about 40Ω. Solder a 4" length of wire to the 40Ω contact. Cover the resistor and all

C



D

soldered connections with heat-shrink tubing, and shrink it in place.

Remove the nut and washer from the rheostat, and insert it through the hole in the enclosure from inside. Fit the indexing tab into the alignment hole, put the washer over the shaft, and gently but firmly tighten the nut with a wrench. Fit the knob onto the shaft and secure it in place by tightening the setscrew with a small flat-blade driver (**Figure C**).

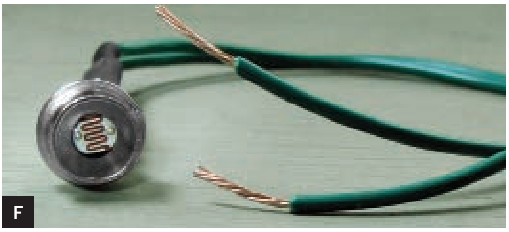
3. MOUNT THE AUDIO POT

This knob controls the intensity of the tremolo effect. First, cut the shaft to the same length as the rheostat using a hacksaw. Then turn the pot all the way "down" (counterclockwise) and file a small flat surface on the side directly opposite the indexing tab. This will ensure that the shaft always turns with the knob (**Figure D**).

Again, identify the pot's "high" contact using the resistance setting on your multimeter. Solder a 4" length of wire to this contact, and then bend and solder the other 2 contacts to a second 4" wire. As with the rheostat, the resistance across the 2 contacts should go from high to low as the knob is turned "up" (clockwise).

Mount the pot in the enclosure, with its indexing tab in the alignment hole. Secure the shaft in place with its bundled flat washer and nut, tightening gently with a wrench (**Figure E**).

E



F

4. ADD THE PHOTORESISTOR

These photoresistors come in packs of 5 with big, medium, and small sizes. We'll use one of the medium-sized resistors and an LED holder to mount it.

Remove the rubber insert from the LED holder. Guide the legs of the photoresistor through the holes in the insert until the resistor body is seated against the insert.

Cut two 4" lengths of green wire. Strip about ¾" of the insulation off each end, twist the copper strands together tightly, and tin one end. Solder the tinned ends to the photoresistor leads. Slip a piece of 2mm heat-shrink tubing over each wire so it completely covers the solder joints and exposed photoresistor leads. Shrink it in place (**Figure F**).

Push the insert back into the LED holder until the photoresistor is seated in the opening. Put the LED holder through the enclosure panel from the front, and tighten down the hex nut and split washer from behind using a wrench (**Figure G**).

5. MOUNT THE MOTOR

The hub we're using to mount the sweep disks has a 3mm arbor hole, but our motor's shaft is only 2mm across. A short section of ink tube from a ballpoint pen makes a perfect adapter. Just push the shaft of the motor into the tube and cut off the excess with a sharp hobby knife (**Figure H**).

Solder a 3" length of wire to each of the motor's contacts. Then pass the motor shaft through the hole in the enclosure from the inside, and secure the motor in place with a #4×¼" wood screw in each of the 2 mounting holes (**Figure I**).

6. MOUNT THE SWITCH

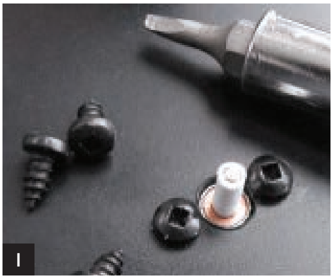
Strip about 1" of insulation from one end of each of six 4" wires. Though the colors don't really matter, it's helpful to have 3 wires in each of 2 colors. I used red and black.

Tin the stripped end of each wire and wrap it around one of the 6 screw terminals on the switch. Give the wire a twist or two, tighten down the screw, and insulate the connection with heat-shrink tubing. One row of 3 contacts on the switch should be all "red" and the other 3 all "black," as shown (**Figure J**).

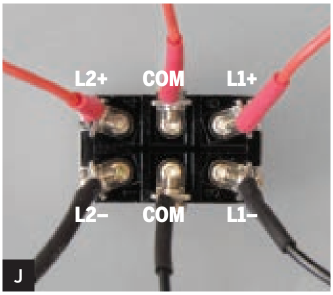
To keep the switch from rotating, apply 2 small pads of double-stick foam tape to the top — one on each side of the handle (**Figure K**). Peel the backing off the tape and insert the switch into the mounting hole from inside the enclosure. Align it, then press the tape into place. Slip the label plate over the threaded shaft and then add the panel nut. Tighten it gently with a wrench (**Figure L**).


G

H


I

CAUTION
Don't overtighten the screws, or you risk stripping out the metal in the motor casing.



J


K

L


M


N


O

TIP A small flat-blade screwdriver may help with lifting and pushing the rubber to get it in just right.


P


Q

7. ADD THE POWER & PHONO JACKS

Attach 4" leads to the DC power jack and each of the 2 phono jacks. In each case, ground (black) goes to the outer or "case" contact. Solder and insulate the connections with heat-shrink tubing (**Figure M**).

Insert the DC power jack through the mounting hole in the top panel, from outside the enclosure, and secure it inside with the bundled washer and panel nut. Tighten gently with a 14mm wrench.

Insert one of the phono jacks through one of the mounting holes in the side panel, from inside the enclosure, and secure outside with the bundled washer and panel nut. Repeat for the other jack. Tighten gently with a wrench (**Figure N**).

8. INSTALL THE MICRO FLEX LIGHT

Remove the D-ring from the end of the micro flex light by using a pair of needlenose pliers "in reverse": close the jaws, insert the nose into the ring, and then gently pull the handles apart to pry the ring open. Then slide the lapel clip fitting off the end of the lamp body (**Figure O**). Discard the ring and clip or save them for another project.

Fit the rubber grommet into the center-top hole in the front panel. It's easy; just squish it in until the lip of the hole is cleanly engaged with the groove in the grommet (**Figure P**).

Insert the bottom of the flex light into the grommet from above and push it into the enclosure (**Figure Q**). This will take a bit of force, but not much, and will hold the light securely in place. You can adjust its position as needed, or remove it completely to replace the batteries.

9. WIRING AND ASSEMBLY

Wire up the circuits using an 8-position terminal strip, as shown, cutting the leads to length and stripping the ends as you go (**Figure R**). These "European-style" terminal strips are nice because all you have to do to make a connection is insert the stripped wire end and tighten the screw. For ease of access and assembly, the terminal strip is not mounted to the enclosure, and just hangs freely. By the time all 16 connections are made, it's quite secure and won't wobble around.

Put the plastic bottom of the enclosure in place and secure it with the 4 bundled screws. Then attach adhesive feet (**Figure S**).

10. POWER IT UP

To run the motor, 3V DC is supplied through the power jack, which takes a size M plug. You can use a 3V wall wart to run the unit from mains power.

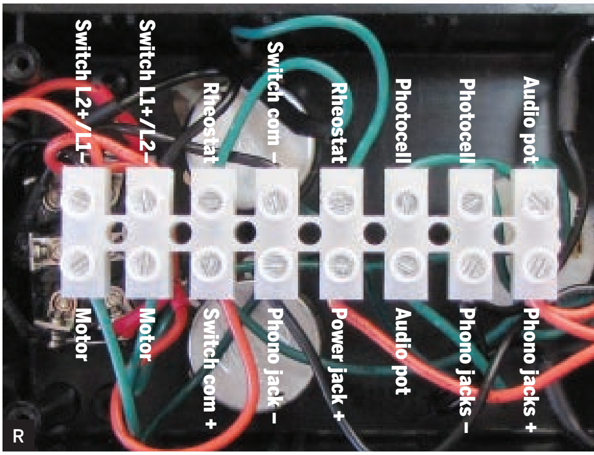
You can also build a simple battery pack with a ready-made 2×AA battery holder, a size M coaxial plug, and a bit of heat-shrink tubing. Attach it to the outside of the enclosure with velcro (**Figure T**).

11. MAKE THE SWEEP DISKS

Download the sweep disk art from makeprojects.com/v/33 and print it onto an 8.5"×11" transparency. If you want to design your own disk art, an SVG version of this file is available.

Cut out each disk using sharp scissors. Then apply a ⅝"-diameter velcro dot to the center of each disk. Use the softer, "loop" velcro on the sweep disks.

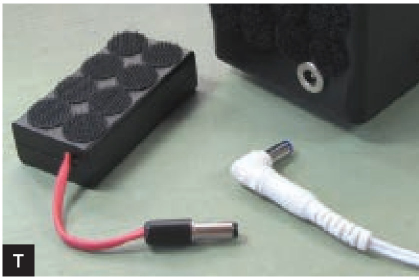
Apply a matching "hook" dot to the top of the aluminum mounting hub (**Figure U**).



R


S

TIP Three feet are less likely to wobble on an uneven surface than 4.


T


U

TIP If you're using a laser printer, you may notice that the printed transparency acquires a slight curl from the heat. To flatten it, simply flip the printed film over and "print" a blank page on the opposite side.

V

Slip the hub over the motor shaft. Make sure the hub is high enough to clear the motor screws when it rotates. Tighten the setscrew, using the Allen wrench that came with the hub, to secure it to the shaft (**Figure V**).

12. ROCK YOUR OPTICAL TREMOLO BOX

Pick your favorite sweep disk and attach it to the hub by joining the velcro dots.

Plug your sound source into one of the 2 phono jacks, and your amplifier into the other. The tremolo circuit is symmetrical, so it doesn't matter which jacks you use.

Plug in the power supply. Turn on the flex light, then flip the switch in either direction. Which direction the disk turns may vary the effect depending on the disk pattern.

The knob on the right, above the switch, controls the motor rotation speed. At low positions, the motor may have a hard time getting started. Try turning the speed up a bit and then adjusting it back down to get the lower speeds.

The knob on the left controls the intensity of the tremolo effect. Turn it clockwise for more tremolo, counterclockwise for less. The brightness of the light on the photoresistor also affects the tremolo intensity, and though the high-intensity LED in the flex light provides plenty, you should experiment with other light sources. Especially the sun!

Sean Michael Ragan is technical editor of MAKE magazine. His work has appeared in ReadyMade, c't – Magazin für Computertechnik, and The Wall Street Journal.

Gunther Kirsch (top; oppostie, Fig. V)

Going Further

To take your Optical Tremolo Box to the next level, consider these improvements to the basic design:

1. Upgrade to a pulse-width-modulation (PWM) motor controller. A series rheostat is a simple, cheap speed control, but it's inefficient, and does not perform as well at low speeds. Here's a good PWM circuit based on a 555 timer chip: dprg.org/tutorials/2005-11a/

2. If you use a PWM controller, switch to 9V power (standard for FX pedals) and upgrade the motor. Most 9V motors (e.g. RadioShack #273-256) are higher quality than 3V motors, and often have fully threaded mounting holes.

3. Add a DPDT "stomp switch" (e.g. SparkFun #COM-11151) so you can turn the effect on and off with your foot.

4. Modify the box to operate using reflected light, instead of transmitted light, so the sweep disks can be printed on plain white paper.

We look forward to seeing what mods you come up with.

Digital Pinhole Photography

Explore your world through a pinhole.

By ***Forrest M. Mims III***

A sophisticated pinhole camera can be quickly made from a digital camera with a removable lens, a camera body cap, a beverage can (or aluminum foil), a straight pin, and some tape.

TIME: A FEW MINUTES **COMPLEXITY: EASY**

Long before the digital photography era, I enjoyed making photographs with a 35mm film camera equipped with a pinhole instead of a lens. The editors of *Popular Photography* magazine liked the results and published my article "The Pinhole: A 'Lens' that Just Won't Quit."

Much has happened since that article was published back in April 1974. A renaissance of sorts has occurred in pinhole photography, and Justin Quinnell is among its leaders. His website pinholephotography.org is loaded with hints, tips, and unique pinhole images. (See makezine.com/go/quinnell for an inspirational video about Justin's work).

Suitable Cameras

Any camera with a removable lens has potential for pinhole photography. Conventional film cameras can be used, but digital cameras with removable lenses are ideal. The exposure time can be easily changed, and results are available instantly. A new entry-level digital SLR costs $500 or more, but you might find a used one for considerably less.

Fig. A: Three images of the sun and an arrow on a computer screen, photographed through 3 pinholes mounted on a Canon 40D digital camera. The largest pinhole (the width of a 0.6mm-wide pin) produced the brightest but fuzziest images (at right). The smallest pinhole (0.3mm) produced the dimmest but sharpest images. Note: all images except Figure C were enhanced using Microsoft Digital Image Pro software.

Fig. B: Handheld beverage-can pinhole image of barbed wire illuminated by flash and the morning sun (1/60 sec., ISO 320).

Fig. C: *Sun Spray*, a handheld image enhanced only by the crown burr formed in the aluminum foil pinhole (1/8 sec., ISO 100).

Gregory Hayes; Forrest M. Mims III (pinhole shots)

Characteristics of Pinhole Images

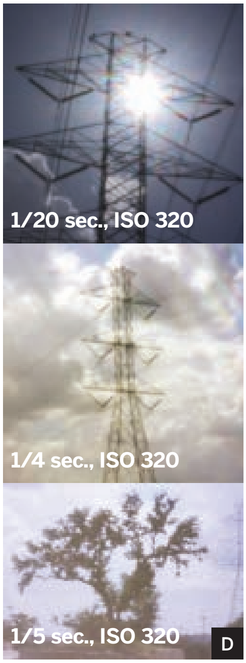
Pinhole images are fuzzier than those made through a lens, but that can be an asset. If the fuzz is excessive, you can sharpen your images by using a smaller pinhole or photo processing software. **Figure A** shows the sharpening that resulted from reducing the pinhole size from 0.6mm to 0.3mm.

Another characteristic of pinhole cameras is nearly infinite depth of field. Make a pinhole photo of a very close object with a distant building or mountain in the background — it's all in focus. You can even use the sun for the distant object (**Figure B**), but it will be fuzzy unless the exposure is brief.

Pinholes punched through foil or thin metal leave behind a projection of torn metal on the exit side known as a crown burr (see makezine.com/go/astakhov). Pinhole photographers often remove the burr with sandpaper. When left in place, the burr can cause uniquely beautiful effects, especially when making pinhole photos of the sun, as shown in **Figure C**.

Pinhole Exposure Times

Pinholes admit much less light than a conventional camera lens, so exposures must be longer. This usually means the camera must be mounted on a tripod or placed on a stable surface. But thanks to the high sensitivity of digital cameras, handheld photos are often possible when the scene is brightly illuminated. I've made handheld pinhole photos at speeds from 1/30 second (bright sunlight) to 1/8,000 second (the sun itself).



D

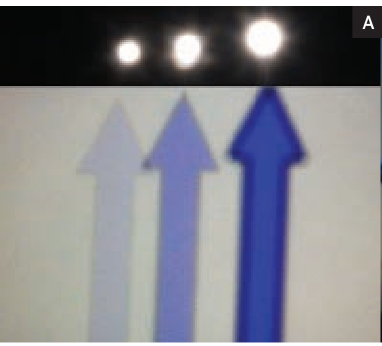
Pinhole Tips & Samples

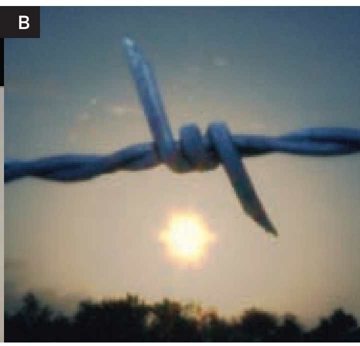
The best advice for the new pinhole photographer is one word: experiment. Try various pinhole sizes, mounting methods, and distances from your camera's sensor. Be careful to keep dust off your camera's sensor when removing the lens to install your pinhole.

As for subjects, the world is your limit. Unlike a camera with a lens, it's easy to include the sun in pinhole photos. Just remember never to look directly at the sun through a pinhole camera.

On the following pages you will see pinhole images of the sun during the annular solar eclipse of May 20, 2012. Both images were made simply by removing the camera lens and holding a sheet of aluminum foil with a few dozen pinholes over the lens opening.

Figure D shows three dramatically different views of a high-voltage power transmission tower, all made without a tripod.


A


B


C

How to Make a Foil Pinhole

The pinhole images I published in *Popular Photography* and my recent eclipse images (shown here) were all made by pushing an ordinary 0.6mm-diameter pin entirely or partially through aluminum foil. Here's how:

1. Use scissors to cut a square of aluminum foil large enough to cover the lens opening of your camera. Heavy-duty foil is best, but standard foil is OK.

2. Place the foil on a desk protector, place mat, or other flat substrate that has a slightly resilient surface. Smooth the foil by rubbing it with the tip of your finger.

3. Carefully press the pin into but not completely through the foil. For initial experiments, the diameter of the hole should be about half the diameter of the pin.

4. Remove the lens from your camera and place the foil over the lens opening with the pinhole roughly centered. The topside of the foil should face away from the camera. Use masking tape to secure the foil in place. Be sure no stray light can enter the camera; it will wash out your images.

Gunther Kirsch (step shots)

How to Make a Better Pinhole

For optically cleaner images, a pinhole formed in thin sheet metal is best. This method is easiest to implement by mounting the metal onto a camera body cap that is placed over the lens opening when the lens is removed. Aluminum or copper sheet metal from a hobby store will work, but the simplest and cheapest source is an aluminum beverage can, pie tin, or food tray.

Pinhole photographers use various methods to form pinholes in sheet metal (search Google for details). I prefer the "brute force" approach, as detailed here at right.

Experiment!

Explore the tutorials at pinholephotography.org and other pinhole photography websites. After you learn the basics, mount your pinhole camera on a rigid tripod and try making portraits of perfectly still friends and relatives. Make a time exposure of the movement of the stars across the night sky. Or mount a pinhole on a light-tight extension tube to make a telephoto pinhole. Once you start making pinhole images, you'll soon think of many other ideas.

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.

1. Rinse out an empty beverage can with water. Carefully cut the top and bottom off, cut lengthwise, and flatten to create one metal sheet.

2. Use old scissors to cut several 1" squares from the flattened can.

3. Place a metal square on a flat wood surface.

   Put the point of a straight pin at the center of the square and hold it in place with pliers.

   Lightly strike the head of the pin with a small hammer so that the pin just pierces the metal to form a circular hole about half the diameter of the pin.

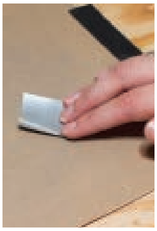
4. Place a sheet of 220-grit sandpaper on a flat surface, business side up. Rub the backside of the metal square against the sandpaper to remove the crown burr, using circular strokes.

5. Look through the pinhole to check its uniformity. About two-thirds of my pinholes made in this fashion appear perfectly circular, which is what you want.

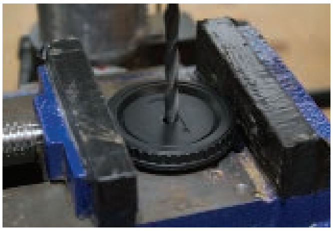
6. Bore a ¼" hole in the center of the camera's body cap.

7. Place a metal square with a pinhole over or behind the body cap so the pinhole is centered in the ¼" aperture.

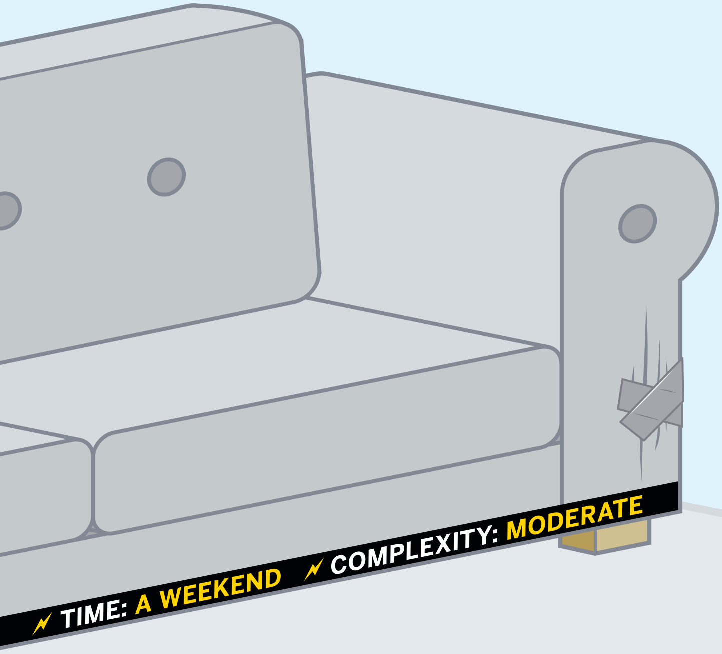
   Secure it tightly with removable masking tape so you can try other pinholes later. When you find the best one, secure it with adhesive.



Make pinholes in several metal squares so you can experiment with them.



A magnifier such as a 10x loupe is very helpful.



Cat Scratch Feeder

Build a snack-dispensing scratching post that will make Kitty forget the couch and curtains.

Written and photographed by ***Phil Bowie and Larry Cotton***

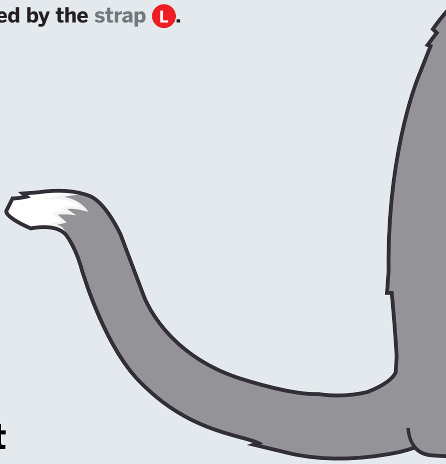
Has your cat left scratch marks on everything from grandmother's kneecaps to your grandfather clock? It's time to train Kitty to use this scratching post instead of everything else in your home.

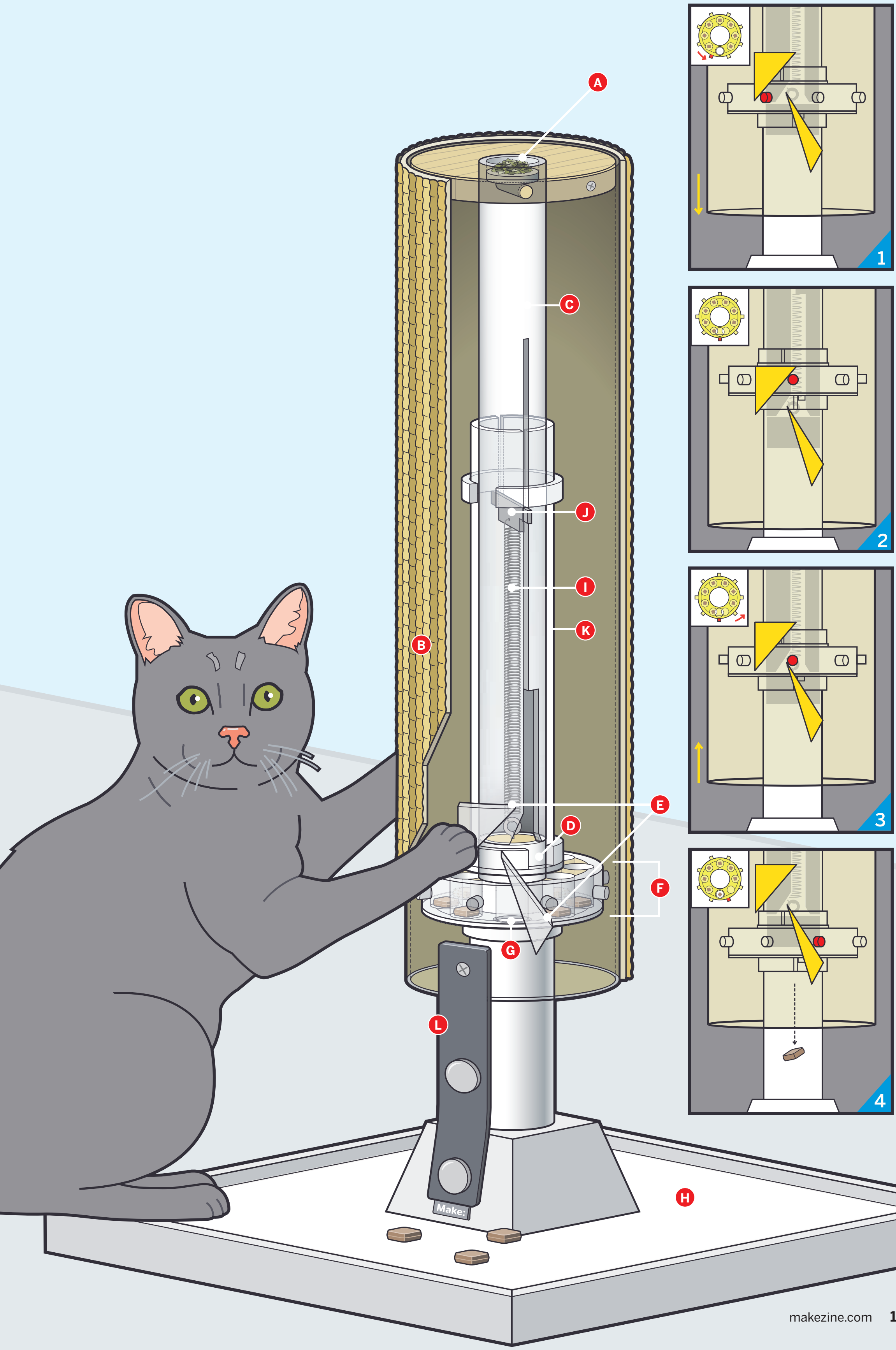
A catnip cup in the top will attract your cat and place her in natural scratching position. Each time the cat claws downward on the spring-loaded carpeted cylinder, this device will deliver up to 4 special treats. Because you control the number of treats, you can keep your cat lean and gradually wean her off the treats altogether as she becomes accustomed to using the post, if you wish.

A catnip cup (A) attracts the cat to pull down on a carpeted scratch cylinder (B) causing the inner tube (C) to press down on a plunger (D) and also causing the wedges (E) to engage rotation pegs.

Pegs rotate a treat turntable (F) which releases treats through a hole in the treat disk (G) whence they fall onto a base tray (H) to reward the cat.

A spring (I) attached to a retainer (J) in the support tube (K) pulls the plunger back up, raising the scratch cylinder to the starting position. The spring rebound is limited by the strap (L).





Timmy Kucynda

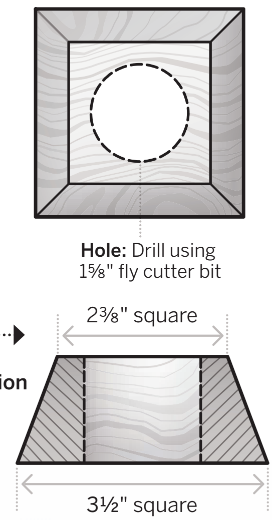
Materials & Tools

- **Softwood shelving board, ¾"×11½"×18"**
- **Softwood strip, ¼"×1"×50"**
- **Softwood or plywood, ½"×4"×6"** for top disk
- **Screw eye, small**
- **HDPE (high-density polyethylene) sheet, 2mm** We found 90mm disks on eBay that were perfect. You could also use furniture sliders or similar plastic material.
- **Fabric snaps, ⅝" OD (2)** such as Dritz, available as a kit
- **Various screws and brads**
- **Table saw** You can do this project with hand tools, but power tools will be more accurate and save time.
- **Band saw**
- **Center punch**
- **Drill press**
- **Handheld drill**
- **Drill bits** including spade bits and an adjustable (fly cutter) bit
- **Power sander and sandpaper**
- **Hammer, small**
- **Pliers: needlenose and side cutting**
- **Metal-cutting shears**
- **Screwdrivers**
- **Files**
- **Square, small**
- **Hot glue gun**
- **Glues: wood glue, hot glue, cyanoacrylate glue (aka super glue), and spray adhesive**
- **Scrap wood** for V-block and other drilling/sawing jigs

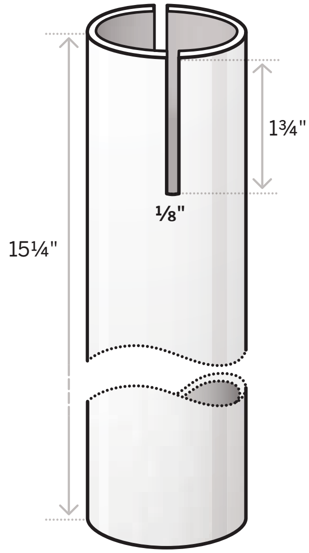
Gunther Kirsch

1a Base & edging

1b Support tube holder

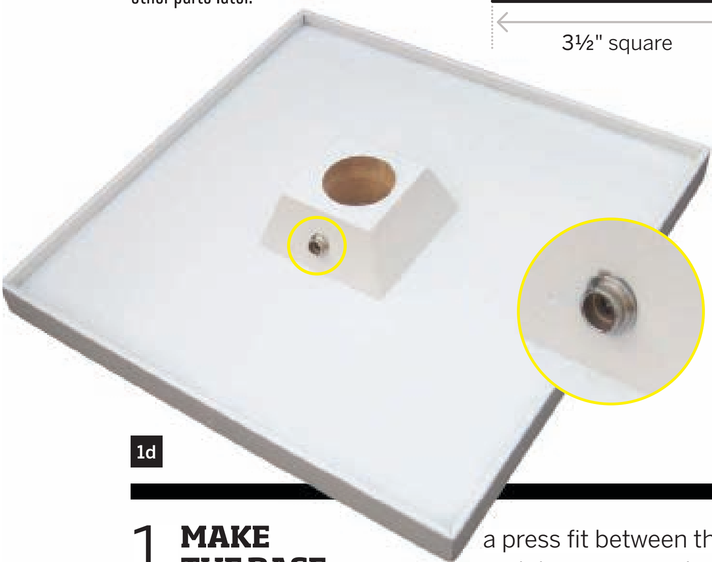


2a Support tube



PVC tubing 1⅝" OD, 9⁄64" wall

NOTE Keep your adjustable bit set at 1⅝" diameter for drilling other parts later.



1d

1. MAKE THE BASE

1a. Cut the base square, mitering ¼" wood strips so they form a lip all around to help retain the dispensed treats. Fasten with brads and a bit of wood glue.

1b. Follow the support tube holder diagram to build the holder. For safety, drill the hole with a fly cutter before cutting the wood to size. The hole is nominally 1⅝", but drill it slightly undersize to ensure a press fit between the holder and the support tube.

Chamfer the holder's edges on a table saw or band saw.

1c. Fasten the support tube holder to the center of the base with wood screws.

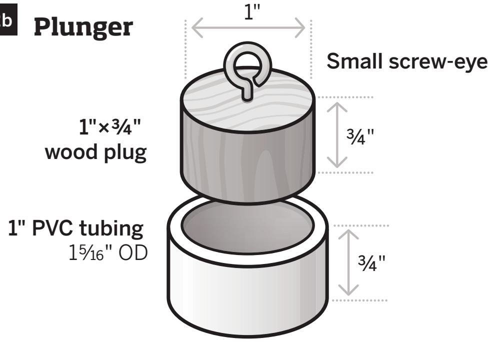
1d. Insert a stub of 1¼" PVC pipe (1⅝"-OD) into the hole as a mask, then sand, prime, and paint the base a light color so the cat treats will show up on it.

Attach a male fabric snap to the center of any face of the holder with a wood screw.

2. MAKE THE SUPPORT TUBE COMPONENTS

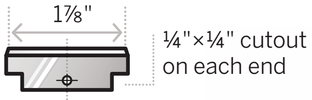
2a. Cut the support tube from 1¼" PVC pipe, using a table saw, following the diagram. To cut the slot in the center of one end, hold the pipe vertically and use wooden pushers at the bottom and side as shown (ask a friend to help).

2b Plunger



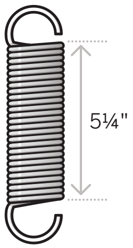
2c Top spring retainer

Make from ½"-wide aluminum.



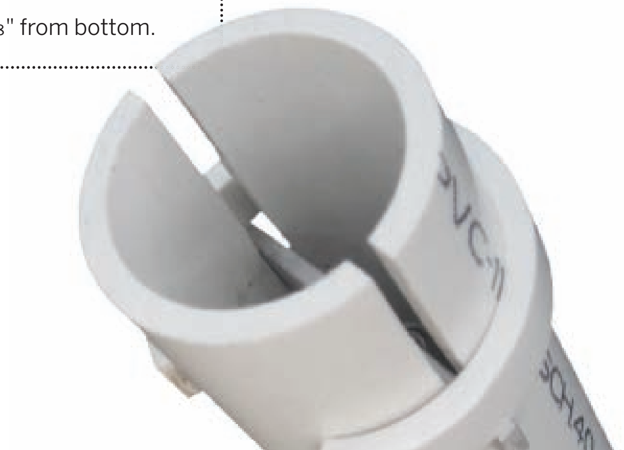
Drill ¹⁄₁₆" hole on centerline, ⅛" from bottom.

2d Spring



2e Split ring

Make 3 from 1¼" PVC.



2b. Make the plunger from 1" PVC pipe, following the plunger diagram. Cut the 1"-diameter wood disk on a band saw, sand it to fit tightly in the ring, and glue it in place. Sand the top and bottom of the plunger flat and square, then insert a small screw eye in the center of one face.

2c. Make the top spring retainer from the aluminum bar, following the diagram, using a band saw. For safety, drill the hole and notch the corners before cutting the part to final size.

2d. Cut the extension spring down to 5¼" over the closed coils, per the spring diagram. Use needlenose pliers to bend out new hook coils on the ends, then cut them with side-cutting pliers. Insert the hook coils into the top spring retainer and the plunger screw eye. Then insert that assembly into the support tube per the assembly diagram in step 4 on page 114.

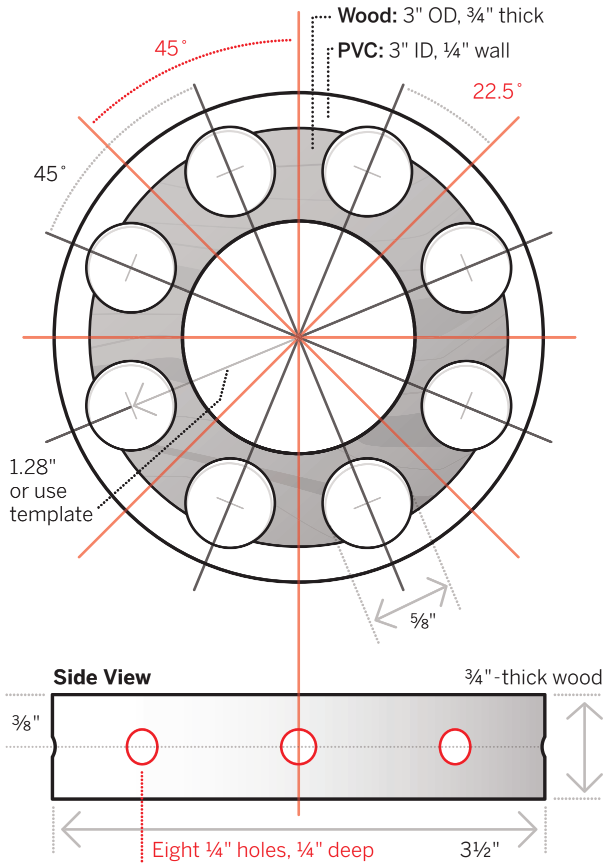
2e. Make 3 split rings from 1¼" PVC pipe per the split ring diagram.

Note that one has a notch in its outside surface near the split, which can be rough-cut with a band saw, and the inside corners filed square.

Put the top spring retainer in place. Then, expand one of the rings without the notch (it's not easy) and push it over the top end of the support tube to hold the top spring retainer in place.

Turntable & rotation pegs (shown at ¾ scale)

Use the full-sized turntable template provided at makeprojects.com/v/33. Peg specs are in red.



3a The turntable is just ¾" deep, but start with at least a 12" length of pipe for safe cutting on a power saw.

IMPORTANT Center-punch all hole locations before drilling.

3b

3c

3d

3. MAKE THE TREAT TURNTABLE

3a. Follow the diagram to make the turntable and rotation pegs. When cutting the ¾" wood and 3" PVC pipe, ensure that the cuts are straight, parallel, and square to the sides. The wood disk should fit tightly into the PVC ring. Glue it in place and sand both faces smooth.

3b. The positioning of the rotation pegs and the locations of the treat holes are critical. The red lines indicate peg locations; extend them onto the sides of the PVC pipe. Draw a line around the outside, centered between the 2 faces.

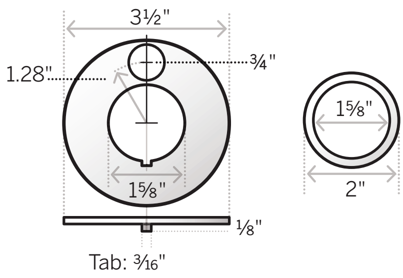
3c. Drill the center hole with a fly cutter bit. This hole should initially fit snugly over the support tube. Drill the 8 treat holes using a spade bit.

Make a drill press jig for the peg holes. Using a length of the 1¼" pipe (1⅝" OD) resting in a wood V-block, with the bit set to stop at a depth of ¼", drill the 8 peg holes.

3d. Cut eight ½" rotation pegs from ¼" acrylic dowel, ensuring the ends are square and smooth. Tap them lightly into the peg holes with a hammer and glue them in place. The ends of the pegs should just clear the ID of the 4" PVC drain pipe.

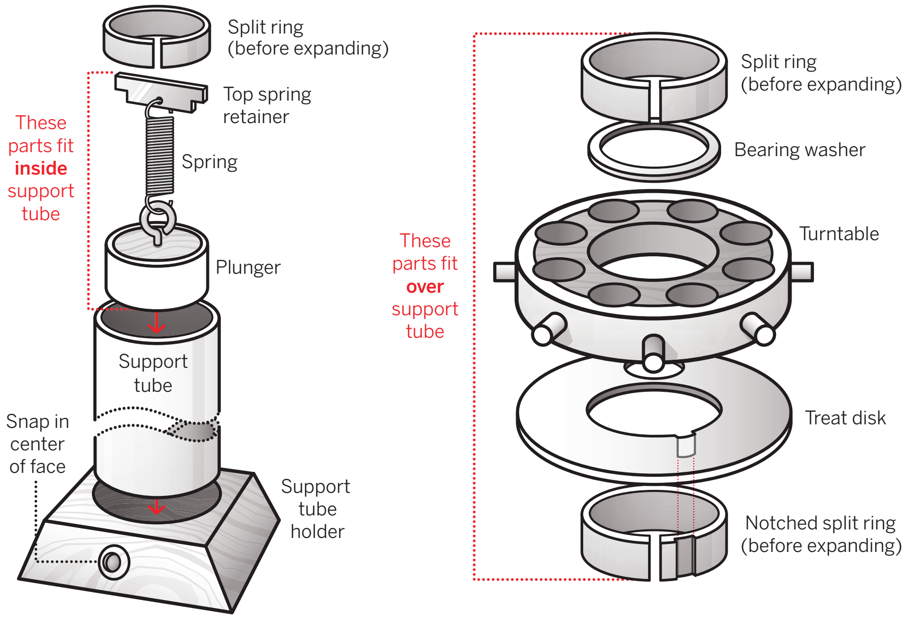
You can radius the ends slightly on a sander to help achieve a close fit.

3f **Treat disk & bearing washer**



4a

4



3e. After the turntable is completed, sand the large center hole so it rotates freely on the support tube.

3f. Cut the treat disk and bearing washer from 2mm HPDE plastic, following the diagram. (If you bought 90mm disks, they're almost exactly the size of the treat disk.) Lay out the 2 parts on the plastic and drill both large holes with the fly cutter bit. Use a ¾" spade bit for the smaller hole in the treat disk. Then cut out all the parts with shears.

Use side-cutting pliers to snip the tab on the inside diameter of the treat disk, and carefully bend it down 90°.

4. ASSEMBLE THE SUPPORT TUBE.

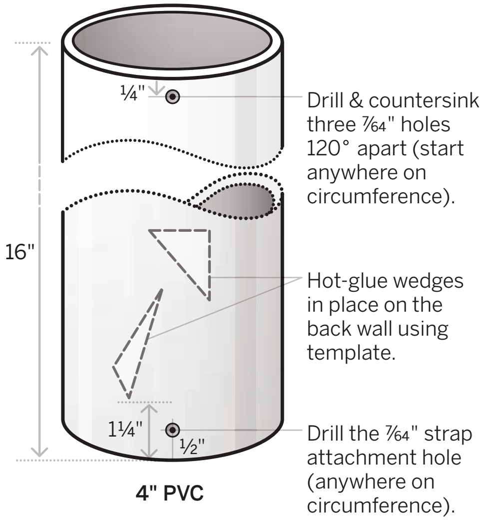
Following the assembly diagram, spread and slip the second notchless split ring onto the support tube from the bottom. Follow with the bearing washer, the turntable, and the treat disk.

4a. Press the notched split ring on last, so that the bent-down tab on the treat disk will be trapped by the notch to keep it from turning.

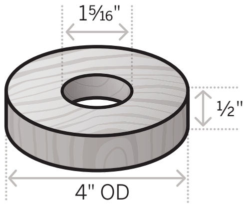
Position the bottom surface of the treat disk 5½" from the bottom of the support tube.

4b. Press the support tube assembly into its holder on the base without fastening it. Don't fasten the split rings either, to allow for adjustment.

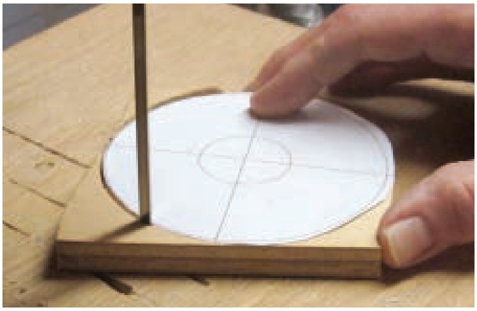
5a **Scratch cylinder**

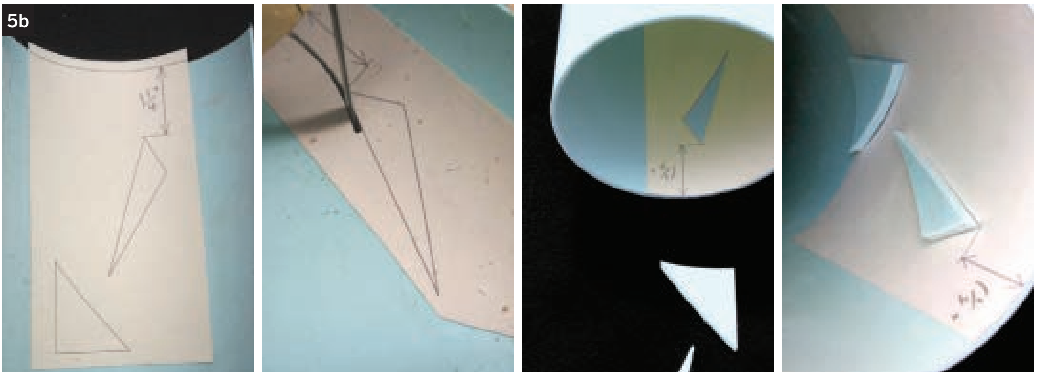


5c **Top disk**



Make from ½"-thick wood.





5. MAKE THE SCRATCH CYLINDER PARTS

5a. Cut the scratch cylinder, following the diagram.

5b. Cut the 2 sets of wedges using the full-sized template at makeprojects.com/v/33. These will rotate the turntable one-half position on the downward stroke of the scratch cylinder, and then one-half position on the upstroke, releasing the treat.

Split lengthwise an 8" piece of 4" PVC pipe. Temporarily spray-glue the template to the inside of one of the pieces, and cut 2 sets of wedges with a band saw. Super-glue the duplicate wedges together, doubling their thickness.

On another copy of the template, cut out the wedge holes. Temporarily spray-glue this template to the inside wall of the scratch cylinder 1¼" from the bottom end, anywhere on the circumference. Hot-glue the wedges in place, using the negative template to position them accurately.

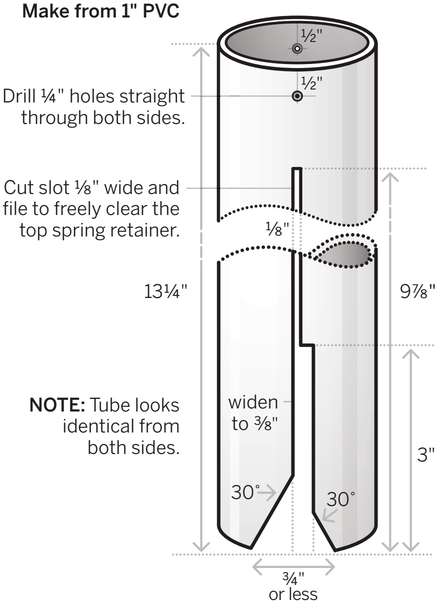
5c. Using a band saw, make the top disk and sand it to fit tightly into the top end of the scratch cylinder. Use the fly cutter bit (reset to just under 1 5/16") to drill its center hole.

Fasten the top disk to the cylinder using 3 small flat-head wood screws.

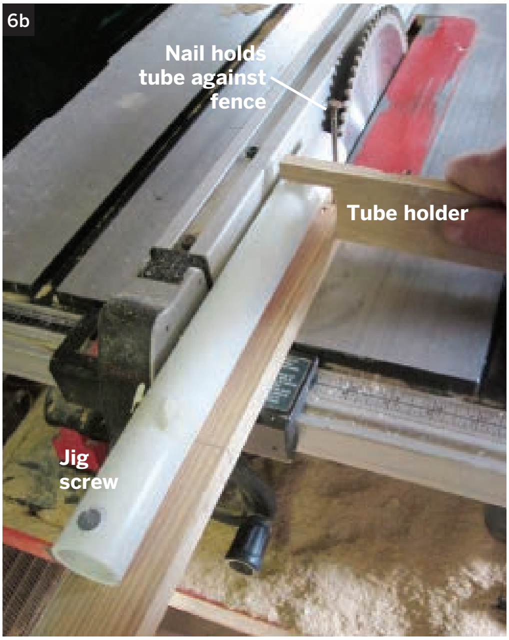
5d. Wrap the scratch cylinder with Berber carpet hot-glued in place.

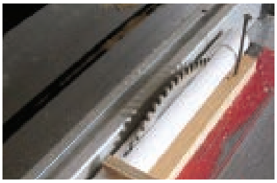
6a **Inner tube**

Make from 1" PVC



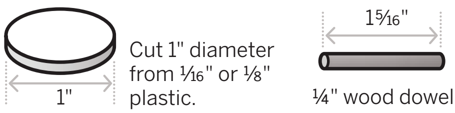
6b





6c

7a **Catnip disk, and disk pin**



6. MAKE THE INNER TUBE

6a. Following the diagram, drill the ¼" holes in the 1" PVC pipe (1 5⁄16" OD). Then make a wood jig and screw the pipe to it through the holes.

6b. On a table saw, cut the top slot ⅛" wide. Allow for the radius of the blade and the thickness of the jig itself to determine where to stop cutting. Finish extending the top slot on a band saw to its full 9⅞" length.

6c. On both sides of the tube, widen 3" of the slot to ⅜" with a band saw as shown. Use a wood wedge to hold the slot apart for easier blade access. File the slot if necessary to make sure it clears the top spring retainer during the plunge stroke.

7. ASSEMBLE THE SCRATCH CYLINDER

7a. Follow the diagram above to make the catnip disk and disk pin.

7b. Insert the catnip disk pin through the end of the inner tube, and glue the catnip disk into place using the pin as a stop and gluing surface.

7c. Press and glue the inner tube into the cylinder top disk. It must be centered within the scratch cylinder.

8. TEST AND TROUBLESHOOT

Load the turntable with treats, and drop the scratch cylinder assembly over the support tube assembly. The inner tube must slide easily into the support tube.

Pull down on the scratch cylinder to cycle your Scratch-a-Treat, testing for smooth operation and ensuring that treats are dispensed.

If you feel friction, there could be several sources:

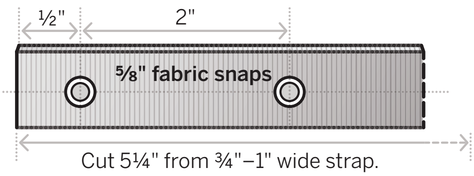
» Between the slot in the inner tube and the top spring retainer. Try removing the scratch cylinder, turning it 180°, and replacing it. Or widen the slot slightly, especially at the top.

» Between the inner tube and support tube. Remember that the inner tube must be centered in the scratch cylinder.

» Between the turntable and support tube. Sand the center turntable hole as necessary.

» Between the rotation pegs and the wedges inside the scratch cylinder. Smooth these parts as necessary to reduce friction.

If treats aren't dispensed, adjust the height of the turntable on the support tube and/or turn the treat disk (and its split ring) so it releases all the treats reliably.



9 **Strap**

9. FINAL ASSEMBLY

Remove the scratch cylinder and fasten the 2 lower split rings to the support tube with short screws. These must not protrude inside the support tube.

Make the fabric strap per the strap diagram and screw it to the inside bottom wall of the scratch cylinder. Turn the support tube in its holder to align the snaps.

TEST BUILDER: Isabella Ghirann, MAKE Labs

Tame That Kitty

When you first set up your Scratch-a-Treat, use the strap's end snap to limit the spring's bounce when Kitty releases the scratch cylinder. Use the shorter snap position to disable the plunge action altogether when Kitty becomes accustomed to using Scratch-a-Treat as a proper scratching post.

You don't need to remove the scratch cylinder to load treats. Simply unsnap the strap, lift the scratch cylinder about 4", rotate it clockwise, and let go. Load the treats into the turntable, then reverse the process to drop the scratch cylinder back into scratching position.

A variety of treats can be used. We favor the crunchy, catnip-flavored Temptations brand.

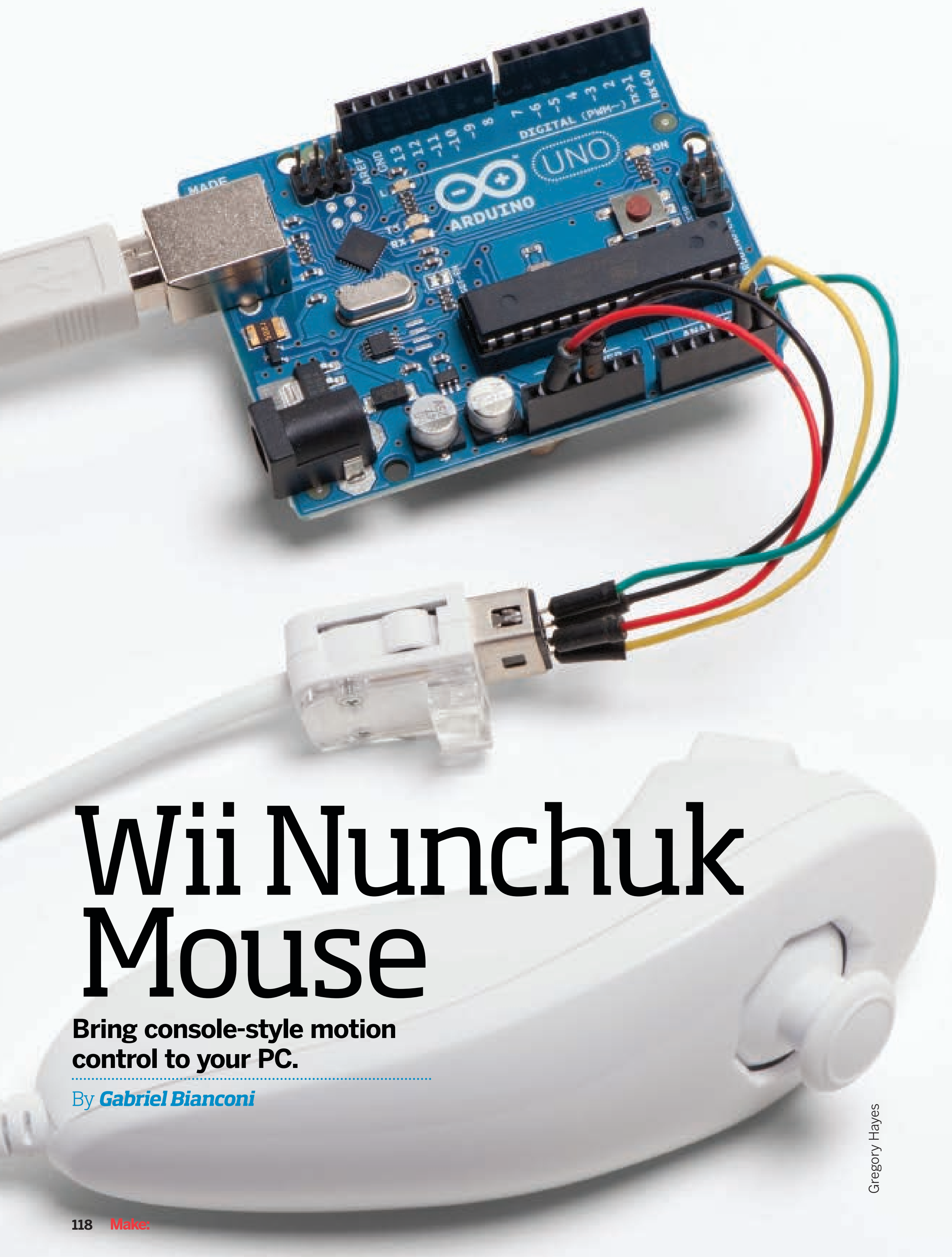
Rubbing a bit of catnip onto the carpet will help attract your cat initially and encourage scratching.

As with all pet training, praise Kitty generously when she uses the Scratch-a-Treat, and administer a stern scolding when she does not.

Grandma's knees will be happy.

Larry Cotton is a semi-retired power-tool designer and part-time community college math instructor. He loves music and musical instruments, computers, birds, electronics, furniture design, and his wife — not necessarily in that order.

Phil Bowie is a lifelong freelance magazine writer with three suspense novels in print. He's on the web at philbowie.com.



Gregory Hayes

Wii Nunchuk Mouse

Bring console-style motion control to your PC.

By ***Gabriel Bianconi***

TIME: 1 HOUR COMPLEXITY: EASY

Today, more and more devices are using motion control. From tablets to cellphones to game consoles, people are getting used to interacting with electronics using gestures. Personal computers, however, have lagged behind a bit. Unable to find a suitable gestural controller for my Windows PC on the consumer market, I set out to build my own.

I based my design on the Wii Nunchuk controller for several reasons. First, it's a versatile, comfortable, well-designed controller; second, it's cheap and easy to find; and third, its native I2C serial protocol is easy to interface with Arduino. As a bonus, the connector will accept standard jumper wires, so there's no need to cut up the cable or use a dedicated adapter.

The Arduino runs a sketch that reads data from the controller and prints to the computer's serial port. The computer runs a Python script, which receives serial data and emulates a mouse.

MATERIALS

- **Nintendo Wii Nunchuk con-troller** $17; third-party controllers may not work.
- **Arduino Uno microcontroller** item #MKSP11 from Maker Shed (makershed.com), $35
- **140mm male/male jumper wires (4)** item #MKSEEED3 from Maker Shed, $9/65

TOOLS

- **Windows PC** Mac/Linux users will have to adapt the Python script.

1. Install the software.

1a. Download the Arduino IDE for Windows at arduino.cc/en/Main/Software. Extract the *arduino-1.0* folder to your hard drive. Inside this folder you'll find *arduino.exe*.

1b. Download the *ArduinoNunchuk* library at github.com/GabrielBianconi/ArduinoNunchuk. Extract the *ArduinoNunchuk* folder to your hard drive. Open the Arduino IDE and select File → Preferences. Note the folder under *Sketchbook* folder and open it in Windows Explorer. Look for a folder named *libraries*. If there isn't one, you should create it. Move the *ArduinoNunchuk* folder into *libraries*.

1c. Download Python 2.7.2 for Windows at python.org/ftp/python/2.7.2/python-2.7.2.msi and run the installer. You can find IDLE, the Python IDE, at Start → Python 2.7 or launch it at *C:\Python27\Lib\idlelib\idle.pyw*.

NOTE You should not download Python 3. The script used in this project won't work with this version.

1d. Download the pyserial module at pypi.python.org/pypi/pyserial. Extract the *pyserial-2.6* folder to *C:*. Launch the command prompt window at Start → Accessories → Command Prompt. Type `cd /d c:\pyserial-2.6` and hit enter. Now type `c:\Python27\python setup.py install` and hit enter again.

1e. Download pywin32 at makezine.com/go/pywin32 and run the installer.

2. Connect the con-troller to the Arduino.

2a. We'll use 4 colors of jumper wires to simplify the instructions. Insert the jumpers into the Wii Nun-chuk's connector as shown in **Figure A**, page 120.

2b. On your Arduino, connect the red wire to +3.3V and the black wire to GND. Connect the green wire to A5 and the yellow wire to A4 (**Figure B**).

3. Upload the Arduino sketch.

3a. Connect your Arduino to your computer via USB. If this is the first time, you'll need to install the required driver. Windows will not be able to install it automatically, so you'll need to select it in *arduino-1.0/drivers*.

3b. Open the Windows Control Panel and search for the Device Manager. You can find the port in which your Arduino is inserted under *Ports (COM & LPT)*. Open the Arduino IDE and select the correct port under Tools → Serial Port.

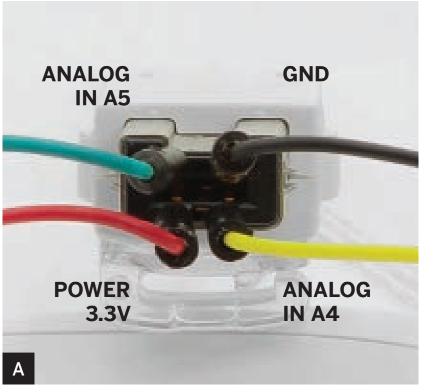
3c. Relaunch Arduino. Select your Arduino model under Tools → Board.

3d. The *ArduinoNunchuk* library that you've installed has an example sketch that prints the data from the Wii Nunchuk to the computer's serial port. Open the example file by selecting File → Examples → ArduinoNunchuk → ArduinoNunchukDemo. Upload this sketch to your Arduino.

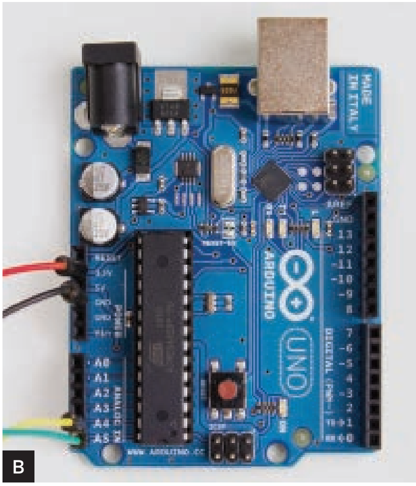
3e. Open the Serial Monitor. At the bottom right, change *9600 baud* to *19200 baud* and wait a few seconds. You should see 7 columns of values that change if you move the Wii Nunchuk, move the analog stick, or press a button. If it's working correctly, close the serial monitor.

4. Set up the script.

4a. Download the Python script at makezine.com/go/nunchuk.



A


B

RESOURCES

- » Python 2.7.2 python.org
- » Pyserial module pypi.python.org/pypi/pyserial
- » Pywin32 extension makezine.com/go/pywin32
- » Arduino IDE arduino.cc/en/Main/Software
- » ArduinoNunchuk Library github.com/GabrielBianconi/ArduinoNunchuk
- » "ArduinoNunchuk – Wii Nunchuk library for Arduino" gabrielbianconi.com/projects/arduinonunchuk/
- » "How to hook up a Wii Nunchuk to an Arduino Mega" gabrielbianconi.com/blog/how-to-hook-up-wii-nunchuk-arduino-mega/

TIPS

If you can't find the example sketch, try relaunching the IDE. If this doesn't fix the problem, you probably didn't install the library correctly.

If you don't see the numbers, you probably did something wrong or skipped a step. Make sure that the wires are connected properly and the baud rate and serial port are set up correctly.

If you get an error when trying to run the file, make sure that the port was correctly set up and both pyserial and pywin32 installed. If this doesn't solve the problem, try restarting IDLE and your Arduino. If it still doesn't work, restart your computer.

4b. Open it with IDLE (Right-click → Edit with IDLE). Look for the line which says `port = 'arduino_port'` and write the correct port (leave the quotes). It should look like `port = 'COM10'` (use the same port as set up in the Arduino IDE). Save the script (File → Save or Ctrl+S).

4c. Press F5 to run the file and wait a few seconds. Enjoy using the Wii Nunchuk as a computer mouse!

Gabriel Bianconi is a high school student in São Paulo, Brazil. He is interested in technology, especially programming, and wants to study computer science in college.

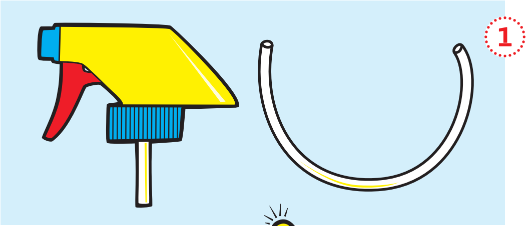
Gunther Kirsch

1.2.3. Omnidirectional Spray Bottle

By ***Jason Poel Smith*** Illustrations by ***Julie West***

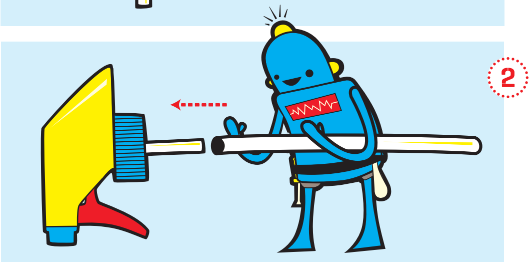
MODIFY A SPRAY BOTTLE SO IT WORKS WHEN HELD AT ANY ANGLE. If you replace the hard suction tube with flexible tubing and a weight on the end, the tubing will naturally fall to the lowest point of the container.

YOU WILL NEED: **Spray bottle, 16oz or bigger** » Flexible tubing, ⅛" ID, ¼" OD, such as aquarium air line » **Stainless steel nuts, ¼" (5)** » Scissors » **Glue (optional)**



1. Cut the tubes to length.

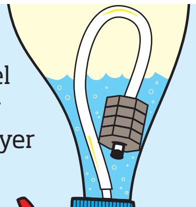
Cut the original spray bottle tube, leaving about 1" sticking out past the screw cap. Then cut the flex tubing about 1" longer than the cut portion of the original tube.

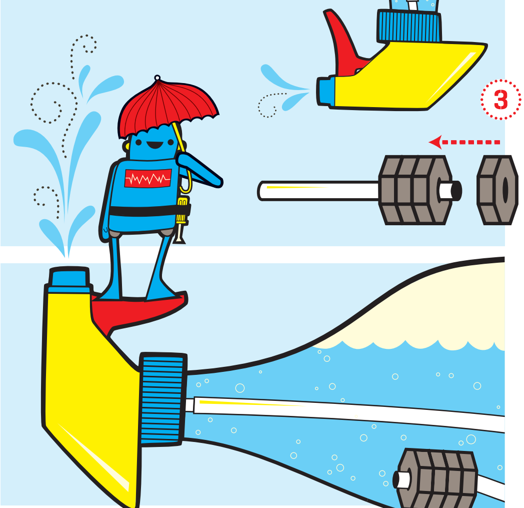


2. Attach the 2 cut tubes.

The suction tube on a typical spray bottle has an outer diameter between ⅛" and ¼", so the flex tubing should make a good seal without any adhesive. Slide it onto the original tube until you get a firm seal, with at least ¼" of overlap. » If you don't get a satisfactory seal, use glue. With both tubes clean and dry, apply a thin layer of glue around the lower ½" of the original tube. Slide the flex tubing onto the original tube, overlapping by at least ½", and slowly twist the flex tube to help spread the glue evenly. Let the adhesive completely cure before continuing.

NOTE: Even stainless steel eventually corrodes. After each use, remove the sprayer assembly to dry.





3. Add the weight.

Twist a nut onto the end of the flex tubing and turn the sprayer upside down to see how low the tube hangs. Add nuts until the tube hangs almost down to the cap. The stiffer the tubing, the more nuts you'll need. I used 5.

USE IT

Fill the bottle with liquid and enjoy spraying up, down, and upside down! If the tube gets stuck, give the bottle a gentle shake.

Jason Poel Smith is a helicopter tooling engineer. When he's not inventing, he's spending time with his amazing family.

Kanpai!

TIME: 2–5 WEEKS COMPLEXITY: MODERATE

Brew sake at home.

By ***Alastair Bland***

The bottles are slender and elegant and colored a frosty white or baby blue, alcohol levels usually hover in the mid-teens, and the price tags often exceed 30 or 40 bucks. For these reasons, sake has gained a reputation among many Westerners as the Eastern equivalent of fine wine – something rare and precious, to be consumed in tiny portions, and more often than not simply out of reach.

Gregory Hayes

Gunther Kirsch

But this favored table beverage of Japan is actually a simple grain-based brew, much like beer. And while it's true that good sake, often called "rice wine," is expensive, there's an easy way around the price tag: make it at home. It takes just 4 ingredients, and anyone, using only the most basic of beer-making equipment, can transform a sack of pearly white rice into fragrant, perfumey sake in as little as 12 to 15 days.

Born in China some 4,000 years ago as rice cultivation took root, sake culture found its way to Japan about 2,000 years later, where it bloomed into a refined and hallowed tradition. Over time, rice varieties would be bred specifically for use in brewing, and today those who make sake — often in tiny microbreweries with their own proprietary yeasts and rice strains — are esteemed as among the greatest of craftsmen.

Brewing sake requires rice, water, yeast, and, finally, one more essential component: a mold native to East Asia called *Aspergillus oryzae*. We have this critter to thank for black bean sauce, soy sauce, miso, and other cultured food products of Asia. *A. oryzae* releases an enzyme that breaks down complex carbohydrates into simple sugar. Since sugar is what yeast turns into ethanol, the first step in making sake is to convert steamed rice into a sticky, sweet porridge.

Purists may wish to start from scratch by buying spores of the *A. oryzae* mold and sprinkling it over a batch of steamed rice. Here, the mold blooms and does its magic: the grain turns as sweet as candy. The rice is now called malt-rice, or *koji*, and can be dried or frozen and stored for months until needed for brewing.

MATERIALS

For 1 gallon of sake:

» **Short-grain rice, white, 3.3lbs**
» **Cold Mountain koji, 20oz tub** Check your local Japantown (I got mine from Nijiya Market in San Francisco), or order online from Pacific Mercantile (pacificeastwest.com) and select the quickest shipping since it needs to be kept cool.
» **Yeast, champagne or dry white wine variety, 1g**
» **Water, 4qt**

TOOLS

Specialty brewing items are available at most homebrewing and winemaking supply stores.

» **Brewing bucket, 5gal** typically 12" OD × 17½" tall
» **Airlock and rubber stopper** adds about 5" to bucket height
» **Mini-fridge (optional)** to fit your bucket and airlock, with a temperature range that goes up to 55°F–65°F. We used a Vissani 52-Bottle Wine Cooler, Home Depot item #MVWC52B (homedepot.com). If weather permits, omit the fridge and leave your brewing bucket in a cool garage or basement where the temperature is a steady 55°F–65°F.
» **Measuring cup**
» **Scale** for measuring rice, yeast
» **Colander, stainless steel**
» **Large pot** for steaming the rice
» **Cotton towels**
» **Funnel**
» **Ladle**
» **Glass jug, 1gal** for secondary fermentation
» **Sanitizing agents** One Step No Rinse Cleanser or iodine
» **Rubber tube** for siphoning
» **Beer bottles**
» **Bottle caps**
» **Hand-operated bottle capper**
» **Siphoning pump (optional)**
» **Bottling valve (optional)**


A


B

Most sake homebrewers opt to purchase dried, premade koji ready to use. A favored product is that of Cold Mountain, which sells 20oz plastic containers full of dried rice inoculated with *A. oryzae*.

You'll also need yeast, and many beer and wine yeasts do just fine. In advanced sake brewing, the water and its particular mineral content are a matter of concern, but beginners can use clean tap water.

Finally, there's the rice. Brown rice is commonly advised against, since the outer layers of each unhusked kernel contain proteins and fats that can, by some opinions, produce off-flavors. Commercial brewers use specially bred sake rice varieties, but these are expensive. Fortunately, table rice can make very respectable sake.

The magic moment of brewing arrives when the lid of the bucket is removed. Here, where 2 weeks before was a slurry of rice, fungi, and warm water, is now a naturally transformed beverage. If all went well, the aromas should be beautiful — stone fruits and guava and flower petals — and to think that they all came from polished white pearls of rice can be astounding. To see firsthand that sake can easily be produced in a bucket in one's kitchen is just as thrilling. Here's how.

C

1. Wash, soak, and steam.

Rinse the rice with cold water through a colander until the water drains out clear (**Figure A**).

Soak the rice for 90 minutes. Fully wrap the rice in a clean cotton towel (**Figure B**), then place it in a colander within a large pot. Add about ½" of water and simmer over low heat, making sure the lid closes tightly and the pot doesn't dry out and burn. Cook the rice for 1 hour or more, adding water as needed.

When finished, properly steam-cooked rice will be sticky and a bit rubbery between the teeth — and palatable. If it's still al dente, keep steaming it.

2. Sanitize.

Sterilize your brewing bucket, lid, measuring cup, rubber stopper, airlock, and your hands with either iodine or One Step No Rinse Cleanser. If using One Step, make a solution of 1 tablespoon per gallon of water according to the instructions, throw in everything above, slosh water over all the equipment, making sure everything is covered, and remove it all after 2 minutes.

Cap the bucket with the lid and airlock, and shake the bucket to coat the insides with the solution. Dump the solution out after 2 minutes. Sloshing some boiling water in the brewing vessel afterward can't hurt.

3. Mix.

Combine the 4qt of cold water, steamed rice, 20oz of koji, and gram of yeast in the brewing bucket. Secure the lid (**Figure C**).

NOTE Any material or surface (hands included) that may come into contact with the sake should be considered potentially "infected." Sterilize everything thoroughly just before use.

4. Ferment.

The starch-to-sugar conversion and fermentation will begin at once and simultaneously. If you've plugged your brewing bucket with an airlock (**Figure D**), bubbling will start within hours, and the glugs will come increasingly rapidly. Put the bucket in a cool place to keep the sake at 55°F–65°F.

The fermentation, and the pace of the glugging, will probably peak between day 3 and day 7. When it slows to one glug every 15 minutes or so, after about 2 weeks, the sake is mostly finished.

5. Sample.

Open the lid and you should see the rice floating on top and yeast settled to the bottom. The sake will be relatively clear and can be carefully (don't stir up those funky sediments at the bottom!) poured or ladled through a cotton cloth into a carafe (**Figure E**) for immediate consumption in case you're thirsty.

Squeeze out the sake from the rice by twisting the cloth (**Figure F**).

6. Ferment some more.

Secondary fermentation is an important step that clears up your sake and allows bad-tasting esters to settle out. First, the sake remaining among the soupy bottom dregs must be separated from the foul-tasting yeast sediment. To do so, pour or siphon the boozy muck, again filtering out the rice, into a sanitized glass gallon jug (**Figures G and H**). This


I


J

TIP Wrap a cloth around the tip of the siphoning pump to keep rice from clogging it (**Figure J**).

is your secondary fermenter (**Figure I**).

Here, the last kicks of fermentation will peter out as the sediments precipitate to the bottom. This may take several weeks, with the jug kept at about 55°F. (Some brewers just put it right into their near-freezing kitchen fridge.)

7. Bottle.

When the sake is clear, with a thick layer of sediment on the bottom, siphon it into sanitized beer bottles. (A bottling valve, which only flows when pressed to the bottom of the bottle, makes it easier.)

Seal the bottles with sanitized caps using the hand-operated capper. Drink within weeks or months.

8. Age (optional).

If you wish to age your sake, you should pasteurize it prior to bottling by placing the filled-but-not-yet-capped bottles into a pot of boiling water. Using a clean thermometer, monitor the rising temperature of the sake. When it hits 140°F, consider the drink sterilized.

Now cap the bottles and stash them away. You might even age some for years.

Alastair Bland is a freelance writer based in San Francisco. He writes frequently of food, science, and the environment. He travels frequently — often by bicycle — and his journeys can be followed at his blog "Off the Road" (blogs.smithsonianmag.com/adventure).

How to Serve Sake

At last, the night will arrive when your home-brewed sake comes to the table. Reverence and respect must be shown, but don't overdo it. For one thing, you don't need to "pair" it with sushi. While sake and sushi are often seen hand in hand, that's only by convention and tradition – like two villagers married in an arranged ceremony, never knowing that their true soul-mates were living somewhere far away. So cook whatever you want – Indian curry, Greek dolmatas, Mexican tacos, French cheeses. Sake likes them all.

Secondly, you can serve your sake from square cedar cups – or just keep it real and use the stemware in your cupboard. In fact, you want a glass that's wide enough to swirl, setting aloft those lovely aromas.

Finally, for Pete's sake, don't drink your sake warm or hot. This has long been a trick for masking off-flavors in lower-quality sake – and your homebrew is anything but.

Gregory Hayes (serving)

Solar Powered Roasting Spit

Make the event memorable with a DIY wood-fired rotisserie.

By ***Saul Griffith***

Author Saul (left) and his friend Dan (right) assemble the drive mechanism from a bicycle wheel, a windshield wiper motor, and a loop of kite string.

TIME: A WEEKEND **COMPLEXITY: MODERATE**

Courtesy Saul Griffith

Not only do I enjoy making things, I also love making food, so any opportunity that combines both is hard to pass up. Friends of mine were getting married, and being the beautiful and unusual people they are, planned a potluck wedding. I decided to do what I'd been hoping to do for years: cook an entire animal on a spit. My wife and I had a small lamb and pig both spit-roasted at our wedding and it was a culinary highlight. How hard could it be to do myself?










A FEW FRIENDS VOLUNTEERED TO HELP (thanks Pete Lynn, Dan Benoit, Joe Brock, and infinitely Mose O'Griffin). At the local farmer's market I met the lovely people from Fatted Calf, a San Francisco charcuterie. They were delighted to supply me with a lamb, and also recommended a great book, *The River Cottage Meat Book*, that included directions for making a spit and cooking on it.

It was the Thursday evening before the wedding when I went to pick up the lamb. The store was full of people buying sausage or some prosciutto. The store went dead quiet as the butcher, having just completed salting and preparing "the beast," brought it out slung over his shoulder. I think everyone in the shop came to me with some comment or story of shared excitement, jealousy, or encouragement. I knew at this point that despite having no idea what I was doing, this particular cooking experience was the type of making that brings communities and people together in a social experience.

That evening we elected to build the rotisserie spit that I thought would be the simplest, most easily transported, and easiest to store.

MATERIALS

» **Sheet metal** for the fire pans and drippings trough. We used a 4'×8' sheet of 16-gauge mild steel.
» **Metal rods or pipes (3)** to hold the pans and trough together
» **Adjustable sawhorses (2)** to support the rotisserie, height-adjustable for temperature control (good idea, Dan)
» **Steel pipe, Schedule 40, 1½" diameter, 10' length** for the spit
» **Baling wire** to hold the roast on
» **Windshield wiper motor, high torque, low speed** to drive the spit
» **Solar panel** to power the rotisserie (thanks, Fenix International)
» **Bicycle wheel** to gear down the rotisserie speed
» **Steel pipe flange fitting**
» **Scrap of wood or metal** to adapt the flange to your bike wheel
» **Eye bolts (2)** longer than pipe diameter
» **Various wood screws, nails, kite string, etc.**

BUILD IT

1. Cut the sheet metal into three 8'-long pieces: two 18"-wide for the fire pans, and one 12"-wide for the drippings trough. Cut holes to thread the pipe through.

2. Cut the metal pipes to size and assemble the 3 troughs. Bend the drippings trough deeply and the fire pans shallowly.

3. Bolt the eye bolts to the top of the sawhorses.

4. Drill and tap the flange to match the hole spacing of the disc brake tabs on the bike hub.

5. Connect the flange and hub/wheel to the Schedule 40 pipe. To adapt the flange to your disc brake or hub, drill a disc of wood or metal to match the hole patterns of both parts.

6. Improvise.

7 A.M. Wedding day – I get up, but have my 3-year-old son and 3-month-old puppy to look after. (My wife is baking the wedding cake.)

9:00 I'm now worried; I haven't made progress on anything, and from reading the book I'm estimating a 6- or 7-hour cooking time with a 5 p.m. eating target. Mose arrives. Sigh of relief.

9:05 We get the fire started in the 2 fire pans. We have enough old eucalyptus logs to cook a bunch of animals, even though it does consume a surprising amount of wood.

9:15 Start preparing the animal itself; we decide to figure out how to spin the animal once it's on the spit.

9:20 Read hilarious section of *River Cottage Meat Book*: "Let's not be delicate here, the pole goes in the a**hole and out the mouth." Learned that there is indeed nothing delicate about cooking a whole animal.

9:25 We use too much baling wire and my hands are bleeding, but the lamb is tied to the pole. All I did to prepare the pipe was drill some holes for pushing wire through. You should think a lot more about how to keep the lamb from rolling around. Systems with orthogonal spikes seem very popular.

9:45 Lamb goes onto the spit above the coals. We're cooking at last. Seven hours until dinner; if everything goes according to plan we'll have minutes to spare!

9:55 We attempt to drive the spit at a recommended 1–3rpm by connecting solar cells through an inverter to produce 12V. There are problems with both the inverter and the drive mechanism.

10:05 Our friction drive made of a BMX bike peg against the bike tire doesn't work well, and doesn't give us enough gear reduction. The motor moves about 100rpm, and the friction drive is only about 20:1.

10:20 Switch to using the battery of a 1959 dune buggy. This turns out to be a bad idea but is awfully fun.

10:30 Back to solar panels, and with the arrival of Joe Brock we have a new idea: a capstan drive. Itworks perfectly. Fortunately I have brought a splicing tool and some old kite string that makes an excellent belt. We just wrap a few turns of the string around the motor axle.

10:40 Everything now appears to be working. The lamb is moving at 2–3rpm and the only thing to do now is tend the fire. And baste the animal. And drink.

4:40 P.M. Still basting and drinking, but it's now time to go watch our friends get married. Quickly check the temperature with a meat thermometer: 140°F deep in the thigh. Perfect.

5:10 They're married! I'm ready to carve. So is Mose. People line up, and it's done. I can't believe 75 pounds of animal can disappear so quickly.

Sometimes making is solitary, sometimes it's social. Both are beautiful things.

Saul Griffith is chief troublemaker at otherlab.com.

VINYL PCB RESIST

Gregory Hayes

MATERIALS

- » **Adhesive-backed vinyl sheets** if you don't have a vinyl cutter, send your design to a sign-making service or custom sticker company.
- » **Copper circuit board blank**
- » **Kitchen scrub pad, sandpaper, or steel wool** for scuffing the copper
- » **Masking tape or transfer tape** or similar low-tack tape
- » **Etching chemicals** such as ferric chloride, or muriatic (hydrochloric) acid with hydrogen peroxide

TOOLS

- » **Gloves, rubber or vinyl**
- » **Safety glasses**
- » **Tray or jar, nonmetallic** such as glass or ceramic
- » **Tweezers (fine) or other sharp tool** like a hobby knife, utility knife, or pushpin for "weeding" vinyl stickers
- » **CNC vinyl cutter/plotter**

Etch your circuits the easy way — with a resist pattern you make on a vinyl cutter.

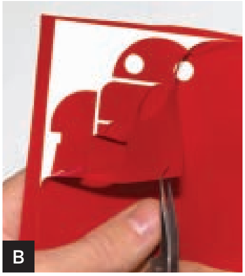
By ***Chris Connors***

There are lots of ways to etch a circuit board, but all of them create a path for electricity by preserving and removing portions of the copper coating on the board. You might have tried drawing a circuit on copper with a pen or grease pencil, or silk-screening it, or transferring toner from a laser printer, and then chemically etching the board. A substance used in this way is called a *resist* because it resists the etchant and protects the copper.

One of the easiest and most reliable resists I've found is adhesive-backed vinyl produced on a sign cutter. This is done by sticking your circuit trace image directly onto the board, and then immersing the board in a chemical bath. The exposed copper is removed, leaving just the copper traces you want for your circuit. Here's how I do it.

TIME: 1–2 HOURS **COMPLEXITY: EASY**

A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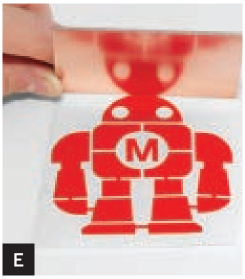
IMPORTANT

Double-check that your design is the right size, and that you left all the correct parts on the sticker when you weeded it!


C


D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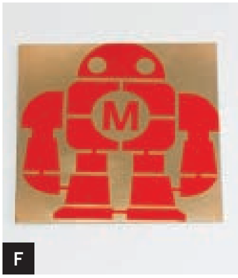

F

Gunther Kirsch

1. Get a circuit board design.

You can design your own circuit traces, or use existing artwork of proven designs. Search the Open Circuits wiki, Adafruit's Github repository, and hobbyist websites like diystompboxes.com to get a taste of what's out there for free.

And remember, you can also transform schematic diagrams into circuit board layouts using free software tools (see page 44).

We designed this board as a super-sized version of the MAKE Learn to Solder robot pin. It's got huge traces, but people also use this method to make fine traces.

2. Cut your design in vinyl.

Convert your board design into an image format your vinyl cutter can use. If you bring the design to a shop, they'll tell you what formats to use.

Cut the design into the vinyl with the vinyl cutter (**Figure A**). If you're using a service, make sure the cut is scaled accurately. If the design isn't the right size, your parts may not fit properly.

3. "Weed" your vinyl stickers.

Carefully remove the unwanted vinyl bits where you want the copper stripped from the board. Leave behind the parts where you want to protect the copper (**Figure B**).

Some services will weed the sticker for you; others may not. When we ordered some from TAP Plastics, they came back weeded.

Most vinyl cutters come with fancy, sharp tweezers, but you can use a utility knife or a pushpin taped into the barrel of an old pen to pick out the parts of the vinyl you don't want.

4. Transfer the vinyl to the copper board.

Scuff the board so the etchant will be able to reach the copper easily (**Figure C**). Circuit board blanks are treated with a clear coating that keeps the copper from oxidizing in the air. If this coating has been removed for any amount of time, you'll see dark spots. These spots shouldn't affect your etching.

Place your weeded sticker on a flat surface and cover it with low-tack transfer tape or masking tape. If you use very sticky tape, the vinyl won't stay on your circuit board.

Use the transfer tape to lift your vinyl sticker off its backing (**Figure D**) and place it onto the copper face of the board (**Figure E**). Smooth it down firmly everywhere to get the best adhesion you can. Then remove the transfer tape (**Figure F**).

5. Prepare the etchant bath.

Put your etchant into a nonmetallic tray or jar with a tight-fitting lid.

Wear safety goggles and rubber or vinyl gloves, to keep the etchant chemicals out of your eyes and off your skin.

Most people use ferric chloride. Other chemicals will also work, such as muriatic (hydrochloric) acid and hydrogen peroxide. For detailed tutorials on both methods check out MAKE's Circuit Board etching video at makeprojects.com/project/b/651 and The Real Elliot's tutorial on Instructables.

6. Etch the circuit board.

Immerse the circuit board in the bath of etchant (**Figure G**). Agitate the board from time to time, to keep fresh etchant working on the copper.

Remove the board frequently to check its progress (**Figure H**). If you etch for too long, you could etch away the circuit traces. However, over-etching is much less likely with this technique, since the vinyl makes a very tight bond with the board.

It's done when the copper is completely removed from the areas not covered by vinyl. Take the board out of the etchant and rinse it under cold running water.

7. Peel the vinyl off.

Once you're sure the copper is cleared to your satisfaction, peel the vinyl resist off the board (**Figure I**). It should come off easily.

If you really need to etch it some more, you can, but placing the vinyl back on may be a challenge. It's best to leave the vinyl on until you're sure the copper is removed.

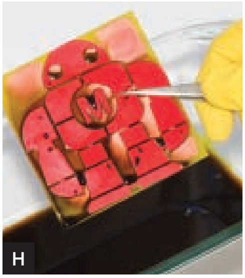
Admire your new circuit board (**Figure J**).

8. Use your new circuit board.

Compare your circuit board to the original artwork. If everything is to your satisfaction, you can now drill out the holes for your components or surface mount them as we did.

MAKE contributor Chris Connors is a teacher who loves to learn with curious people who are interested in inventing the future. He wrote the "Mendocino Motor" project in MAKE Volume 31.


G

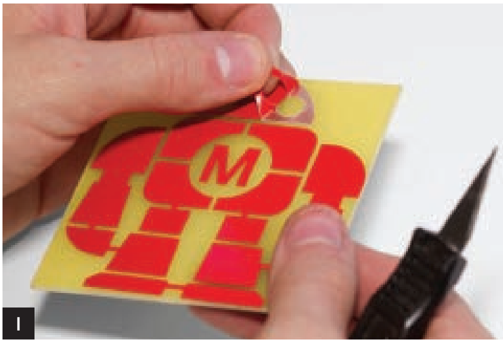

H

ETCHING TIPS

Using a smaller container will help you to use less liquid and still cover the board.

If your etching liquid is warm, it will act faster on the copper, reducing your etching time. You can prepare a warming tray filled with hot water, and place your etching tray or jar in it to raise the temperature. Make sure you don't overheat it.

If you etch in a small jar, you can seal the lid and shake it gently to agitate it with less risk of spilling.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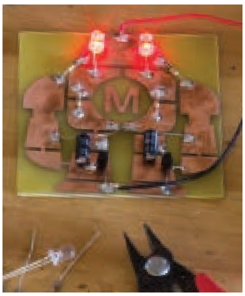
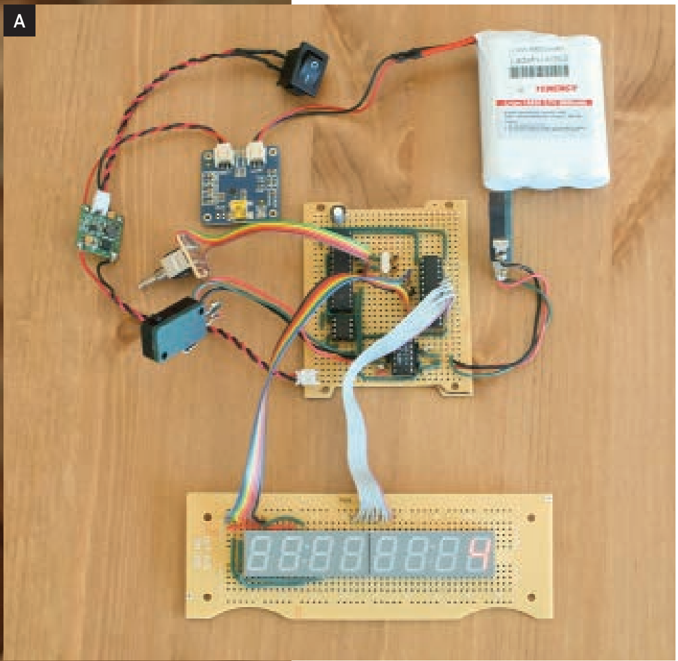


+ Grab this robot circuit board design at makezine.com/go/robotresist and etch your own. Then follow the directions there to solder a flashing-eyed robot circuit!

The Counting Box


A

How I built a simple counting circuit housed in bamboo for my son.

Written and photographed by ***Nathan Pryor***

More than a few times I've peeked in at night to find my son in bed with a calculator in one hand and a flashlight in the other, sound asleep after pushing "1 + = = =" and watching the numbers climb until he couldn't keep his eyes open. So, for his fourth birthday I decided to build him a dedicated machine that would do nothing but count up and count down at his command.

My initial idea was simple: a large multi-digit seven-segment LED display, two big arcade buttons to add and subtract, and a 10-position rotary switch in the middle. Turn the rotary switch to choose a value from one to 10, then push a button to increase the number displayed on the LEDs by that amount. Push the other button and it would go down by the same.

The Circuit

The circuit came first in this project, since the size of the case would depend on the size of the finished electronics package (**Figure A**).

At the core of it all is an ATmega328, one of the most common Arduino processors. A pair of 4-digit LED clock displays show the number, driven by a Maxim MAX7219

LED display driver chip capable of handling 64 LEDs, or 8 seven-segment digits, using only 3 output pins on the ATmega.

After building the circuit on a breadboard and writing a basic test program, I had my first introduction to *switch bounce*, the electronic noise or chatter on the millisecond level as a switch's contacts open or close. What seems like one button push to us can be read by a microprocessor as dozens, hundreds, or more. Fortunately, the arcade buttons I ordered happened to be double-throw switches. These allow a fairly simple debounce solution in hardware using 2 NAND logic gates for each switch. A 74HC00 integrated circuit provided all 4 required gates in one chip.

The rotary switch was binary coded, so it was only a matter of connecting its 4 pins — one for each of the bits required to count to 10 — to the ATmega's input pins, reading each and combining them, then converting to decimal.

Now that the circuit could count, I needed a way to store the current value of the display. You don't want to get your Counting Box up to an amazingly high number only to lose it when you turn the power off. This should be an easy job for the ATmega's internal EEPROM, but when I looked at the specs it was only rated for 100,000 write cycles. With a display that could go up to 99,999,999, that seemed inadequate. Instead I found the 24LC256 EEPROM memory chip with 1,000,000 write cycles — still not as high as the Counting Box could reach, but a lot closer. In actual use, though, the ATmega's onboard memory would more than likely be sufficient.

I did my prototyping and programming with an Arduino Duemilanove, but for the final build I used the same ATmega chip to build a standalone circuit on stripboard. I prefer a standalone microcontroller in my projects because it uses less space than building in an entire Arduino board, costs less, and leaves my Arduino free for the next project.

The Counting Box can be used to help introduce mathematical concepts like skip counting.

The LED display is on its own board, connected by ribbon cable to the main processor board. The 99,999,999 count that the 8 digits allow is definitely overkill, but using the 4-digit LED displays saved a lot of wiring and soldering compared to using individual digits.

For power, I planned on using rechargeable AA batteries.

The Software

The software has 3 primary functions: handling button pushes to increase and decrease the number by the selected amount, displaying the number, and storing the number to memory.

Button pushes come through as interrupts, which do pretty much what it sounds like they would — interrupt any other actions taking place in the program. The alternative to this is to constantly poll the button to see if it's being pressed, but this is inefficient compared to essentially asking the button to let you know when it's being pressed.

When a button is pressed, the program reads the value of the rotary switch, adds or subtracts that amount from the variable, then breaks it into individual digits to send to the MAX7219 for display. In every loop, the program compares the current value of the variable to the value of the variable on the previous loop. If they're different it stores the new value to the EEPROM memory chip.

You can zero the Counting Box by setting the number selector to 8 and holding down the decrease button when you power it on. Similarly, setting the number selector to 3 and holding the increment button during power-up will display statistics such as highest and lowest numbers reached and total number of button presses over the life of the box.

To save power, the ATmega goes to sleep and the LED display goes dark if no buttons are pushed for one minute. Pushing either button will wake the system.

B

Building the Box

With the circuit and software done, I set them both aside. They could definitely stand some further optimization, but their only real requirement was that they work. The box, though, would be seen every day and had to look as good as it could. It had to be friendly to young hands and resilient enough to withstand the occasional drop. Wood was the perfect material, but I don't have the precision woodworking skills or shop to build what I wanted. Laser cutting to the rescue!

To lay out the pattern of joints on the corners, I used an online utility called BoxMaker (boxmaker.rahulbotics.com). Enter the outer width, depth, and height of your finished box, the thickness of the material, and the kerf (the width of material removed by the cut), and it generates a PDF of all the required pieces.

I imported this PDF to Adobe Illustrator, made a few minor tweaks to the spacing for symmetry between left and right sides, and placed the elements like the window cutout and buttonholes.

Before uploading for cutting, I printed the plans and spray-mounted them onto ¼" foam core board, then cut out and assembled the pieces (**Figure B**). Foam board is a lot cheaper than laser-cutting, so this stage is a much better place to find errors (like a tab where a slot should be, or a box not deep enough to hold a button).

Not only did the mockup fit together, but all of the components fit into it. With that final check done, I uploaded the design to Ponoko (ponoko.com) to be laser-cut from bamboo plywood.

Two weeks later a package arrived with the crisply cut wood (**Figure C**). The pieces were beautiful, but they didn't fit together. I'd specified too wide of a kerf (the width of a cut), and in compensating for that the BoxMaker program had adjusted the widths of the notches to close up gaps that didn't exist. With a file and some sandpaper I was able to widen the notches enough to get the box together.

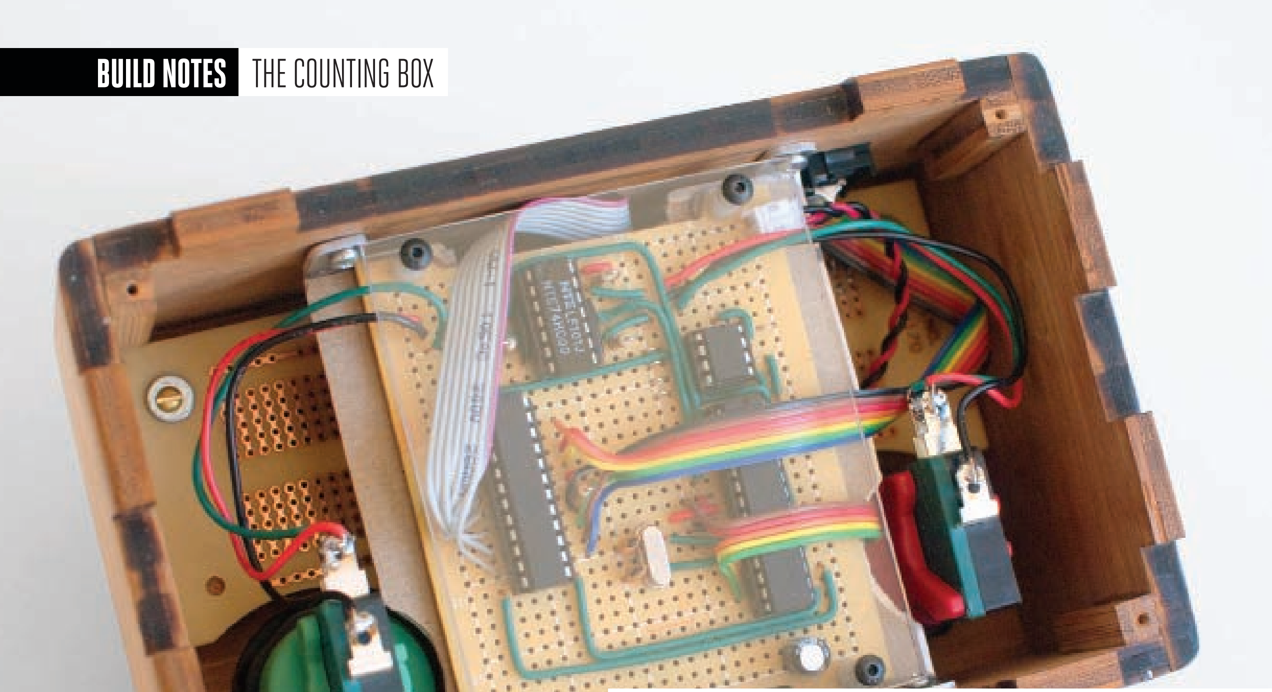
I glued the joints, sanded a radius on all the corners, then finished the wood with a polyurethane gloss for protection and to give the bamboo a warm, amber glow.

The red acrylic window covering the LEDs was laser-cut at the same time as the wood. I was hoping for a tight fit that wouldn't require any glue so I made 6 different versions of the window, each sized a few hundredths of an inch larger than the last, and used the one that fit best.

As I started putting it all together, I realized I wasn't happy with the way the AA batteries fit into the case. They were ugly, and taking them out for charging would be a hassle. To replace them, I used a lithium-ion battery pack and USB charger (**Figure D**), both from Adafruit (adafruit.com). The 3.7V battery feeds into a voltage step-up circuit to provide the 5V needed.

C

D



E

F

Like a lot of us, my son likes to look inside things and see how they work. The last-minute power supply change let me put the circuit facing outward where the batteries would have been, allowing the door on the back to serve as a window for him to peek at the electronics inside. To keep fragile wires safe, I covered the circuit with a piece of clear acrylic cut to size and held by standoffs (**Figure E**).

The door in the back of the box is held on by four 3mm neodymium magnets epoxied into holes drilled into the door panel and the frame (**Figure F**). The magnets are strong enough to keep the door secure in regular use, but they give when pried open using the half-moon cutouts on each side.

Using the Counting Box

In addition to the obvious thrill of seeing how high the numbers can get, it's easy to come up with games to play with the Counting Box. Ask questions like, "How can you get to 49 in the fewest button pushes? Can you do it with the selector switch set to the same value the entire time?" The Counting Box can also be used to help introduce mathematical concepts like skip counting. More advanced ideas like multiplication and division come quickly when it's made apparent that they're nothing more than repeated addition or subtraction.

I'm not sure who's learned more, me in building it or my son in playing with it, but either way the Counting Box adds up to a lot of fun.

+ More at hahabird.com.

Nathan Pryor is a software developer and graphic designer who enjoys turning off the computer and building things with his hands. He has a hard time remembering to clean up after his last project before starting the next.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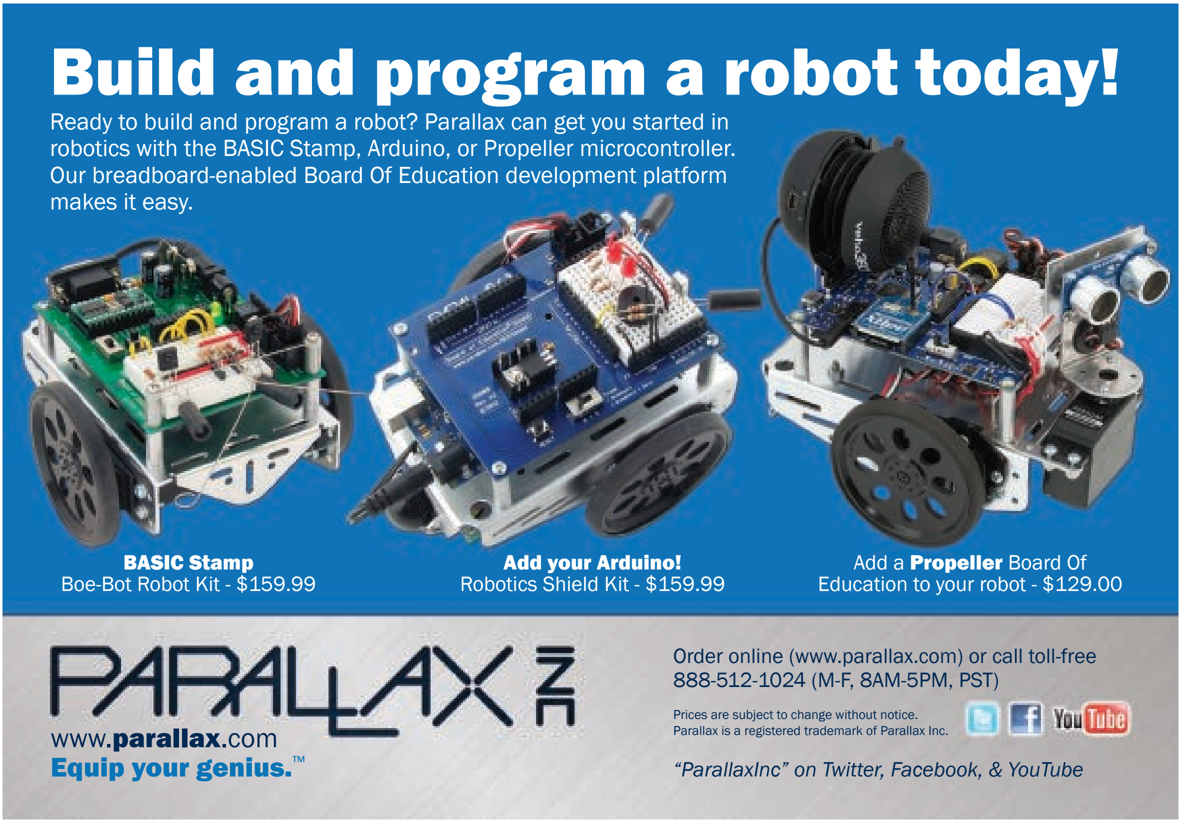
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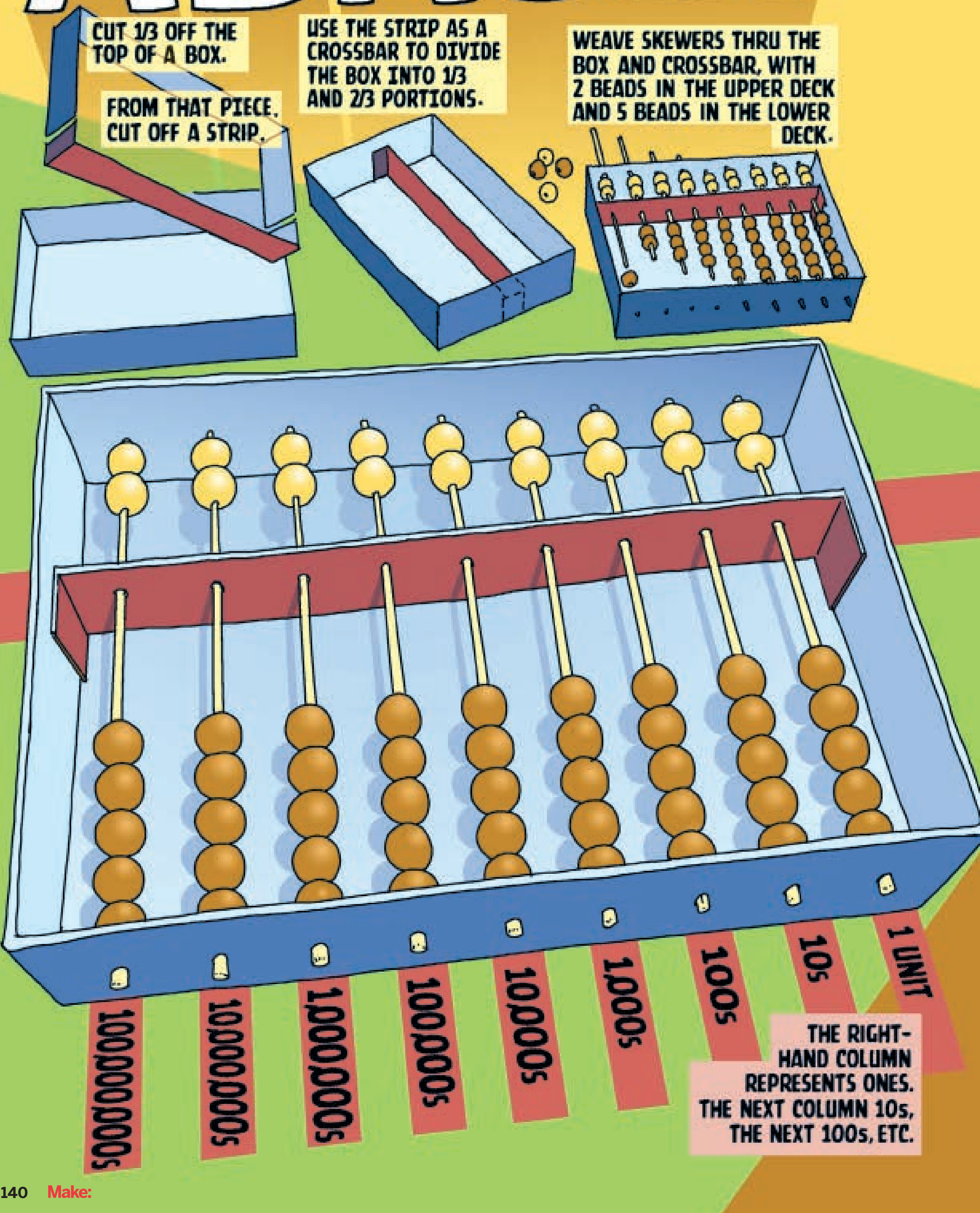
CUT 1/3 OFF THE TOP OF A BOX.
FROM THAT PIECE, CUT OFF A STRIP.
USE THE STRIP AS A CROSSBAR TO DIVIDE THE BOX INTO 1/3 AND 2/3 PORTIONS.
WEAVE SKEWERS THRU THE BOX AND CROSSBAR, WITH 2 BEADS IN THE UPPER DECK AND 5 BEADS IN THE LOWER DECK.
100,000,000s
10,000,000s
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10s
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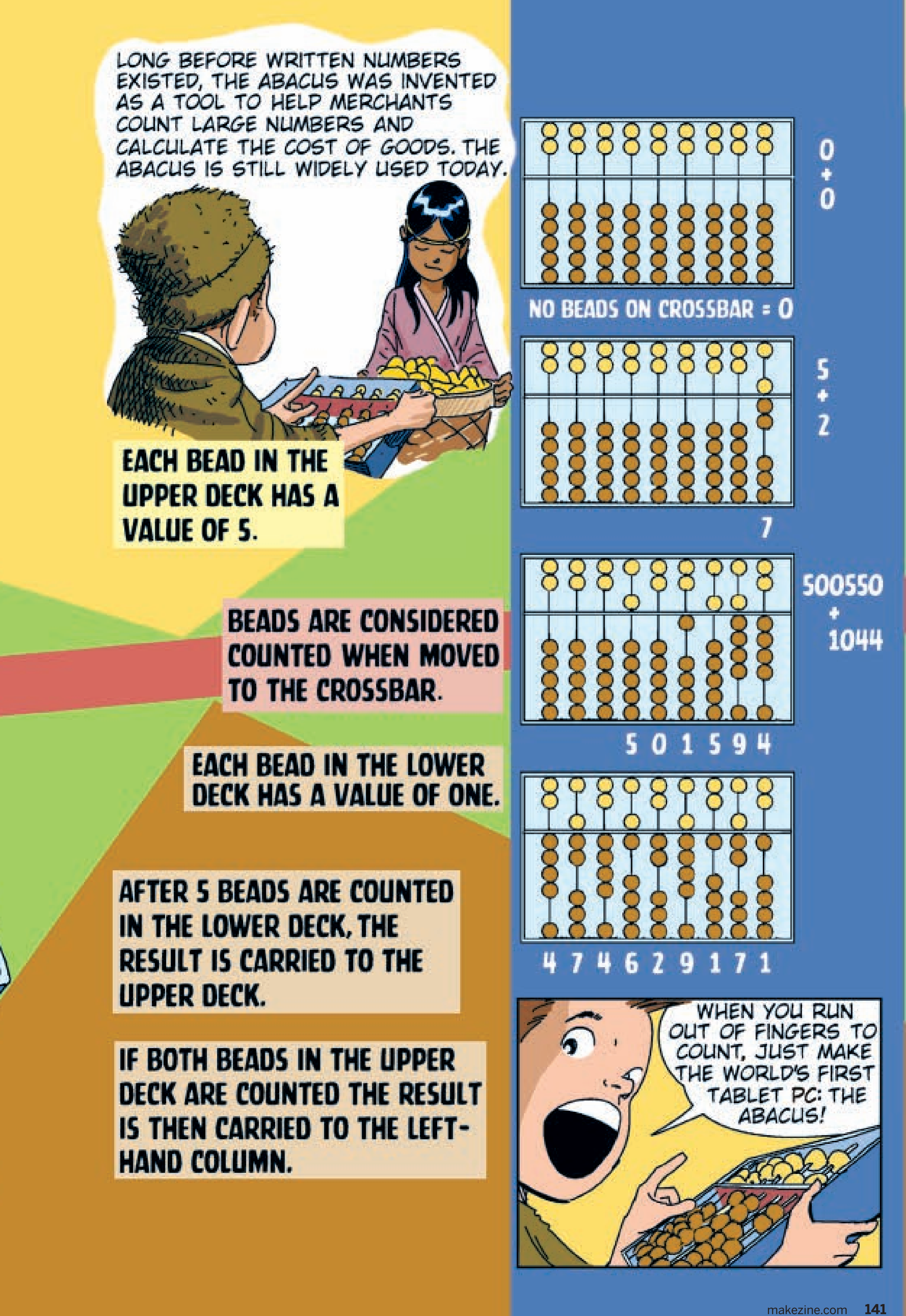
THE RIGHT-HAND COLUMN REPRESENTS ONES. THE NEXT COLUMN 10s, THE NEXT 100s, ETC.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0
NO BEADS ON CROSSBAR = 0
EACH BEAD IN THE UPPER DECK HAS A VALUE OF 5.
5
+
2
7
BEADS ARE CONSIDERED COUNTED WHEN MOVED TO THE CROSSBAR.
500550
+
1044
5 0 1 5 9 4
EACH BEAD IN THE LOWER DECK HAS A VALUE OF ONE.
AFTER 5 BEADS ARE COUNTED IN THE LOWER DECK, THE RESULT IS CARRIED TO THE UPPER DECK.
4 7 4 6 2 9 1 7 1
IF BOTH BEADS IN THE UPPER DECK ARE COUNTED THE RESULT IS THEN CARRIED TO THE LEFT-HAND COLUMN.
WHEN YOU RUN OUT OF FINGERS TO COUNT, JUST MAKE THE WORLD'S FIRST TABLET PC: THE ABACUS!

Presidential political campaigns were much different in the nineteenth century, and to many people, (me included) they sound like much more fun. Instead of ceaseless televised debates and commercials, scripted sound bites, and never-ending media analysis, the key political tool was the parade.

Abraham Lincoln ***and the*** Political Campaign Torch

By ***William Gurstelle***

Gunther Kirsch

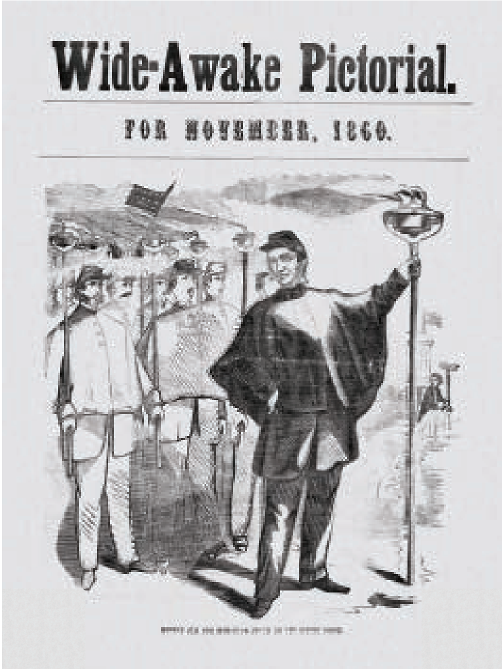
WHILE EVERYONE MAY STILL LOVE A PARADE, Americans of 150 years ago, it seems, were absolutely enamored of them. Imagine for a moment you're a member of the "Wide Awakes," one of many political marching clubs organized to drum up support for political candidates. Since marching is what you do, you and your fellow Wide Awakes do it often and are very good at it. Everyone in the group (and there are thousands) owns a torch. Your torch — a new gimbal-mounted, nickel-plated tin torch in the shape of a Union Army musket — is particularly eye-catching.

When an evening march is organized on behalf of your presidential candidate, Abraham Lincoln, your club takes to the streets, waving torches with pride and artistry, even using them in the manner of rifles, presenting a display of close order drill to the crowds lining the streets. It's very exciting.

Mr. Lincoln himself rarely attended actual parades, because at the time, candidates did not campaign personally. They stayed home and let others make speeches on their behalf. But on Aug. 8, 1860, Lincoln did participate in a rally near his home in Springfield, Illinois. He was mobbed by an enthusiastic crowd and was lucky not to have been injured.

These parades often lasted two to three hours. The costumed or uniformed participants sang campaign songs and shouted slogans as they marched. To satisfy the need for parade torches, scores of small manufacturing companies sprang up across the United States to fabricate them. Their factories ran at full steam, stamping out hundreds of thousands of unusually shaped torches — from rifle look-alikes for the aforementioned close order drill ceremonies, to torches built in the shape of faces, animals, capital letters ("L" for Lincoln), hats, pinecones, brooms, and pick axes.

Night after night, all over the country, people marched by torchlight, hoping the bright lights held aloft would awaken sympathetic feelings in onlookers and carry their candidate to victory. But the era of such campaigning tactics was soon to wane. In the 1860s and 1870s, strategies such as parades were the best way to reach people of all social status. However, as literacy rates rose and newspapers became less politically biased (at least overtly) political campaigning became less spectacular and more educational. By 1900, the importance and frequency of the torchlight parade declined dramatically, and the torch-manufacturing industry slid into a steep decline from which it never recovered.



Courtesy HarpWeek

Keeping Safety in Mind

1. Use only outdoors.

2. Kerosene is not as flammable as gasoline but extreme caution is still required. It must be stored in an approved container.

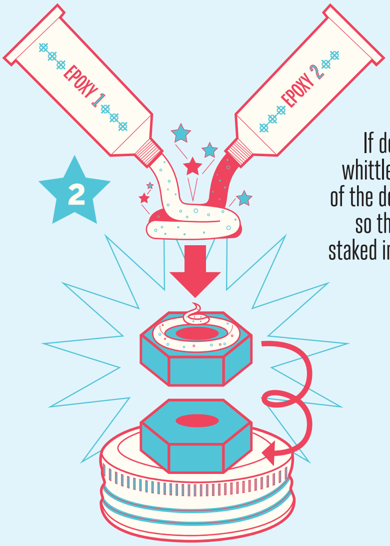
3. Keep a fire extinguisher handy. Use extreme caution when lighting, handling, filling, or holding the torch. Never fill the torch while hot.

4. Check often to make sure the can is securely attached to the dowel.

5. Do not hold the torch too much off vertical or it might drip kerosene.

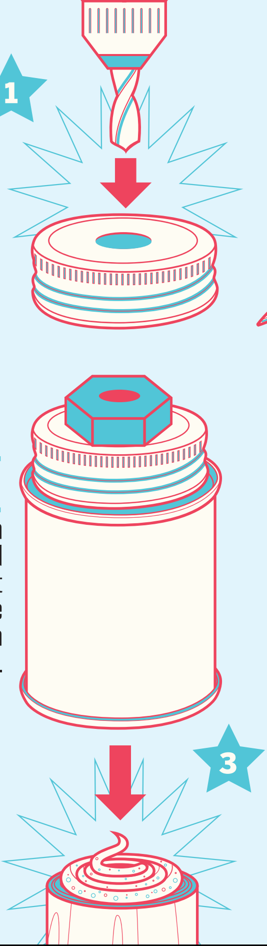
How to Make a Parade Torch

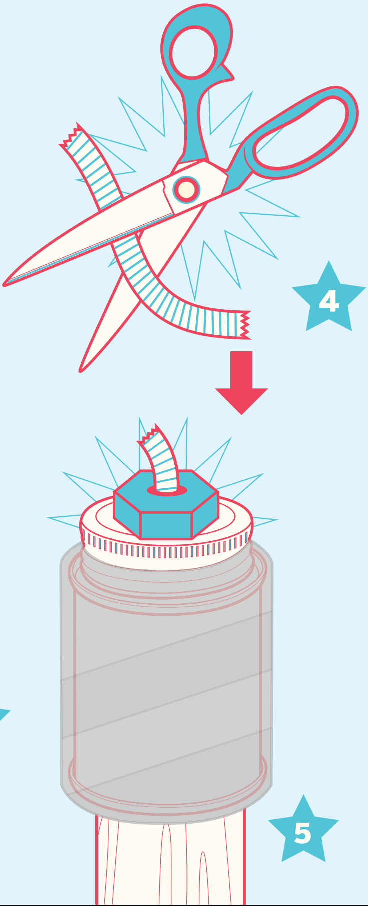
No nineteenth century political candidate worth his salt would allow supporters to march on his behalf without making sure there was a blazing torch in everyone's hands. Here's how to make your own.



NOTE

If desired, you can whittle the other end of the dowel to a point so the torch can be staked in the ground in your backyard.





TIME: AN AFTERNOON **COMPLEXITY: EASY**

MATERIALS

» **Metal can, small and clean with screw-on or replaceable push-on lid**
» **JB Weld or other high-temperature epoxy adhesive**
» **Hex nut, 5/8"**
» **Cotton rope, 1/2" diameter, 2 1/2" to 4" long** depending on can height
» **Wooden dowel, 1" diameter, 3' long**
» **Kerosene** Do NOT use alcohol or gasoline.
» **Aluminum foil or high-temperature aluminum tape**

TOOLS

» **Drill with 5/8" bit**
» **Fill spout** for the kerosene
» **Long-handled lighter or fireplace match**
» **Fire extinguisher**

1. Drill a 5/8" hole centered in the lid of the clean metal can.

2. Using JB Weld or other high-temperature epoxy, make a wick collar by gluing the hex nut over the hole, as shown.

3. Using high-temperature epoxy, glue the can to the wooden dowel. Let the epoxy harden before continuing to Step 4. Check label directions for curing time.

4. Trim the rope to fit the can and insert it through the hex nut so that 1/2" of rope sticks out of the lid. It should fit snugly.

5. Wrap the can with aluminum foil or high-temperature aluminum tape, forming a skirt around the can.

Using the Torch

Outdoors, fill the can one-quarter to one-third full with kerosene, using a fill spout.

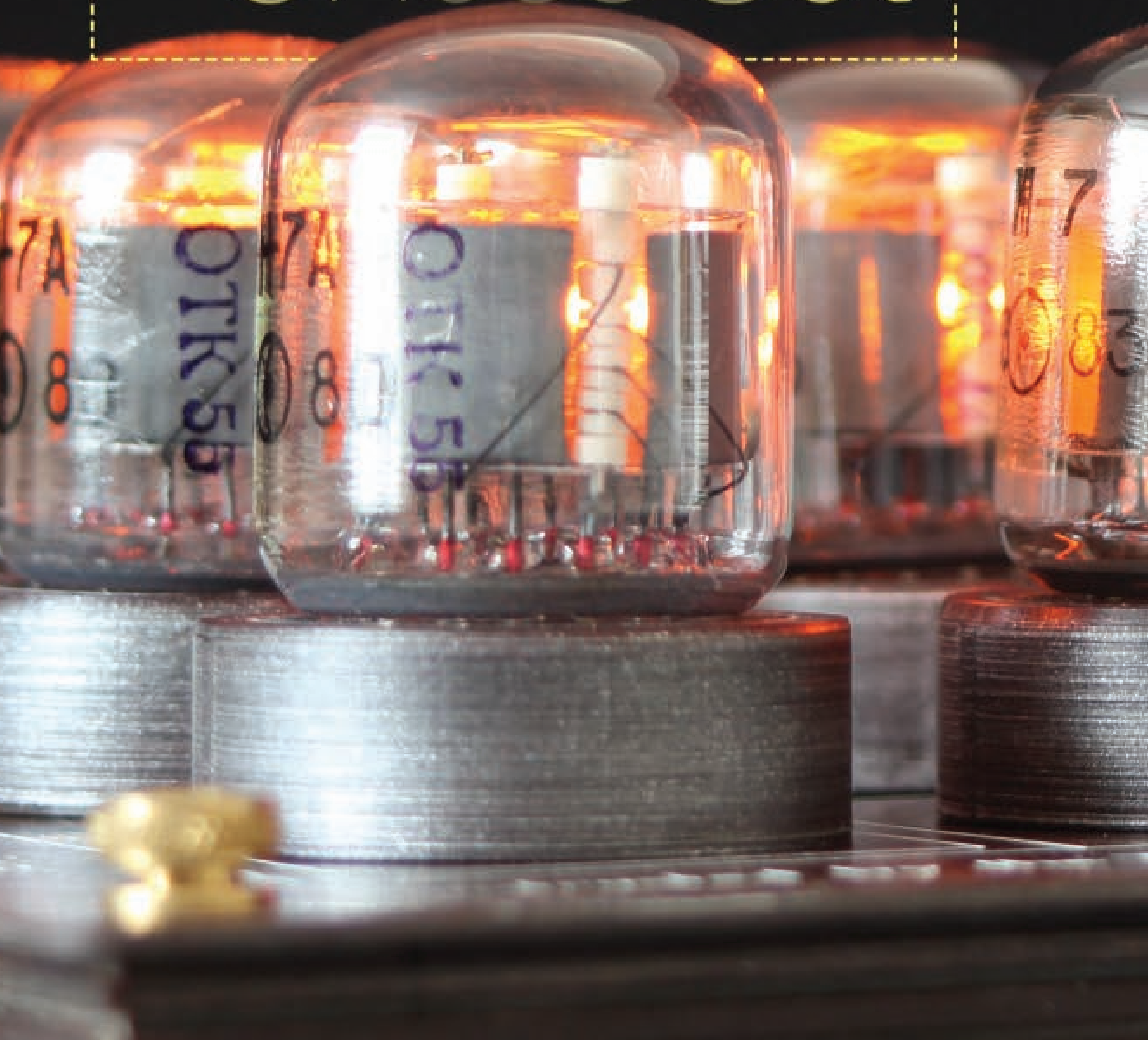
Make sure the lid is pressed down securely or screwed tightly after filling, with a 1/2" wick of rope sticking out.

Let the rope wick draw kerosene up. After 1–2 minutes, light the wick using a long-handled lighter or fireplace match. ■

Julie West

William Gurstelle is a contributing editor of MAKE. The new and improved edition of his book *Backyard Ballistics* has just been released.

Nixie Tube Chess Set



A Nixie tube clock morphs into something new: checkmate.

Written and photographed by ***Tony Adams***

I'VE ALWAYS BEEN FASCINATED BY the glow of ionized gases, but never got around to putting together a Nixie tube clock – the whole craze of the last decade seemed to pass me by. When I finally decided to make one, I knew it would have to be something a little different to stand out. I wanted to do it without wires, not just hidden but wireless, powered inductively by coils acting as an air-cored transformer.

Building the first single-digit modules, I thought they looked a little like chess pieces. A crazy idea started to form, one that wouldn't go away even though it seemed impossible to make it work. Using this design, 64 coils would need over 50 watts. Was there any way to make it work with less? I guessed that the power consumption would need to be kept below 25 watts to prevent overheating. Some feverish redesigning resulted in a single-coil prototype, which drew 20 milliamps. Yes, it could be done, but how practical would a chessboard with 64 individual transformers and driver circuits be?

I bought a full-size sheet of copper laminate and cut out a 14-inch-square board. The winding of the coils progressed slowly over the next few days. The case and pieces took a couple more weeks. Finally, I set it up one evening on the kitchen table, blogged it, and waited for the comments. I still haven't recovered from the shock. Hits on my blog exploded and I had to scramble to change to a host that could handle the load. I just shipped the first round of kits, and we still don't have a completed Nixie clock in the house.

Tony Adams is a freelance electronics engineer. He has been building circuits since he was 6 years old, and has spent the last 15 years repairing industrial lasers to keep the bills paid. He now also makes Nixie tube chess set kits. lasermad.com

TOOLBOX

Red Clouds Collective Coffin Tool Roll $45 redcloudscollective.com

» I'll admit I'm a sucker for *anything* made out of waxed canvas and leather. The pockets of this beautiful soft case weren't quite the right shape for my sculpting loops, so I evicted them and replaced them with my leather-working tools – skivers, bevelers, awls, and such – which have proven to be much happier tenants. The thick 10oz canvas was made to hold its own against sharp slicey-dicey tools. The brass zipper pocket is roomy enough to hold extra blades and various bric-a-brac, and the simple tie makes me feel a bit more bucolic every time I tuck in … er … wrap up my tools at night. *–Jason Babler*

Gregory Hayes

UNCLE BILL'S SLIVER GRIPPERS

$6 slivergripper.com

These tweezers are the Platonic ideal; I'm not actually sure why other tweezers exist, unless you need superbly coiffed eyebrows. These are absolutely perfect for removing splinters, glass, hard plastic, metal shards, ticks, bee stingers, thorns, and anything else you could conceivably lodge in your skin. Honed to a needle-sharp point, they let you dig in to get really tiny splinters exposed, and then the angled tip means you can grip it perfectly for quick removal. (Nothing is better for a bee sting, since you can remove the stinger without squeezing the poison sac into the wound.) Since my Aussie husband insists on going barefoot in his shop, and our young son follows suit as often as possible, I use them on a regular basis. I bought half a dozen of them; you should too. *–Arwen Griffith*

Big Gator Drill Guide

$25 tapguide.com

I'll haul my drill press out of storage for big projects, but it's a pain when I just need a few small, precise holes. Big Gator's U.S.-made drill guide is a handy gadget that ensures my cordless drill bores straight and true. It's a wedge-shaped piece of special-alloy steel with a row of 17 holes ⅛" to ⅜" in diameter. A V-groove down the bottom allows it to be used on corners and round stock, but I mainly use it on flat surfaces. It needs to be clamped in place, first. A metric version is also available. *—Stuart Deutsch*

Typhoon Spherical Tungsten Carbide Bur

$16 ***foredom.net***

In the cluttered field of third-party Dremel accessories, Foredom's Typhoon bits stand out. I loaded one of the tungsten carbide bits into my trusty rotary tool — the bits are Dremel-compatible but fit similar products — and dug into a hunk of wood. It tore right in, creating a surprisingly smooth groove that shows off the product's biggest boast: that they leave a smoother finish than the competition.

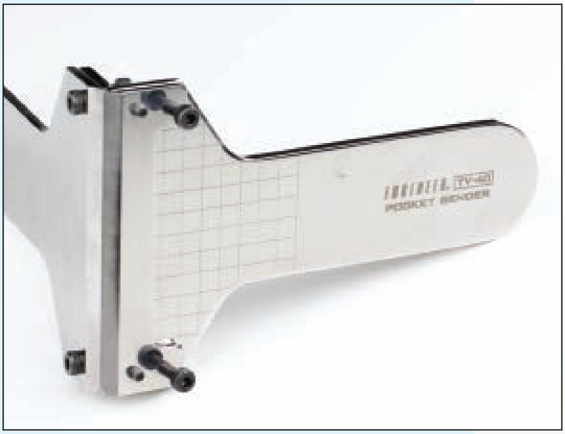
Helping you create the smoothest effect possible, Typhoons come in two grits. The blue bits are fine grit; the red bits are coarse. Both eagerly tackled my wood block, but Foredom claims the burs work well on fiber-glass, plaster, rubber, and acrylic, as well as hard and soft wood.

On the downside, their spherical business end limits them to a specific role — they're not really for precision work, but rather for removing a lot of material very quickly without leaving rough edges. Many other shapes are available through the Foredom website.

—John Baichtal

Engineer Pocket Sheet Metal Bender

$59 ***iheartengineering.com***



There are several ways to bend small pieces of sheet metal. A quick option is to use a mallet, a clamp, and a wooden block, but this method can lead to large-radius and unsightly bends. A metal bending brake is your best bet for sharp, good-looking bends, but even the smallest and most economical brakes must be mounted to a dedicated spot on your workbench.

This compact Japanese-made hand-held sheet metal bender can be used to bend aluminum up to 1.5mm (0.06") thick and 5cm (2") wide. It's ideally used for making small brackets, holders, and enclosures that require clean 90° bends.

Because of its limitations in size and design, the Engineer pocket bender is more of a specialty tool than a general purpose one. Even so, it produces better bends than can typically be achieved without a bench-top brake. *—SD*

Engraver's Universal Clamp

$30 **micromark.com**

Gregory Hayes

Being a tabletop wargame miniature modeler, I've coveted this tool in the Micro-Mark catalog for years. Like many other miniature modelers, I use wine corks, temporarily glued to the bases of minis, to hold work while it's being painted, modded, and detailed.

The Universal Clamp uses metal pins slotted into 60 available holes, which are sunk into two metal semicircles that thread together to tighten the work between the pins. This configuration allows you to clamp and hold all sorts of odd-shaped objects. I tested it by clamping 28mm Warhammer 40K figures for making modifications and detail painting. I love the feel of the hardwood handle and the stability and degrees of freedom it affords. It feels much easier to paint fussy highlights and tiny details holding the piece in this device.

The only drawback, especially when having to really tighten for drilling, gap-filling, and other jobs that require pressure, is that you run the risk of bending plastic mini bases. The eight pins it comes with are also easily lost. Stowage in the wooden base would have been a nice touch. Overall, I'm happy with the tool, but will likely use it mainly for painting.

—Gareth Branwyn

Ingersoll Rand 2132G Half-Inch Edge Series Air Impactool

$159 ***ingersollrandproducts.com***

This impact wrench is designed for quiet operation. My dad, now in his 70s, has been hard of hearing since a noisy air tool damaged his ears during a garage renovation 20 years ago, and this feature influenced my choice of the 2132G to replace his old Allied Pneumatic.

First, the highlights: I liked the feel of the 2132G better than the hand-me-down tool. Though it weighs about the same, it's better balanced, more compact, and easier to maneuver. I was also impressed by the documentation, which includes an exploded diagram and a detailed parts list.

The 2132G features forward-driving power adjustable through four stops, and only develops 100% power in the reverse direction – ensuring that you will always be able to loosen any bolt you tighten with it.

On the downside, though the 2132G was quieter than my old driver when operated with no load, I could hear little difference when actually changing a tire. Also disappointing is the lack of an oil port on the tool itself; the directions specify an inline lubricator, but I sometimes use my compressor for spray painting and don't want oil in the line. Nonetheless, this is a great, comfortable, high-performing tool at a fantastic price point, and I'm pleased with the swap.

–Sean Ragan

Gunther Kirsch

EXCALIBUR 9-TRAY FOOD DEHYDRATOR

$250 ***excaliburdehydrator.com***

Over the years, I've gotten more and more interested in food preservation. There's nothing more satisfying than seeing rows of gleaming jams and tomato sauce. The next step, of course, is dehydration. Dried apple rings lead to racks of fragrant dried herbs, then cotton-candy-like dried watermelon, then jerky, then fruit leathers. Now we seem to spend pretty much every weekend in summer and autumn either standing over steaming pots on the stove or loading up trays in our dehydrator, ready to reap the rewards all winter.

I first heard about Excalibur from a friend's cousin, who had just walked the Pacific Crest Trail, largely subsisting on meals he had dehydrated himself. "We started out with cheapo dehydrators," he told us, "but we seemed to go through one a year. Just start out with an Excalibur — you'll end up saving money." We opted not to get the timer model; it's easy enough to hook up to a cheap timer from the hardware store.

—AG

Engineer Screw Pliers

$34 ***iheartengineering.com***

These 6¼" combination pliers have uniquely shaped and grooved jaws specially designed to ease the stubborn tasks of positioning, inserting, and removing small machine screws. You can use them on truss-head fasteners up to M4 and #8, as well as round and pan-head fasteners up to M5 and #10 in size.

These pliers are darned comfortable to use and have become my favorite go-to tool for small assembly projects. Although usually lauded for their screw-head gripping power, the pliers perform superbly in general wire-cutting, parts-gripping, and twisting applications. That the pliers have super soft and grippy elastomer-coated spring-action handles is icing on the cake.

I have completed many projects over the years without these pliers, but good luck getting me to give 'em up now. Get your own! *—SD*

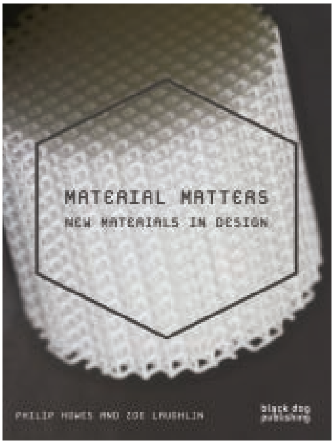
TAMIYA PLANETARY GEAR BOX SET

$24 ***tamiyausa.com***

This is an ideal kit for a tinkering child, aspiring kinetic artist, or young engineer. All of the components are made of plastic, but that doesn't take much away from the quality of the kit – it's very well made and fun to assemble. By interchanging gear stages, you can get eight different ratios between 4:1 and 400:1 from the included 3V DC motor.

The primarily photo-based assembly instructions are very clear, making it easy for you to switch between different gear ratios and output shaft attachments. I found that tightening the stages together wasn't the best option – the motor would only run when there was a bit of slack in the system. Tamiya includes grease with the kit, which would perform just fine on a real robotic or artistic platform. *–Eric Weinhoffer*

BOOKS

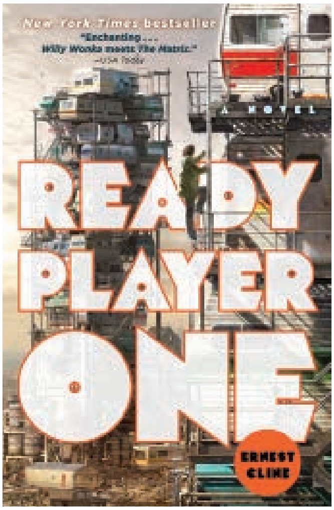


Material Matters: New Materials in Design

by Philip Howes and Zoe Laughlin

$30 **Black Dog Publishing**

This veritable catalog of materials familiar and fantastic is both a gorgeous coffee table tome and an information-packed reference. For each material, properties, applications, and sources of more information are listed alongside full-color images and short paragraphs of overview text. Interspersed are profiles of particularly interesting usages, like "Shaping with Magnetic Force." Expand your materials horizons and step into the realm of spray-on fabric and metal microlattice, the lightest solid on Earth. *—Goli Mohammadi*

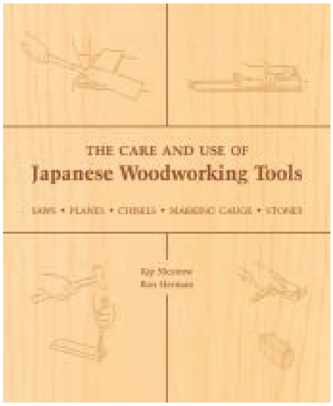


Reader Player One

by Ernest Cline

$14 **Broadway**

A good work of science fiction should be on every maker's nightstand. *Ready Player One* is on mine. Thirty years in the future, life takes place in Oasis, a vast online utopia developed by eccentric billionaire James Halliday. After his death, he leaves three keys hidden in the game, which unlock the door to his fortune. Protagonist Wade Watts, or Parzival, as his avatar is named, is taken on an 80s pop culture adventure spanning movies, video games, music, and more. *—Jake Spurlock*

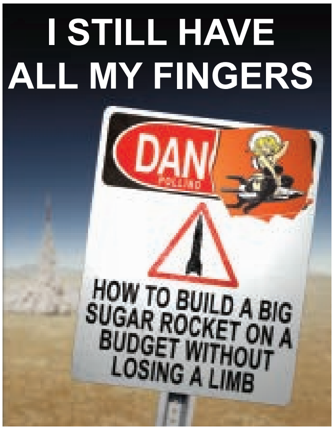


The Care and Use of Japanese Woodworking Tools

by Kip Mesirow and Ron Herman

$20 **Stone Bridge Press**

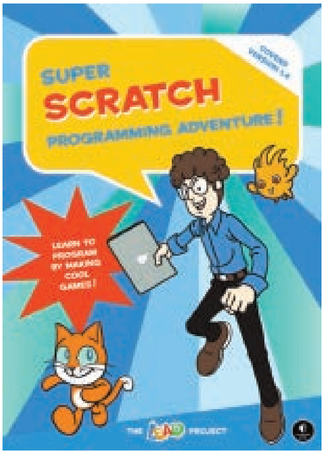
I'm a huge fan of the few Japanese saws that I own — nothing else really compares in terms of versatility and ease of use. I was thrilled when I found this book, geared toward hobbyists like myself as well as experienced woodcrafters looking to make a transition to Japanese tools. This elegantly illustrated introduction to the art of maintenance makes it clear that good habits and an intimate knowledge of how your tools work are key to tool longevity. *—Meara O'Reilly*



I Still Have All My Fingers by Dan Pollino

$30 ***Inverse Engineering Press***

In this manual for building a 72-inch amateur rocket, everything but the parachute is repurposed or scratch-built, including the motor and propellant. The rocket accelerates to over 400 miles per hour in 3 seconds and travels to an altitude of 6,000 feet. The book, like the rocket, follows a modular plan. Detailed, well-written instructions and a clear photo explain each step. More than a cookbook, nearly every step explains why. Technique, tool, or material options are given for many steps, giving experienced rocketeers flexibility. This is not a project for a beginner, but if you're at all interested in amateur rocketry, it's good reading. *—Daniel Kirk*



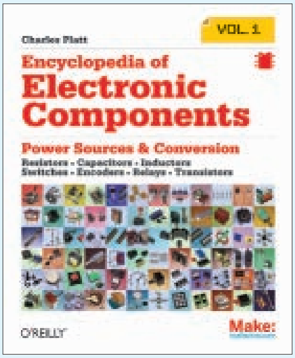
Super Scratch Programming Adventure!

by the LEAD Project

$25 ***No Starch***

The most useful thing about this book was that I learned how each block in Scratch works. The way that the author explains things is clear, but you have to read and do all of the projects to fully understand Scratch. I think it would have been better if there was a glossary or table explaining the use of each block. The example projects are, however, helpful. The programming is at a good level, but the themes and comic-strip stories were a bit young for an 11-year-old (like myself). Overall, I would rate the book a 7.5 out of 10. *—William Sidle*

New from MAKE and O'Reilly



Encyclopedia of Electronic Components

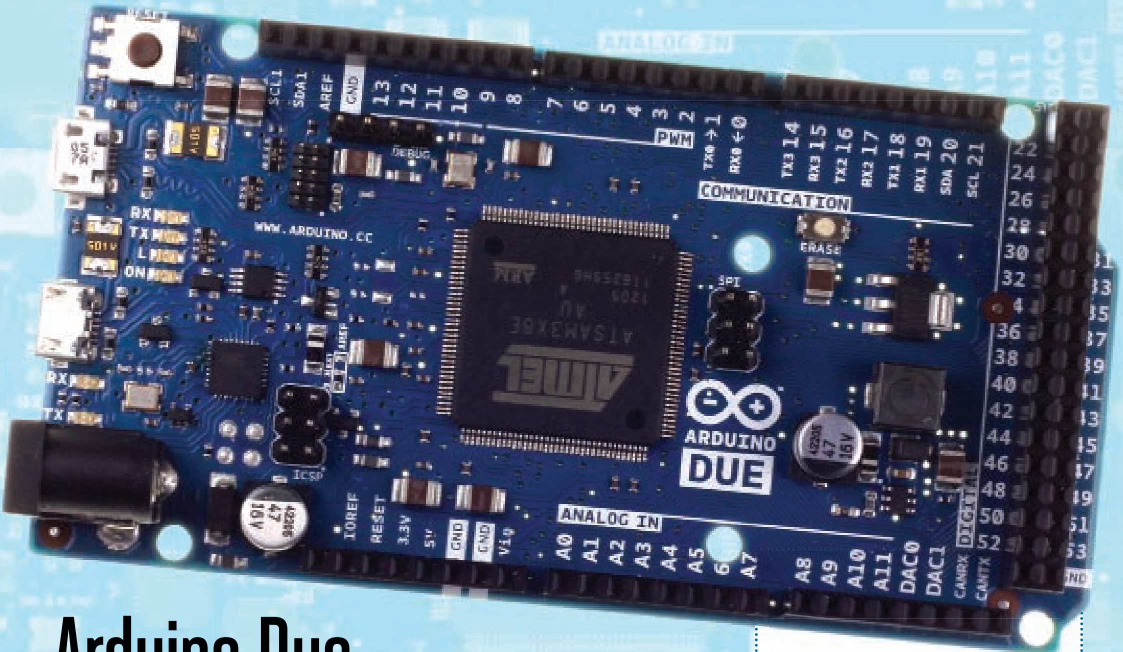
by Charles Platt

$25 ***O'Reilly Media***

Perfect for teachers, hobbyists, engineers, and students of all ages, this reference by Charles Platt — longtime MAKE contributing editor and author of the popular *Make: Electronics* book — demystifies the world of electronic components. Beginners will quickly grasp what each component does and why, and more experienced users will find a handy detailed quick reference.

What's Cool in Arduino

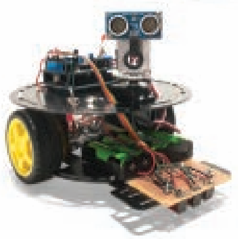
By **Marc de Vinck**



Arduino Due

$50 ***makershed.com*** #MKSP16

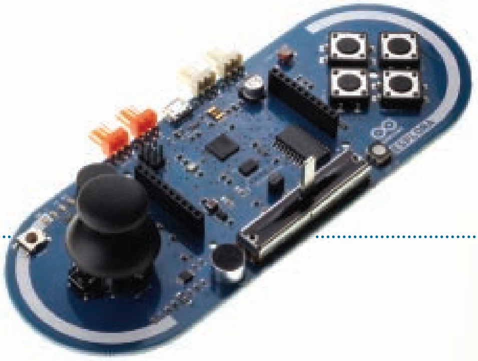
The Arduino community has been growing at a steady pace since its introduction just a few short years ago. Most users will be eternally happy with the little 8-bit microcontroller, but there is a growing community of super-users who have been yearning for more power. The Arduino Due, a 32-bit ARM Cortex-M3 based microcontroller may look like the Arduino Mega, but its handsome looks and pin-compatible layout are where the similarities end. The Due features 54 digital I/O pins (16 of which can be used for PWM), 12 analog inputs, 4 UARTS, 2 DACs, and 2 USB connectors, one for external peripherals like a keyboard or mouse, and one for debugging. Yes, debugging!



ROVERA ARDUINO ROBOT KIT

$170 (2W), $195 (4W)
makershed.com

Our new Arduino-powered robot kit and development platform. See the full review on page 36.



Make Your Arduino Plug and Play with the ESPLORA

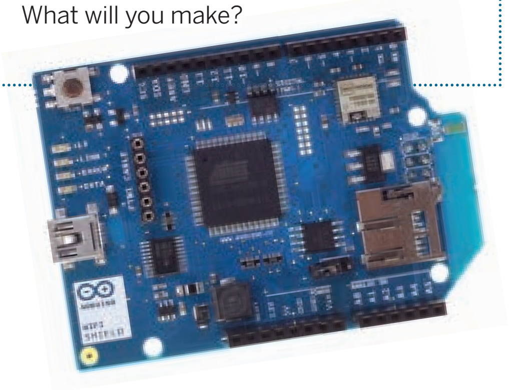
Learn more at ***arduino.cc***.

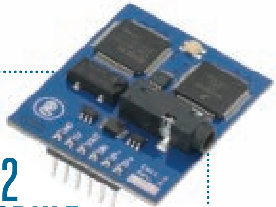
Your Arduino just got a joystick. Based on the Arduino Leonardo, this new board contains many of the most common components used by makers, including sensors for sound, temperature, and light, as well as a three-axis accelerometer and more. With an onboard joystick, D-pad-like pushbutton arrangement, LCD screen socket, and multiple TinkerKit inputs and outputs, it's instant gratification for gamers and tinkerers alike!

Make Your Arduino Connect with the ARDUINO WIFI SHIELD

$85 ***makershed.com*** #MKSP18

Introduced in August, the official wi-fi shield from Arduino makes going wireless with your next project really simple. Just download and install the official wi-fi library, which includes some sample code, and you'll be ready to join the growing community of makers building all sorts of internet-connected devices. I've got a cat who tweets and a dog who blogs. What will you make?





Make Your Arduino Talk with the EMIC 2 TEXT-TO-SPEECH MODULE

$60 ***makershed.com*** #MKPX25

Give your Arduino a voice with the Emic 2 Text-to-Speech Module designed by Joe Grand of Grand Idea Studio, Inc. Simply pass the module a little code from your Arduino and it will speak, or even sing, your text. It includes nine pre-defined voice styles with dynamic control of pitch, speaking rate, and word emphasis. It sounds great! Be sure to check out the product page for a video of the shield in action, including a bit of singing.

Make Your Arduino Write with the IOT PRINTER

$90 ***adafruit.com*** #717

Let your Arduino print out shopping lists, lottery numbers, checklists, or tweets with the Internet of Things Printer Project Pack from Adafruit. With only a minimal amount of soldering and some downloadable code, you can have your Arduino connecting to the internet and printing away. Be sure to check out the product page for a really fun video of the IoT Printer in action. Tweet, twitty-tweet-tweet, tweet, tweet, tweet.

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VISIT US ON

Invented & drawn by **Bob Knetzger**

TOY INVENTOR'S NOTEBOOK

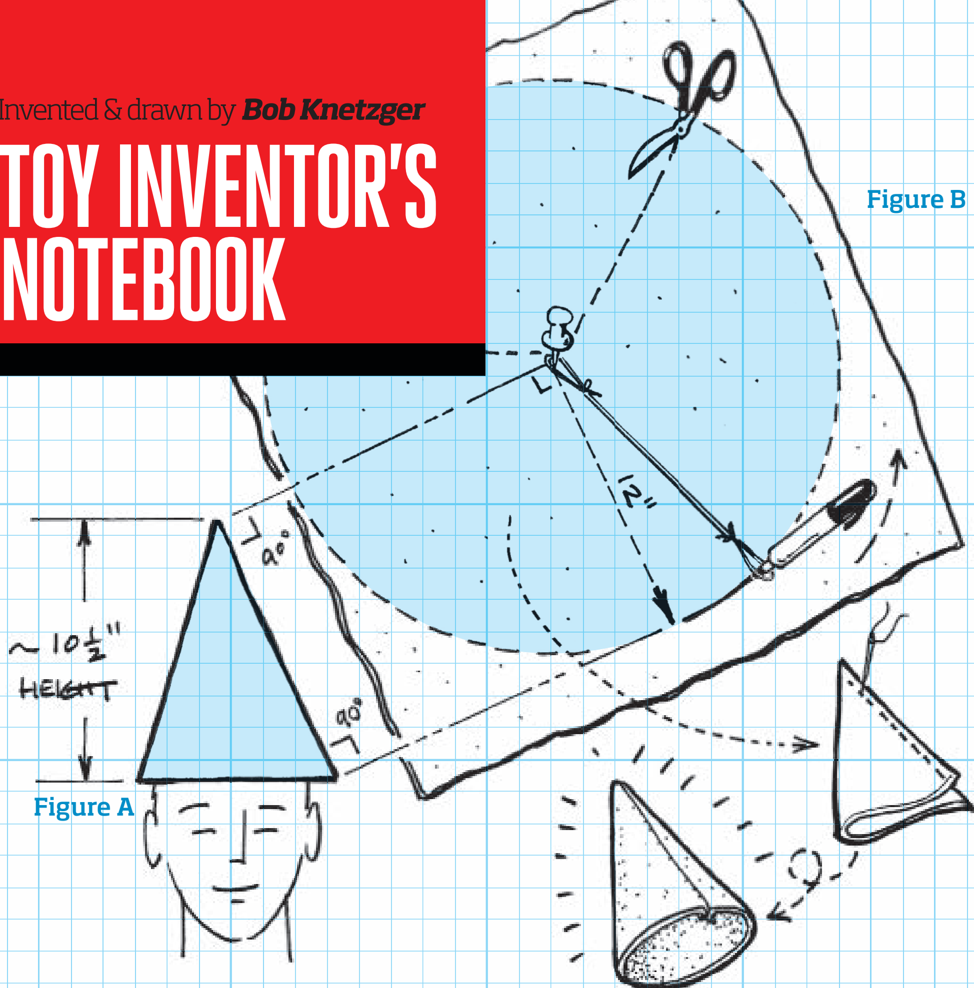


Figure A

Figure B

Gnome Math Required!

A few years ago, I had to come up with a batch of gifts to give to friends and family – fast! Our backyard garden gnome was the inspiration: I'd make felt gnome hats for everyone. All I needed to make the pattern was a little math and a piece of string.

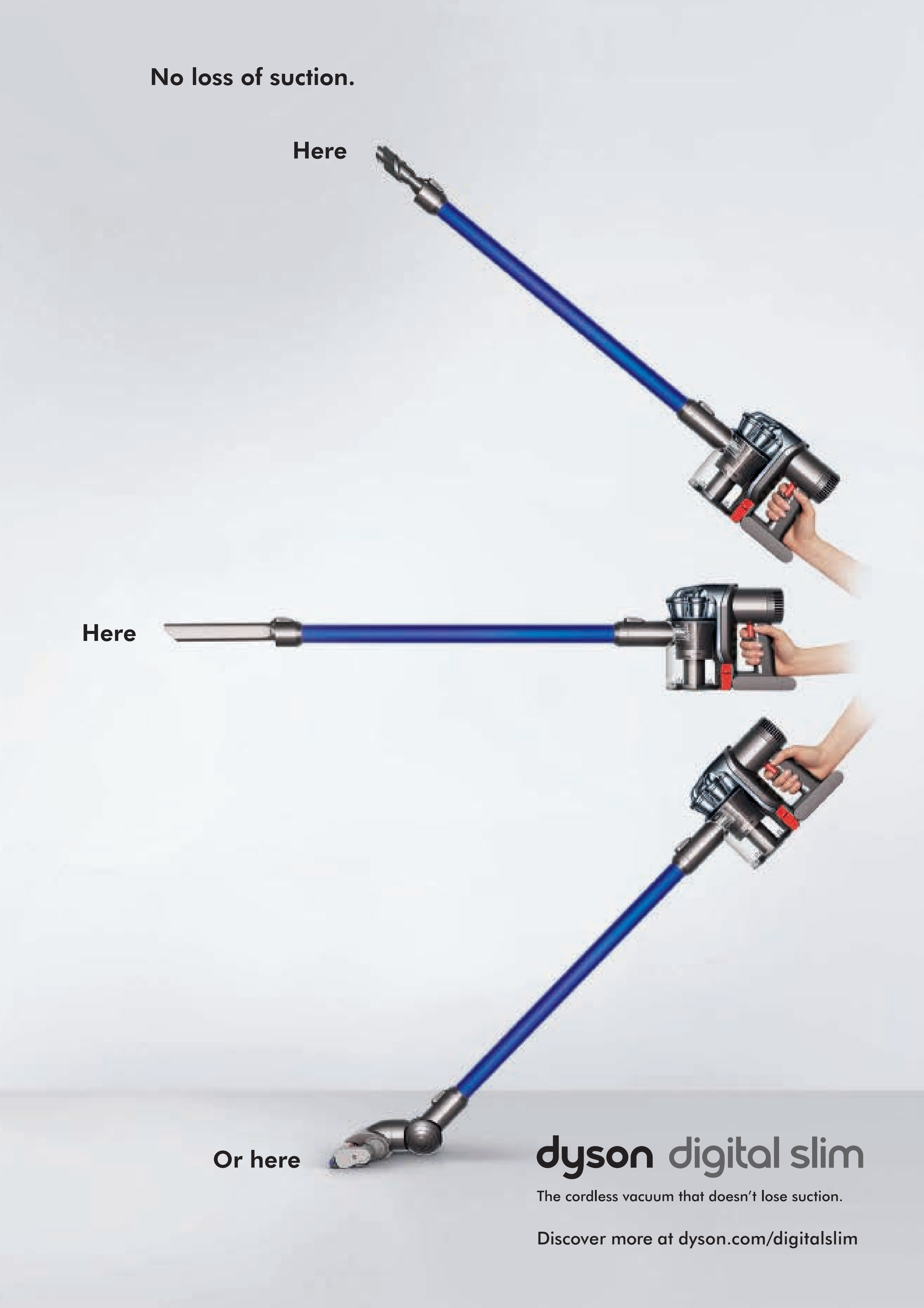
I knew the basic shape was a cone that could be "rolled" from a circular piece of felt – but what should its dimensions be?

I made a quick orthographic sketch with an auxiliary view to find out. I envisioned a cone, not too squat or too pointy, about 10½" high. In the frontal view (**Figure A**) this vertical dimension is not really the radius (it's foreshortened), but the *edge* of the cone does represent the radius. So by making an auxiliary view (**Figure B**) that's perpendicular to the projection lines, the edge view of the side of the cone becomes the true-length radius of the flat circle. Now I knew the radius dimension: 12".

To lay out the circles on felt, I tied loops on each end of a piece of string 12" long. I pinned one end to the felt as a center. I put a pen through the other loop and, keeping the string taut, drew a circle about 75" in circumference ($2\pi r = C$). A 7½"-diameter hat size has about a 23" circumference, so each felt circle yielded 3 hats.

Cut and fold each third-of-a-circle over, sew to join the edges, and turn them inside out – voilà: regulation gnome hats. (And with the leftover felt pieces, I made mini-sized gnome hats for pets!)

+ To see photos of friends and family enjoying their hats, visit makezine.com/go/gnomehats.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ISBN: 978-1-449-32765-1