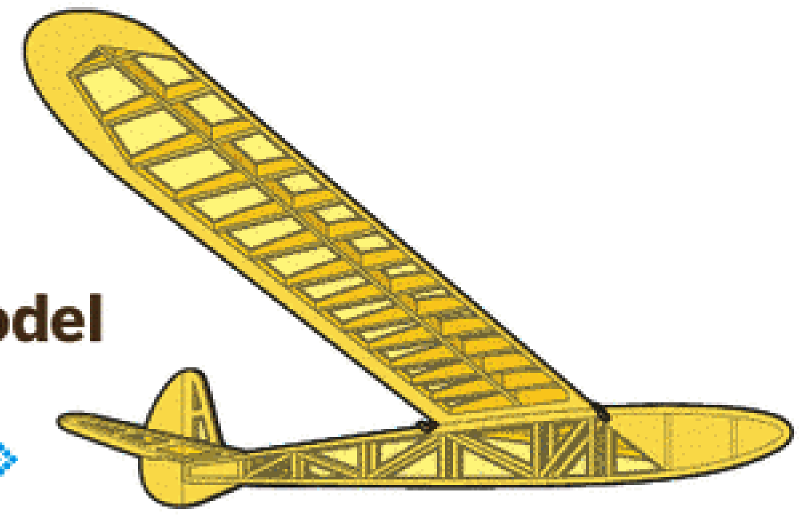
Make:

technolog ur time

Retro
Balsa Model
Airplane
page 108 »



REDISCOVER LOST KNOWLEDGE

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Volume 17

Make: technology on your time®

SPECIAL SECTION LOST KNOWLEDGE

ON THE COVER: Jake von Slatt shows how to create sparks and influence people with a Wimshurst machine. Photograph by Elena Dorfman.

READY, AIM, PUNK: Butane, brass, and fire a raygun do make.

Columns

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Making Your Way in an Uncertain Economy

Glen Kadelbach's life as a Maker began at seven years of age - long before he was a ShopBotter - when his grandfather gave him a hammer and a hand saw. Life on a farm offered many opportunities to fix and make things - like barns and gates - and as he grew, so did his interest in making. He began to make props when recruited by his photographer sister to help with her sets, and in 2002 he incorporated his first business, GR Kreations, Inc. Glen purchased his ShopBot in 2007 and added Vectric's Aspire 3D software to his Maker arsenal in 2008. He still makes photo props, but now his work also includes anything he and his customers can dream up. Today, Glen runs four businesses and uses his ShopBot to make things from whatever materials he can get his hands on - wood, plastic, foam, even cardboard. Glen's love for making continues to grow along with his businesses.

"I feel really good about my shop and the technology that I have. Owning a ShopBot along with Vectric's Aspire has opened up so many doors and has shown me so much opportunity. I would not want to be without either. Business for me is great. We have chosen not to participate in the current recession."

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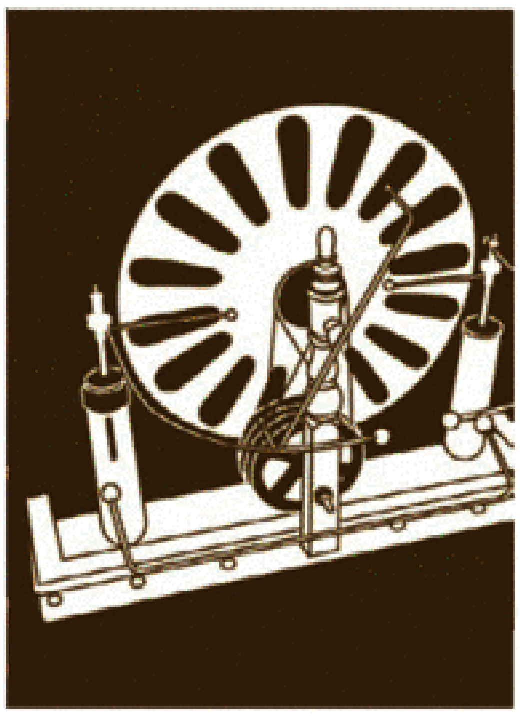

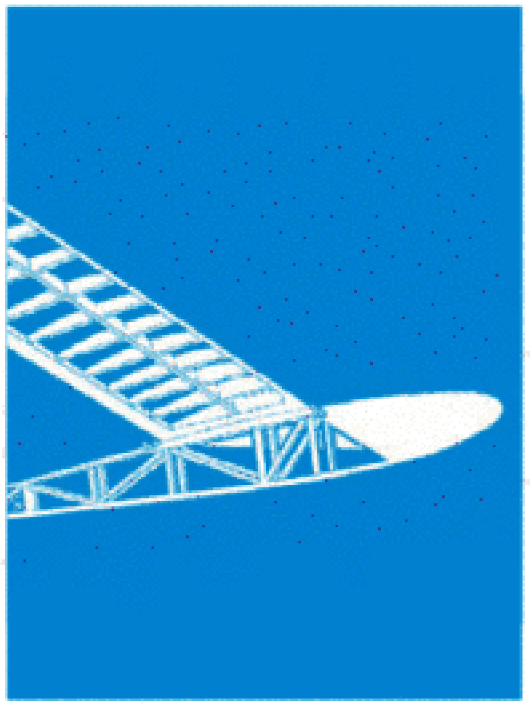

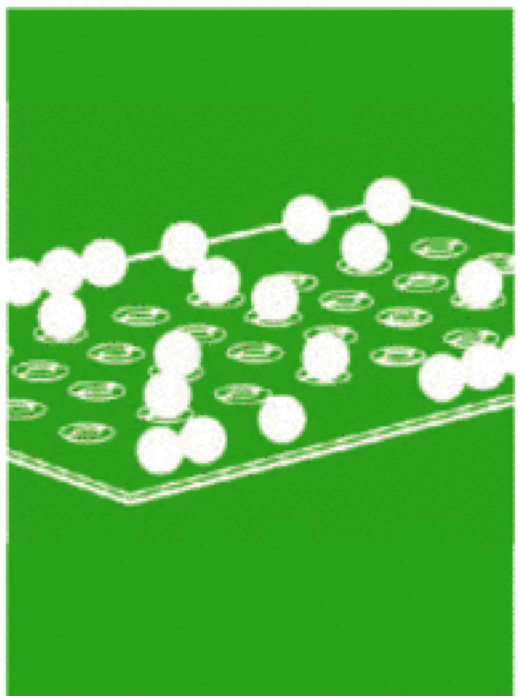

Volume 17

Make:

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READ ME: Always check the URL associated with a project before you get started. There may be important updates or corrections.

Maker

1.37

DREAM MACHINE: Japanese artist Kazuhiko Hachiya brings anime to life.

> **"It has been the risk-takers, the doers, the makers of things — some celebrated, but more often men and women obscure in their labor — who have carried us up the long, rugged path towards prosperity and freedom."**
>
> *—President Barack Obama*
> *Inaugural Address, 2009*

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Contributors

Gareth Branwyn (Special Section editor) has a confession. He's more of a ruffled-sleeved romantic than a pocket-protected geek, more artist than engineer. So it's no wonder that he's enamored with steampunk, the maker subculture (celebrated in this volume) for amateur technologists who are hopeless romantics at heart. When not hanging out under top hat and gaslight, he's a contributing editor to MAKE, a daily contributor to the MAKE blog at makezine.com, and an editor at Make: Books.

Ryan Heffernan (*Teaching Time* photography) is a location-based editorial and corporate photographer working out of Santa Fe, N.M. The goal of his photographic work is to tell stories by capturing genuine moments of humanity. He loves the challenge of distilling an everyday scene into a single, provocative frame that captures the essence of that moment and invites the viewer to share in the story. Current projects include photographing Kenyan marathon runners living and training in New Mexico. He also spends a good bit of time skiing, fly-fishing, and taking photos of his bulldogs.

Before becoming a writer, **Lisa Katayama** (Kazuhiko Hachiya profile) worked at a company in New York City that sold military equipment to the Japan Defense Agency. She is now a San Francisco-based freelance journalist who's currently working on a story for *The New York Times Magazine* about men in love with anime characters. A knitter, she likes making sweaters for her two miniature pinschers, Ruby and Malcolm, "even though they don't like to wear them." Her favorite tool is a ceramic kitchen knife she bought in Tokyo and her favorite food is "the surprise dish that comes in flavors I never even knew existed."

Frank Ford (*Tips*) has always been a maker. Before he could walk or talk, he was on the floor rummaging through Mom's kitchen cabinets and reassembling cookware; as a result, his first Christmas present was a drip coffee maker (really — he loved it!). Frank made his way through Tinkertoys, Erector Sets, models, and countless experiments, and was the only one in his college dorm with a vise mounted on his desk and a drawer full of tools. Things haven't changed much since. He's worked for the last 40 years making and restoring stringed instruments (frets.com), and five years ago, at the ripe age of 60, he started seriously on the path to be a machinist and toolmaker (homeshoptech.com).

A traditional portrait artist specializing in alternative lifestyles, **Suzanne Forbes** (*Lost Knowledge Catalog* illustrator) can also be thought of as "an extra-freaky illustrator." In her work, she sees things "that shock me even now, and I wouldn't have it any other way. San Francisco is full of creative performers, wildly stylish divas, mad genius inventors, and artists whose lives are their work. And I get to draw these amazing people, and record them for posterity. It's a privilege." The Berkeley, Calif., resident lives with her "large, manatee-like cat," and is currently working on a series of corset-themed paintings.

Jake von Slatt (*Wimshurst Influence Machine*) is the devoted husband of a very tolerant Lady von Slatt and the father of two whip-smart girls. He spends the majority of his working hours as Linux sysadmin at a small research firm in the Boston area but has recently reduced his hours to co-write a book on steampunk subculture with award-winning science fiction author Jeff VanderMeer. When Jake was 14 and his bicycle frame broke, he saw it as an opportunity not to ask his parents for a new bike, but to ask them for a welding torch. He continues to view every challenge or adversity in life as an opportunity to acquire shiny new tools!

Photograph of Gareth Branwyn by Victoria F. Gaitán; and of Jake von Slatt by Mike Pecci


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BY GARETH BRANWYN

Romancing the Steam

"Steampunk!? That's so last year!"

It's so last century and a half, actually, but who's counting? Apparently, a few people are counting, as someone always chimes in with this sentiment whenever we post anything to the MAKE blog from the alternative-Victorian subculture known as steampunk. But while some are sounding the death knell of steampunk (we hope it's a brass bell they're clanging), we suspect many readers may not even know what it is yet.

Steampunk traces its literary roots to the dime novels of Jules Verne and H.G. Wells, and the invention-adventure tales of the late 1800s eventually dubbed Edisonades. In the 1980s, sci-fi and fantasy writers like K.W. Jeter, James P. Blaylock, and Tim Powers began placing their "gonzo-historical" fantasies in an alternative 19th century, where high tech mixed with gaslight, brass, and steam.

Bruce Sterling and William Gibson's 1990 novel, *The Difference Engine*, fully crystallized the genre, positing a central question: what would have happened to the future if Charles Babbage's design for his "difference engine," a proposed Victorian-era mechanical computer, had actually been built and the digital revolution had begun a century earlier? From this fertile question, a thousand speculative fictions bloomed.

Then something interesting happened a few years ago. Unlike other designer subgenres of sci-fi, steampunk's consumers didn't just want to read it anymore, they wanted to build physical expressions of it. They wanted to *be* steampunk: to dress the part, make the fantastic gadgets, and blog about it on brass-and-wood-modded computers. Think of it as Steampunk 2.0, a participatory genre that's leaked off the page and into the real world, smudging the margins between fantasy and reality, the last two centuries, and technologies of the past, present, and future.

While there's plenty of debate as to why steampunk fans insist on taking it so far, its actual practitioners tend not to overthink it. We like our cover spokesgentleman Jake von Slatt's approach. In episode 3 of *Make:* television (makezine.tv), he says: "What makes steampunk important is the community it's created — an incredibly diverse community of people: 65-year-old steam hobbyists in the U.K., fans of goth-industrial music in Seattle, people interested in making steampunk clothes, fashion, jewelry, and so on. My greatest hope for steampunk is that it will continue to attract people into this really wonderful community."

Von Slatt calls himself a "maker who happens to work in a steampunk style." He sees steampunk as a kind of carrier wave for holding people's interest in the art of making things. At Maker Faire, you'll find many other enclaves of people riding on different maker carrier waves: art car builders, mutant bicycle makers, robot combatants, fire artists, circuit benders, and many more. They're all makers; they're just working in whatever aesthetic appeals most to them.

For those who love the intersection of romance and technology, and fancy reviving the cooler aspects of the Victorian era, steampunk has obvious appeal. If it's not your cup of tea, there are plenty of other maker communities that'll gladly welcome you into their garages, too.

We're calling the theme for this issue Lost Knowledge, because we want to cast our net wider than steampunk — to explore any type of forgotten technology, from ancient Greek computers to analog copying machines to apocalyptic zine printing of the 18th century — and because we're suckers for a little techno-romance ourselves. But obviously, it's not lost or it wouldn't be in these pages.

In fact, technology may be difficult to lose. In a recent interview, technology scholar and *Wired* co-founder Kevin Kelly observed that, unlike biological species, technologies are actually hard to drive into extinction. For example, there are now more people flint-knapping (making stone arrowheads) than during its prehistoric heyday. Why? Because people enjoy keeping old skills alive. And it's fun!

It's also proof that, along with steampunk, there are countless technological carrier waves from the past. So find one that appeals to you, climb aboard, and start making! Dressing the part is up to you.

Gareth Branwyn is a contributing editor for MAKE.

BY CORY DOCTOROW

Love the Machine, Hate the Factory

We've heard a lot about how scary the industrial revolution was — the dislocations it wrought on the agrarian population of the early 19th century were wrenching and terrible, and the revolution was a bloody one. From that time, we have the word *Luddite*, referring to uprisings against the machines that were undoing ancient ways of living and working.

But the troubles of the 1810s were only the beginning. By the end of the century, the workplace was changing again. Workers who'd adapted over three generations to working in factories at machines, rather than tilling the land and working in small cottage workshops, once again found their lives being dramatically remade by the forces of capital, through a process called "scientific management."

Scientific management (which was also called Taylorism, for its most prominent advocate, Frederick Winslow Taylor) was built around the idea of reducing a manufacturing process to a series of optimized simple steps, creating an assembly line where workers were just part of the machine. Each worker's movements were as scripted as those of a cog or piston, defined by outside observers who sought to make the work go as smoothly as possible, with as few interruptions as possible.

Taylor, Henry Ford, and Frank and Lillian Gilbreth used time-motion studies, written logbooks, high-speed photography, and other empirical techniques to find wasted motions, wasted time, and potential logjams in manufacturing processes. Practically every industry saw massive increases in productivity thanks to their work. The Gilbreths' research gave us modern surgical procedures, touch-typing, and a host of other advances to human endeavour.

But all this gain was not without cost. The "unscientific" worker personally worked on several tricky stages of manufacture, often seeing a project through from raw materials to finished product. He or she could choose how to sit, which tool to use when, and in what order to complete the steps. If it was a sunny day with a fine autumn breeze, the worker could choose to plane the joints and keep the smell of the leaves in the air, saving the lacquer for the next day. Workers who were having a bad day could take it easy without holding up a production line. On good days, the work could fly past without creating traffic jams farther down the line.

For every gain in efficiency, scientific management exacted a cost in self-determination, personal dignity, and a worker's connection with what he or she produced.

> The biggest appeal of steampunk is that it exalts the machine and disparages the mechanization of human creativity.

For me, the biggest appeal of steampunk is that it exalts the machine and disparages the mechanization of human creativity (the motto of the excellent and free *SteamPunk Magazine* is "Love the Machine, Hate the Factory"). It celebrates the elaborate inventions of the scientifically managed enterprise, but imagines those machines coming from individuals who are their own masters. Steampunk doesn't rail against efficiency — but it never puts efficiency ahead of self-determination. If you're going to raise your workbench to spare your back, that's *your* decision, not something imposed on you from the top down.

Here in the 21st century, this kind of manufacture finally seems in reach: a world of desktop fabbers, low-cost workshops, and communities of helpful, like-minded makers puts utopia in our grasp. Finally, we'll be able to work like artisans and produce like an assembly line.

Cory Doctorow lives in London, writes science fiction novels, co-edits Boing Boing, and fights for digital freedom.

Tales of inspiration in school and debates on artistic expression.

I really enjoy your magazine and read it cover to cover. One thing I like is the small gadgets and projects in the magazine. It's so interesting I can't stop reading it! I am 12 years old and we get it at school. My whole family loves it too.

—Michael Jon Nisly, Hutchinson, Kan.

I'm no Judy Garland fan (nor do I dislike her, for that matter), and I'm rarely the first person to push for political correctness. But I have to say that in the Ghost Phone article [*Volume 16, "The Disembodied Voice of Judy Garland Speaks"*], the suggestion of pills and liquor on the night table is in really poor taste. Given that Garland died of a drug overdose, I would think that her family and friends would find the article ugly.

MAKE, to me, is a classy publication that rates "things which create wonder" high in priority, and rates the salacious and snarky very low in priority. This feels more like Perez Hilton. This piece was below you, and I felt very put off by it. Not the best editorial call, MAKE.

—John Cornwell, San Francisco, Calif.

Author Greg MacLaurin responds: My focus for the article was to share the Ghost Phone idea with everyone. The idea of bringing old telephones alive by hiding an MP3 player inside is simple and wonderful, and I want other people to create their own art with it. One person told me that she has some cassette tapes of her long-lost mother on an answering machine, and now she wants to create her own Ghost Phone with that. It's perfect! And since the Judy Phone was my first Ghost Phone, it made sense to use it as an example. But the article is about process, and not the Judy Phone.

Some people don't like the Judy Phone. But when people see it in person, they sit on the bench, pick up the phone, look at the pills and booze, and listen to Judy talking about her own life. They begin to think a bit about who she was. This is art that has layers. Sure, it seems strange and silly on the surface, but that wasn't my intention, and fortunately it's not the impression that people get when they experience it.

I've been surrounded by lots of death and tragedy, and my art reflects this. It's not unfeeling. It's deeper and truer. Like the Judy Phone.

I just received the latest MAKE, and was quite pleased to see one of the letters from readers was a positive note from a 5th grader on his wind tunnel build based on my article [*Volume 15, "Model Wind Tunnel"*]. This brought an ear-to-ear smile to my face.

A side note: This week I was asked to give a talk at my son's elementary school about aerospace engineering. Besides the wind tunnel, I brought a rocket cam from MAKE [*Volume 07, "Rocket-Launched Camcorder"*] that was a huge hit — especially when I played the video. There were tons of energized kids wanting to go off and build things afterward.

My next project is mounting a CVS camcorder on a Pinewood Derby car to film a race as it happens, then next, building a 5-launch-rod digital model rocket controller for the Cub Scout rocket derby. Fun stuff! What a great magazine!

—Doug Desrochers, Burke, Va.

MAKE AMENDS

The name of photographer Pat Molnar was misspelled in MAKE, Volume 16. We regret the error.

In Steps 2 and 3 of "Hacking the Glade Wisp" in Volume 16, references to a 150MHz signal should have been to a 150kHz signal.

On page 155 of "Chatter Telephone" in Volume 16, the Hang-Up Hinge instructions ask you to drill "four ¼" holes through the sides of the phone," but they should in fact be four ⅛" holes.

In "DIY-brary" in Volume 16, several errors eluded fact-check: Rick and Megan Prelinger shared an interest in the American landscape (not landscaping), and Rick considered restarting *Landscape* (not *Landscaping*) magazine. Also, the Prelinger Library and the Internet Archive challenged a 1992 copyright law that automatically extends copyrights up to 75 years (not 50). Thanks for the corrections, Rick, and we're sorry for the mix-up!

MAKER'S CORNER

BY DAN WOODS

Penny for Your Thoughts

One of the reasons this is the coolest team I could ever hope to work with is that we all get to wear different hats. But it's no secret around the MAKE office that my favorite hat of all is general manager of the Maker Shed store. What's not to like? I get to exchange ideas with everyone about new kit ideas, tools, toys, microcontrollers, books, games, and yes, projects that we think ought to be kits but aren't yet.

Over the past two years, our store has grown considerably in terms of the number of people we reach, number and variety of products we carry, number of indie makers supplying products, and even the size and spectacle of our physical pop-up stores at Maker Faire (about 10,000 square feet and growing). Maker Shed is the fastest-growing piece of our business right now. In fact, during two of the gloomiest months for retail in the past 40 years, Maker Shed 2008 holiday sales were up 79% over prior-year holiday sales.

We're apparently doing something right here. But we can't take all the credit. Our formula is pretty simple, really. We have a team of smart people who take the time to visit schools, clubs, and community events; ask a lot of questions; and listen to what you have to say.

However, we're not resting on our laurels. I want to hear from even more of you. On your terms. We're putting up a simple survey at makershed.com/survey. I invite you to take it and share your thoughts. However, if you'd prefer to simply jot down your thoughts in an email, I'd be delighted to read it. I'm dan@oreilly.com. Want to see more products of a particular type? More science projects? A certain kind of tool? Kits for a certain age group or maybe classrooms? Maybe you'd like to see our store arranged differently, or perhaps get club or group discounts. Whatever comes to mind, I'd love to hear about it.

Most importantly, if there's one project kit you've always thought would be cool, or a maker toy you remember from years ago but haven't been able to find, drop me a line. Maybe we can find it or we know of a maker supplier who'd be interested in making it for us.

If you've shopped at the Maker Shed, thank you. If you haven't, I invite you to peruse the store at makershed.com and then take our survey or send me an email and tell me: What can we do to make the place even more interesting or useful for you?

Dan Woods is associate publisher of MAKE and CRAFT.

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How-To Tuesdays
Each week we build something from the pages of MAKE, the Maker Shed, or just something the makers out there send us. Check the site each week on Tuesday and also take a look at our past builds!
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MADEONEARTH

Report from the world of backyard technology

Photography by Wesley Fleming

Going Buggy

Although many (or all) of us try to keep our encounters with bugs short and infrequent, glass artist **Wesley Fleming** likes to spend all day with them. With an entomologist's passion and meticulous attention to detail, he recreates them in the form of tiny glass sculptures.

"There's nothing more weird or crazy than bugs," says Fleming, who lives in Bozeman, Mont. And he's always been interested in odd creatures: as a kid he loved the characters from *Star Wars* and comic books; at the toy store, he picked the strangest-looking action figures. Fleming remembers that he was especially fond of characters that combined human and insect features.

Fleming first had the inkling to work with glass after purchasing a single lampworked bead in 1999. Intrigued by the colors and shapes on the bead's surface, he began taking classes and ultimately, quit his full-time job to pursue glass sculpture.

After happening upon an insect collection at an art show, he knew that he wanted to focus his work on the intricate surface textures, shapes, and colors of bugs.

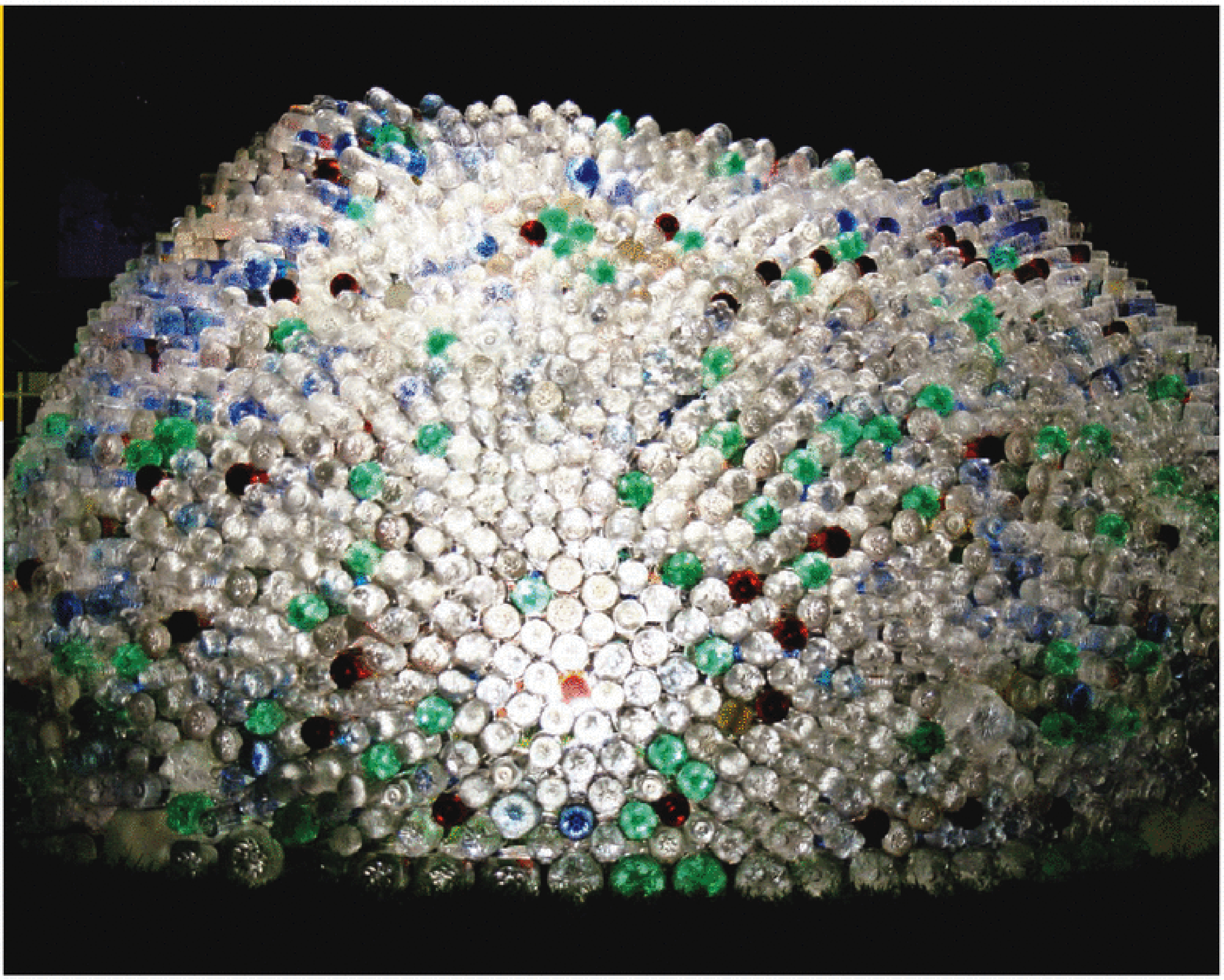
Fleming forges the fine details of each "specimen" by controlling the heat on his torch. First, he heats the glass to a honey-like consistency, and then he plays with gravity, surface tension, and layering to create each miniature.

The bugs are rendered in painstaking detail, especially considering their finished size: on average, 2 to 3 inches.

How realistic are the glass bugs? While traveling in Turkey, Fleming showed one of his beetle sculptures to a shop worker, who jokingly placed it on a friend's knee. Startled, the second friend jumped up and brushed away the "bug," shattering it. Although it was frustrating to lose the piece, Fleming considers it the highest compliment to his work.

—Linda Permann

>> **Fleming's Sculpture Gallery:** wesleyfleming.com



Super Green Greenhouse

Jasmine Zimmerman, like many of us, was thinking that there must be something cool and useful she could do with all those used plastic bottles. So when she was commissioned by Solar One in New York City to create an environmental installation for the 2007 Citysol festival, she decided to act on her thoughts. Zimmerman used hundreds of plastic bottles to create a functional greenhouse.

The Bottle House ties in nicely to the green themes now popular at art festivals. So far, the multidisciplinary artist has created two Bottle Houses, one for the Citysol fest and the other for the 2008 Bumbershoot festival in Seattle. Both were well received. "It's an excellent example of repurposing a harmful and overlooked material into one that will grow vegetation," points out Inhabitat blogger Alexandra Kain.

The most difficult aspect of creating the greenhouses was maintaining the structural integrity. The bottles are held together with permanent silicone, and Zimmerman found that she has to build the houses at a specific pace so that the silicone sets up correctly as she creates the inclines of the walls.

Both beautiful and practical, the Bottle Houses are intended to raise awareness around bottled water consumption. "I wanted to use everyday, discarded materials to transform our waste into the birth of new life," she says, pointing out that Americans consume more than 90 million bottles of water every day, and only one in five bottles is recycled.

You may be familiar with some of Zimmerman's other work: her rubber band installations around Manhattan have been featured on Boing Boing, and she was recently awarded an artist residency at the Museum of Glass in Tacoma, Wash.

Zimmerman plans to exhibit the Bottle Houses in empty lots, rooftops, parks, and vacant buildings to help spread the word. She hopes her work will have an effect on the choices people make in everyday life. And maybe others will be inspired to make something cool and useful out of all those plastic bottles.

—Bruce Stewart

>> **Zimmerman's Projects:** jasminezimmerman.com

Photograph by Charles Ellis

Photograph by Clifford Hill

Hennepin Crawler

If a camel is a horse designed by committee, then what is the Hennepin Crawler?

It looks like a jalopy, but it's really a big bike, designed by **Krank-Boom-Clank**, four Santa Rosa, Calif., artists who wanted to build something that moves as gracefully along railroad tracks as it maneuvers around the playa at Burning Man.

Two of the members, **Clifford Hill** and **Skye Barnett**, had built an art car for Burning Man in 2007. For the Crawler, they drew in fellow welders **David Farish** and **Dan Kirby**.

"It was a very organic process," says Barnett. "The only thing we had set was that it would be pedal-powered and that it had four seats — since there are four of us."

They also got involved in planning a local event, the Great West End & Railroad Square Handcar Regatta, which aimed to raise awareness for transportation beyond the car, including bikes and commuter rail. So they designed the Crawler (Farish was fond of the antique-sounding Tom Waits song "9th and Hennepin") to ride the rails, too.

Found materials helped dictate the design: Barnett returned from one dump run with a $15 metal hammock holder. It eventually became the centerpiece of the Crawler's curvy chassis.

"I refer to it as improv, because we were using metal like Play-Doh," says Hill. "We would try something, break it if it didn't work, try something else." They got together once a week — "Our Thursday night TV watching got all screwed up," says Kirby — and cranked into the night to get it finished.

Now they pedal it out to community events, where it draws a lot of interest. "People ask who designed it," says Hill. "Everybody pulled their weight. People can't handle that."

Hill says their goal is to "plug this notion of art and celebration in a public context, inspiring more people to do creative things with bikes, especially kids."

"Kids see it, they find out there's bike parts in it, and then they realize they can make something like that," says Farish. *—Dave Sims*

>> **Hennepin Crawler:** krankboomclank.com

Power to the People

What do you get by combining a spinning wheel with electricity? An energy and economic resource poised to transform rural India, of course.

Bangalore-based engineer **R.S. Hiremath**'s "e-charkha" starts with the charkha, a hand-cranked tabletop wheel that spins yarn from raw cotton and other fibers, and was promoted by Mahatma Gandhi as a symbol for Indian independence. He then updates it and equips its base with a generator that stores spinning energy in a lead-acid battery, which can then power an LED light or small transistor radio. Two hours of spinning creates enough energy to provide at least 7.5 hours of electricity, a boon for rural India's developing villages.

Hiremath's idea for the invention came as a child, while playing with both his grandfather's charkha and a bicycle equipped with a hub-dynamo, or an electrical generator that powers an attached light.

"This interested me to see how the charkha and dynamo could be joined together to produce electricity," he says. "It took almost 35 years for me to figure out all the parts to suit rural India."

With a patent that includes magnets, winding wire, driver circuits, gears, and mechanical components, the e-charkha brings new possibilities to India's masses. Spinners can now work longer hours generating a commodity — yarn — while keeping current on agricultural news and weather, or listening to music. They can also read books without resorting to toxic kerosene lanterns.

Growing up in India's small towns and villages, Hiremath learned what it's like to live in pitch darkness. After completing a mechanical engineering degree in Karnataka, India, he started M/S Flexitron, an organization focused on developing low-cost appropriate technologies for rural India. The e-charkha is one of more than 270 such products.

Since late 2007, thousands of e-charkhas have been distributed for free in rural India's most remote areas through a government-sponsored program, with a target goal of 300,000 to 1.2 million over the next three to five years.

—Laura Kiniry

>> **Flexitron Company:** flexitron.fuzing.com

Photograph by Yashwanti Pritri

Photograph by Christopher Tallon

Paper Hardware

Los Angeles-based **Christopher Tallon**, a graduate of the UCLA School of the Arts and Architecture, engages the histories of both fields in his playful reiterations of hand tools, free weights, and other decidedly un-fragile objects.

Reminiscent of Baroque *trompe-l'loeil* murals, Tallon's true-to-life sculptures are inspired by the most prosaic, even macho, objects, remade with the simplest of raw materials: paper.

But what is a new hammer or a pristine set of wrenches when the first tap or twist will ruin it? Upon reflection, Tallon's works address utility and its absence. More directly, they're just plain fun.

Tallon's paper barbells, saws, and vises have been exhibited in galleries in L.A. and San Francisco and, in late 2008, in a juried exhibition at the Los Angeles Municipal Art Gallery. In a city crawling with artists — at least 600 entered the competition — Tallon's surprisingly fresh-looking tool bench was a highlight (it took second place), and his meticulous craftsmanship is the key.

It would be easy to mistake Tallon's replicas for the real thing, but the hitch is that none of the objects he duplicates are intended to be as clean as the resulting facsimiles. Even a tool bench in a store display would likely bear some mark of its use; after all, tools are supposed to be dirty.

At a time when U.S. manufacturing — and school courses in woodworking and machine shop — are threatened with extinction, Tallon's unused and unusable tools take on new meaning.

The recent economic downturn might indeed have Americans rethinking their disregard for the value of making. But if the age-old dyad of "man and his tools" does come to its rest, Tallon will ensure that it has a cheerful coffin.

—Annie Buckley

>> **More of Tallon's Tools:** latchgallery.com/tallon

In the Round

From a small town in the Black Hills of South Dakota, **Dick Termes** turns his artist's eye to the globe. Literally. No flat surfaces for this painter; rather, his Termespheres invite the observer into another dimension that allows us to perceive the world as if in real time.

Imagine you're in a beautiful building and you rotate slowly around to see every surface — the walls, the ceiling, the floor. Now you're Termes, so you use six-point perspective to paint this total view on the outside of a sphere. Six-point allows you to draw the total — up, down, and all around — scene.

Over the past 32 years, Termes has painted rooms, buildings, towns, nature, and a myriad of subjects from this unique perspective. "In art, the most important thing to find is an original thing to do," he says. "The sphere adds a whole new set of geometries that fits with the real world better than a flat surface."

Termes starts with plastic spheres he buys from light fixture factories, or for the larger globes, direct from Union Oil Company. He then sandpapers, gessoes, and paints with acrylics.

In addition to his artwork, Termes holds workshops to share his methods and enthusiasms with a far-ranging group of students, including Lakota Sioux children in South Dakota, mathematicians, Jungian society members interested in dream worlds, and art lovers worldwide.

His passion for art, science, and philosophy are evident, but as he says, "Total visual space, of course, has been my main interest."

The sphere seems to reflect the balance and harmony in Termes' life. He and his wife live in four domes with his ongoing creations of global beauty.

"I am happy with my life. I think I have a good balance, maybe because I work with the sphere and the sphere is so perfect: it relates to the globe — Earth — with its geometries and design problems."

—Donna Tauscher

>> **Termes' Worlds:** termespheres.com
Termespheres in Motion: makezine.com/go/termes

Photograph by Dick Termes

Transatlantic Tunnel

Photograph by Karl Hindson, courtesy of Twofour Digital

In May 2008, a group of us ventured out to the Fulton Ferry Landing in Brooklyn, N.Y., to explore the mysterious Telectroscope by **Paul St George**. We'd read about this strange and beautiful Victorian-era apparatus, but none of us had experienced it up close.

As the story goes, St George is the great-grandson of Alexander Stanhope St George, who, in the mid-1890s, came close to completing one of the greatest engineering feats of all time — a transatlantic tunnel connecting New York and London via a curious contraption dubbed the Telectroscope.

The Telectroscope is a powerful telescope, but instead of peering into the heavens, it sees through the Earth, connecting New York to London, 3,500 miles on the other side. Both the tunnel system and this optical device were marvels of Victorian engineering, and the project has ended up taking more than a century to complete.

There is an alternative, equally interesting theory on how the Telectroscope is connected. This story doesn't start in the late 1800s, but rather, the early 2000s. The project was brought to life by the artist St George and produced by Artichoke, a London-based creative organization known for its extraordinary public shows. They worked with Tiscali, a telecommunications firm, and Twofour Digital, a media company, to create an ultra high-quality video conferencing system.

Each Telectroscope houses a Sony EX1 camera, a Breeze Technologies Ice Blue encoder/decoder, and a Sanyo XP-100 projector. The camera captures the video and the encoder/decoder converts it to an MPEG-2 format. The video is streamed over a Tiscali VPN fiber network, then data is decoded and projected onto the internal screen. The result is an amazingly realistic real-time image 6 feet in diameter, housed within the Telectroscope itself.

In the end, the story of St George's great-grandfather may have some truth to it. The Telectroscope is a transatlantic tunnel between New York and London, only it's digital, not analog.

—Marc de Vinck

>> **The Amazing Telectroscope:** telectroscope.net

MAKING TROUBLE

BY SAUL GRIFFITH

The Year of Peak Waste

Yes, we are all depressed. It appears to me that everyone I know is working harder than ever before, scrambling in this strange new world that was thrust upon us while the Global Economic Crisis took hold of our little monkey brains and made our primate instincts do the worst: panic.

But maybe, just maybe, it's the best news ever. Perhaps it's actually fantastic. Let's look at some data: in terms of energy use and, consequently, carbon output, the only proven technology humanity has for reducing CO_2 output at the global scale is economic crisis (see graph). The data is not yet in for 2008, though given that OPEC slashed production multiple times in the latter half of 2008, it looks as if, once again, recession has provably reduced our "reliance" on carbon-based fuels.

So while you sit there contemplating employment uncertainty, take solace in the fact that the dolphins are probably doing backflips of joy, and polar bears are likely hibernating in a slightly more secure Arctic, dreaming of a few extra years of viable ecosystem ahead. The reality is that all of our economic activity, whether it be buying gas to fill our cars, or buying stuff to fill our houses, or even food to feed our stomachs, uses energy from one source or another. This is why, knowing how much money you spend, you can estimate with reasonable accuracy how much energy you use, and how much CO_2 you are responsible for putting into the atmosphere.

This equation is why there is a conversation in the circles of people who think about climate change and energy about "decoupling" the economy from CO_2. Simplistically, there are two ways this decoupling can be achieved. The first is by swapping clean energy sources for dirty ones. Electric cars run on solar-power electrons instead of oil. Wind power instead of coal. Geothermal instead of natural gas. The second decoupling happens when we achieve the same quality of life and service, at much lower energy or carbon output. How can this be realized?

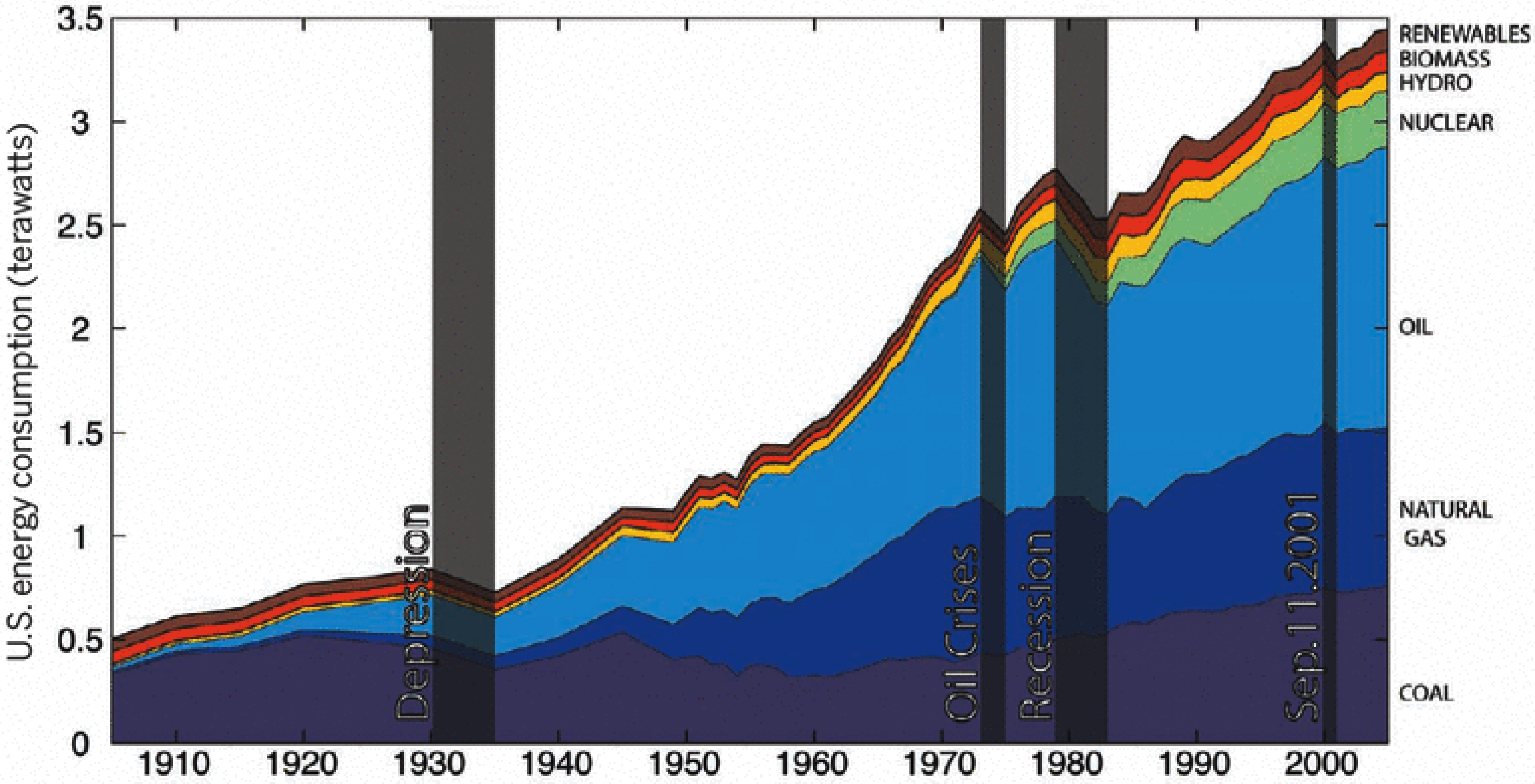
In the last decade or so, efficiency gains in the steel industry mean that we can now produce steel with 10%–20% less energy than previously required. Better refrigerators use less energy per unit of food kept cool and fresh. This side of the energy equation is often called efficiency. Efficiency can get us a long way, but for many things that we do, or find "necessary" in modern society, we already do them surprisingly efficiently.

Globally, the best models suggest we need to reduce the amount of carbon going into the atmosphere by 80%–90% by 2050. That's a lot. It looks incredibly unlikely that we'll figure out how to make steel with 80%–90% less energy or CO_2 produced. That's also true for aluminum, plastics, paper, and most modern materials. What does this mean? It means we need to use less of all of those materials, which means making products that last longer. It means repairing those products. It means maintenance.

> By being more careful and thoughtful about *what* we waste, we could have *quality* consumption.

Let's try and imagine the beautiful version. Children will play with beautifully engineered wooden toys without toxic additives in small plastic parts. The wooden toys will be repaired as necessary between generations. You will have handsome shoes, repaired by a cobbler. Instead of dealing with a website or superstore, you'll interact with someone who is interested in the weather that you share, how your shoes are performing, and whether you are using beeswax treatment often enough to keep the shoes soft and waterproof. Rather than unflattering Ikea generics, you'll own beautiful furniture, handmade and well oiled and polished.

Why would I bring this up now? Isn't this the steampunk issue? Let me give you a glimpse into my thoughts right now. I'm writing in December of 2008. We are in the midst of the economic stupidity. Twice this week there were blackouts on my street. They hit me with an overbearing relevance: I was reduced to candles, there was no wireless internet, and my house was quiet. Peaceful, actually. I made soup on my gas stove and used two tea candles



RECESSION POWER: Historical data implies that we reduce energy consumption during economic downturns. The question of our times is how we reduce energy consumption while retaining a vibrant and interesting economy.

each night to light my endeavors. I actually had time to sit and think. Just a notebook, a pen, and some candlelight, all sprinkled with calm quiet — real thinking time.

I had just been in London with a friend, Matt Webb. We discussed consumerism, and the economy, and the environment in combination. He posited that 2008 would become known as the year of "peak consumption." I liked the term and the concept, but I think that "peak consumption" implies a diminished quality of life. This made me think about peak waste, which is essentially the same, but with an important nuanced difference. We all, it seems, want to know how to live better, and how to live in a way that's less damaging to the environment. Peak waste seemed to encompass this idea better, the idea that we should strive for a higher quality consumption through lower waste.

All these things seemed to tell a larger story to me. When I think of steampunk, I think of a movement that glorifies the period of the new industrial revolution, that first moment when people really started to enjoy fossil fuels. At the same time, steampunk is also nostalgic for the craftsmanship and brass-and-walnut engineering that was typical of that period. "Lost knowledge" seems to typify what we lost after that early mix of craftsmanship and the new industrial revolution. I'm sure I'm glorifying the moment, and historians will prove me wrong, but I see an opportunity in the concept of steampunk.

It appears we can worship the new and embrace it, but by reducing our consumption of the old, being more careful and thoughtful about *what* we waste, we could have *quality* consumption. A consumption that considers the human element, and doesn't outsource it. A consumption where you know the person who made your bicycle or your music player. Not a consumption where all you know is that your shiny iPod was made in foreign lands and magically teleported to you in a pristine and hygienic retail store using unknown amounts of CO_2-producing energy. The economics of this clearly need some ironing out, but we've managed to create an incredibly complicated credit system for buying a lot of poorly made things, so it should be possible to use it to instead buy a few well-made things.

So, as we sit, unemployed and fearful of the unknown future, perhaps there is something beautiful to occupy makers. We can do the *Fahrenheit 451* of making, each of us picking up a legacy trade or skill and learning it to a degree that it can be taught and passed on, and introduce a more human face to the technology we take for granted. We can even make that technology "green." Let's make sure 2008 was the year of peak waste.

Saul Griffith is a co-author of *Howtoons* and a MacArthur fellow. saulgriffith.com

Image by Saul Griffith and Jim McBride

BY BRUCE STERLING

The Kosmos in a Box

We call it the Antikythera Device, or sometimes "the world's oldest computer." That's not what the machine's maker called his box. He would never have wanted it lost in a Roman shipwreck, near the obscure, rocky island of Antikythera.

If that maker saw his high-tech gizmo now, boy, what a comedown. It sank to the bottom of the Mediterranean under a tonnage of pottery, statues, and furniture. It was smashed to pieces. Its stout wooden frame flaked away like wet paper. It was also severely corroded. Fossil dinosaurs have been found in better shape.

Once, there was room to claim that modern ideas about this machine's complex functions might be far-fetched. However, in 2005 the machine's fragments were digitally CAT-scanned, revealing that the Greek maker carved specific instructions inside. Those scales and labels eliminate any doubt: we've got a crank-driven, precisely geared bronze orrery.

The Antikythera Device predicts the position of the sun and the phases of the moon, and it probably tracks all five visible planets. It also predicts eclipses, and, as a final throw-in bloatware feature, it will tell you whenever the Greek Olympic games occur. All this in a single mechanism from 85 B.C., or very near it.

To understand the huge extent of the lost knowledge here, we need to grasp what this lost object once meant — not to us who found it, because for us it's mind-blowing — but within the context of its own time and place.

All we've got is a few hints. We'll have to blue-sky it a little.

Let's consider the maker. For him, that machine was surely no marvel. He had to laboriously hand-cut dozens of meticulous gear teeth into more than 30 hard bronze wheels. Then he mounted all those gears in working order, complete with frame, dials, pointers, and a crank. A long, hard, exacting job.

This machine is not a royal gift, all gussied up as a fancy collectible. It's also not commercial, because it's much too complex for untrained users. This cosmic box is the work of an academy. It's a pocket universe from a university. It was built by a graduate student. Somebody young, smart, and determined, stuck in front of a professor.

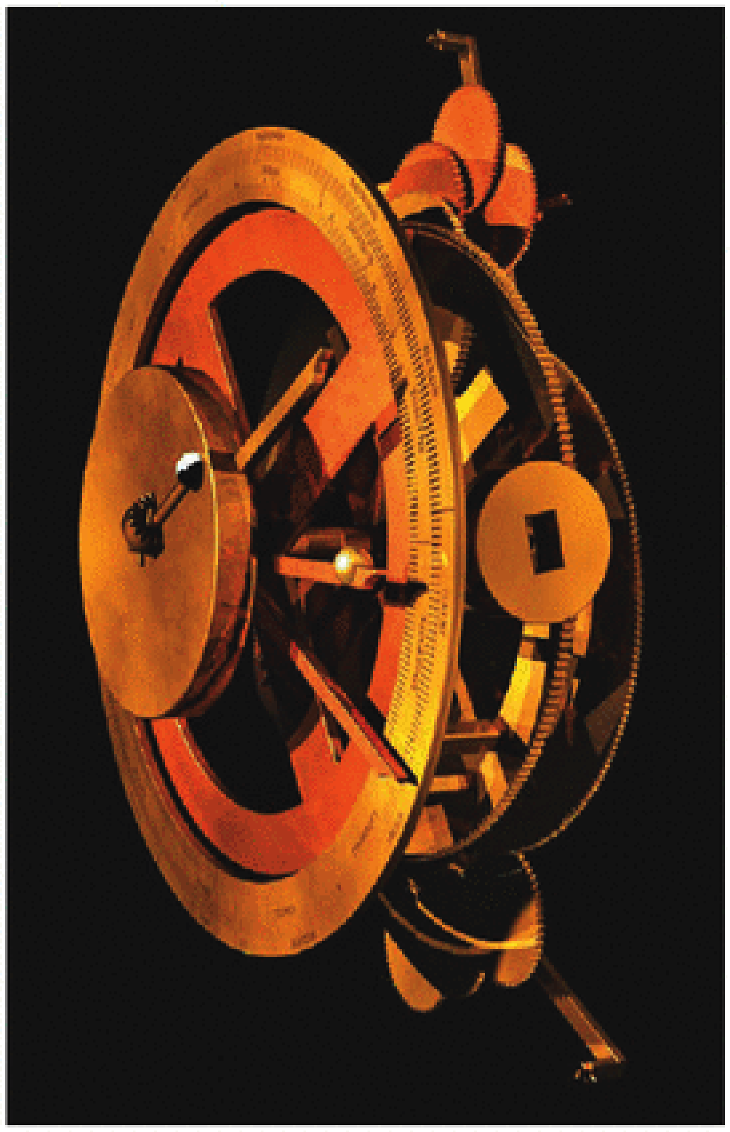
The Antikythera Device predicts the position of the sun and the phases of the moon, and it probably tracks all five visible planets. It also predicts eclipses, and, as a final bloatware feature, it will tell you whenever the Greek Olympic games occur. All this from 85 B.C., or very near it.

I'm inclined to suspect that this machine actually *was* our friend's academic education, that the box was his working diploma, a physical proof of the ordeal he had been through. Because it's portable: it's the size of a laptop. It's a bit heavy — you sure wouldn't want to swim with it, if your galley was sinking off Antikythera — but you could lug it with you around the known world.

You could take it home. Back to the family estate, with the vineyards and the olives and the goats. There you could crank it up and show your Dad where the moon would rise on his next birthday.

Your Dad's a tough army veteran; he scourged the Earth with the heirs of Alexander's generals (that's where he got the huge estate and all the slaves), but you're a fine gentleman from the Rhodes Academy.

It took you four long years to build your *kosmos* in a box — you, and maybe 20 other elite students. Most freshmen couldn't cut the metal there. They just couldn't hack it. They flunked out. You graduated: you successfully built a model cosmos. Now you fully get it about astral epicycles. You can crank history forward and backward; yes, you can even predict eclipses. "Well, son," says soldier Dad, beaming approval, "maybe I grumbled about the cost of your college education. But no wonder we run the



DECONSTRUCTING THE ANTIKYTHERA DEVICE: (clockwise from top left) FRONT: The gears and pointers at the front of the mechanism. There is a zodiac scale, which displays the positions of the sun and moon; a calendar scale, which shows the date in the Egyptian calendar; and a moon phase display. BACK: Elements colored in bronze are those for which there is direct evidence; elements in copper are those that have been conjectured to complete the model. BACK DIALS: The main upper dial is a 19-year, 235-month Metonic calendar; its two subsidiary dials are Olympiad and Callippic calendars. FRAGMENT: The front of the main surviving fragment of the mechanism. It contains 27 gears. The large gear with four spokes at the front is called the Mean Sun Wheel.

known world! By Zeus, we Greeks are civilized!"

It is absolute, metal proof that you are not just empty talk like those so-called "cosmopolitan" philosophers. You can tell horoscopes with your device, even get a decent job teaching. It also proves that you matriculated from Rhodes, where the Rhodians build giant war machines — where they built the Colossus of Rhodes out of *somebody else's* war machines. The Colossus is truly one of the Seven Wonders of the World!

Wondrous things happen in Rhodes, and even weirder ones in its close ally Alexandria, the boomtown of the Hellenistic world. In Alexandria they build wild gizmos like jet-propelled aeolipiles. You grease up one of those babies, fire up its steam cauldron, and it swiftly becomes the fastest-moving object known to man.

Of course, you have to explain a lot to get skeptical Greeks to support advanced aeolipile makers. You have to explicate to doubtful people that the air, the *pneuma*, is not "nothing," but possesses material substance, unlike the element fire, which has immaterial substance. Physics can get complicated. It can get *hugely* complicated, really Greek and subtle.

Unlike the unsubtle Romans, who also have strong ideas about a universal cosmic order. Except, unlike your nifty little gearbox, their orderly ideas involve huge aqueducts and roads. Solid, world-gripping stone roads, with Roman armies marching on them.

So the problem here isn't too few *kosmos* boxes. The problem is *too many* ancient computers. Once the sense of cosmic wonder fades, the boxes are arcane, they're fussy, they're mystically detached and geeky. No business model there. Too many features. Not enough apps to empower the everyday user.

And all that fancy bronze gearing ... hey, bronze, that's valuable stuff. The kids can repurpose grandpa's fusty old gearbox and make some new objects of solid, practical value. Like coins. Coins and swords. Bronze coins and swords ... who can't love those? Coins and swords are universal!

Bruce Sterling (bruces@well.com) is the author of several science fiction novels and nonfiction books.

Maker

EARLY ADOPTER: Portrait of Gustave Trouvé from *Histoire d'un Inventeur* by Georges Barral, one of several original texts at The Bakken Library and Museum of Electricity in Life, in Minneapolis.

Trouvé Magic

Gustave Trouvé was like Thomas Edison, Alexander Graham Bell, and Igor Sikorsky rolled into one.

By Karen K. Hansen

Talking with makers in the 21st century, you might find the conversation turning to alternative energy, electric vehicles, medical breakthroughs, and special effects. These subjects would be *déjà vu* to Gustave Trouvé, a French inventor born in 1839, who created the first electric vehicle and outboard boat motor, the most-used military telegraph, endoscopes that stirred controversy and revolutionized medicine, and theatrical effects that wowed international audiences.

Photography by Bruce Chalgren. Courtesy of The Bakken Library, Minneapolis, Elizabeth Ihrig, librarian. thebakken.org

GUSTAVE TROUVÉ

Né le 1er janvier 1839 à La Haye-Descartes (Indre-et-Loire)

D'après le portrait exécuté par M. Fernand de Launay,
Admis au Salon des Beaux-Arts de Paris en 1889.

With the magic of our MAKE Wayback Machine, we were able to interview the man whose contributions to society were rivaled only by those of Edison. You may come away thinking Trouvé deserves a brighter place in the spotlight of history.

Monsieur Trouvé, were you always a maker?
Évidemment! I could happily spend from morning to evening tinkering and constructing little carriages, telegraphs, mills, rabbits, automated birds inflated by air. Although I didn't partake much in the children's games of my age, I loved to amaze friends with the toys I made for them.

When I was 6, I made a wind-powered marionette mill of wood, lead, and pewter. The connecting rods and cogwheels made the little figures move like people cavorting in the woods.

At 7, I constructed a steam engine using a gunpowder box and some hairpins. Then, in a sardine tin, I made a tiny fire engine with an air and water pump that apparently was new at the time.

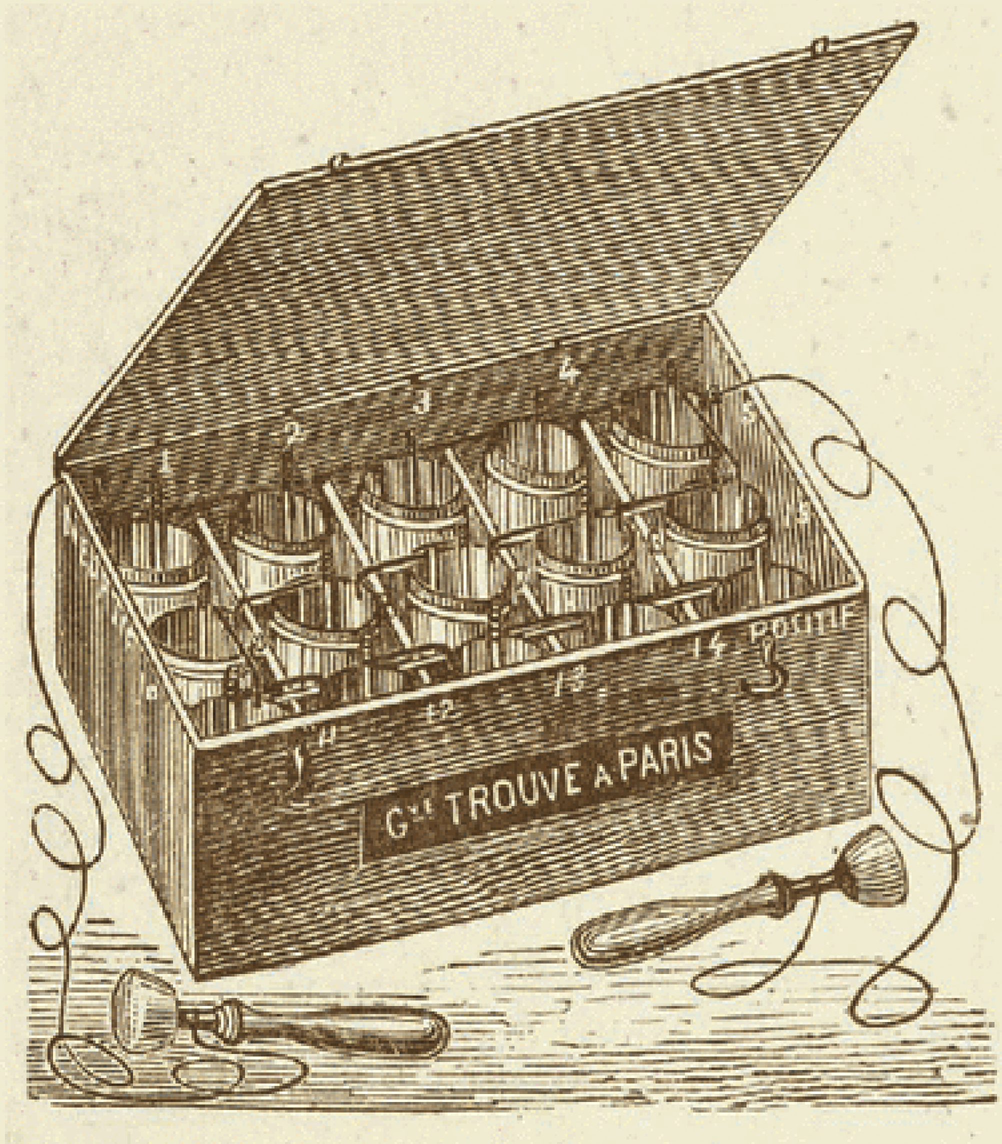
After studying mathematical sciences and mechanical arts, I was fortunate to work in Paris in a premier clockmaker's shop. My patrons and colleagues seemed impressed with my manual skills, and I learned much from them.

During my leisure time, I studied architecture, mathematics, chemistry, and physics. But with electricity it was like love at first light.

In 1866 I established my workshop in Paris. My flattering biographer, Monsieur Georges Barral, claimed I possessed a gift for turning concepts into action. Perhaps that is why inventors and customers flocked to the workshop.

The electric rifle I invented employed two small batteries. Capable of firing 18 to 20 shots per minute, it eliminated deviations in accuracy caused by the shock of a hammer. It was an object of public curiosity at the international Exposition Universelle in 1867, where it was presented to Emperor Napoleon III. An expert in weapons development, *l'empereur* admired its simplicity.

If your early inventions attracted such attention, why do so few people in North America know about you?
Je ne sais pas! Perhaps they need to study French! Or maybe it is the nature of invention that the name of the first — or the most famous — inventor lives on, while those who contribute modifications go unheralded.



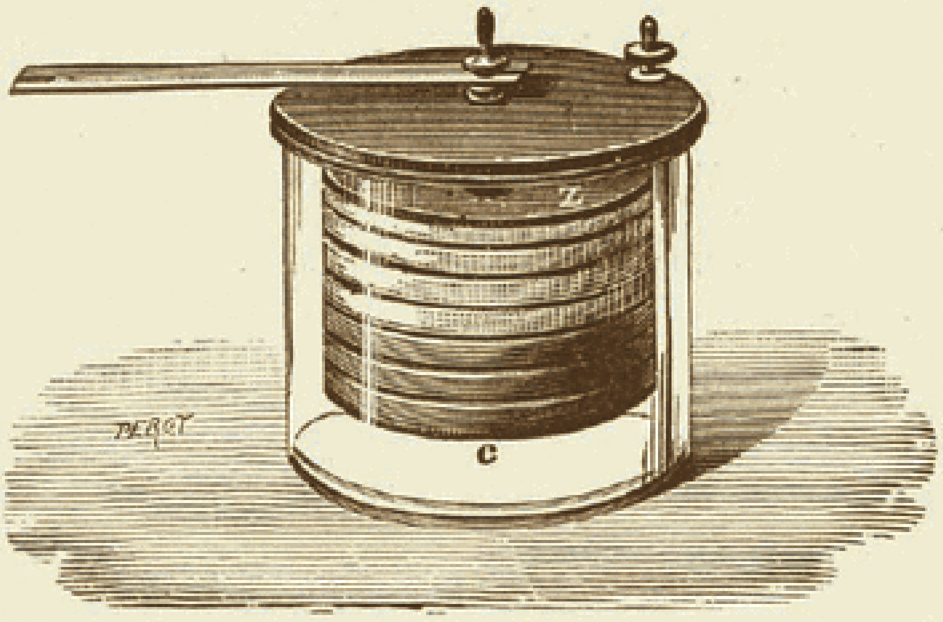
CHARGE ME UP: (this page) The very economical Trouvé-Callaud battery, with constant and continuous current optimal for medical use; (facing page) Trouvé's moist-cell copper-zinc battery in a glass vase with paper disks; his universal automatic battery, shown in use and in repose; a cutaway illustration of Trouvé's battery-operated electric rifle.

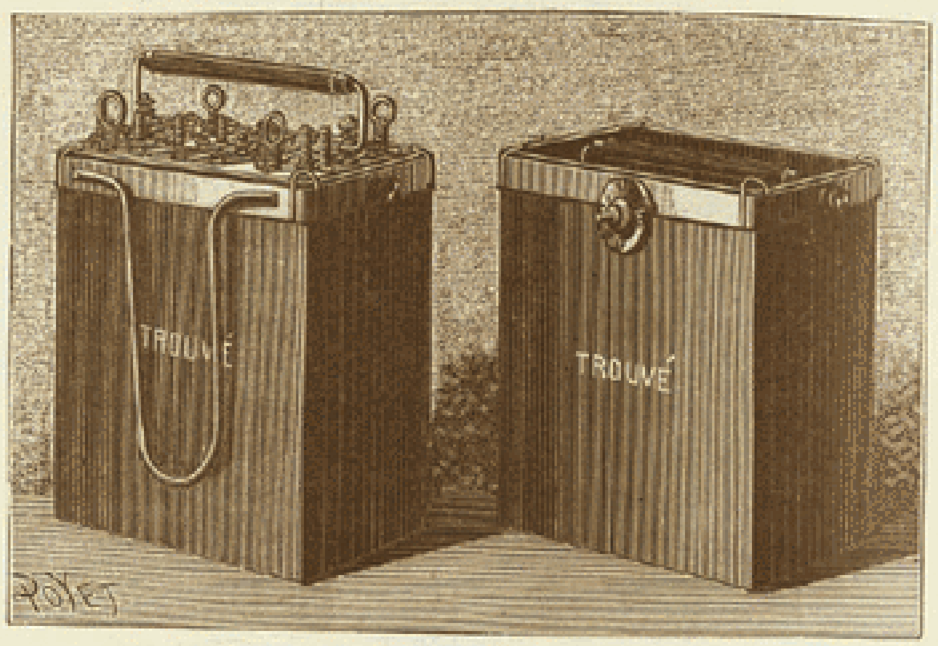
For example, I made valuable improvements to the telephone, boosting sound volume and improving the magnets. Forgotten!

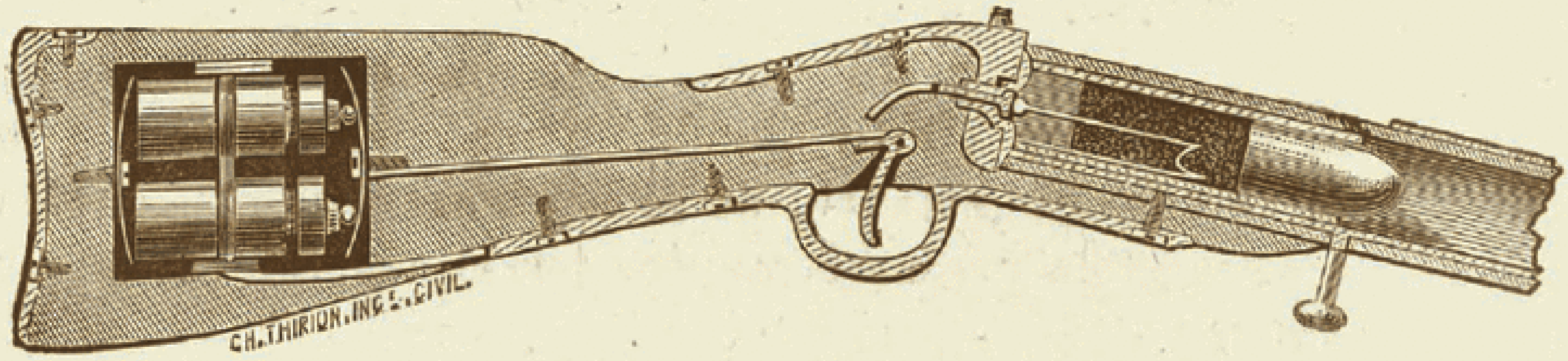
However, when I led the way with inventions, the acclaim was international and gratifying. A scientific journal of London wrote, "If England has Swan, America Edison, France has Trouvé."

Why spend so much time on batteries? That's hardly a route to fame and fortune.
Alors, electricity was beginning to transform society, yet batteries were fraught with limitations. For me, they were fundamental building blocks that needed to be improved in order to be truly useful in multiple applications. I developed many types: wet-cell, dry-cell, moist-cell, sealed, portable, pocket, automatic, reversible, and more.

I was one of the first who combated the opinion that wet-cell potassium bichromate batteries would be very inconstant and inapplicable to







experiences lasting more than a few minutes. In a note to the Academy of Sciences, I established that constancy and duration could be achieved when carbon surfaces were of sufficient size, solutions were properly prepared, and zincs perfectly amalgamated.

Some of your batteries were open-topped and others were in glass jars. How did they work?
My moist-cell battery worked in a glass vase with two flat disks: one zinc and one copper. Between these disks were blotting-paper washers. The lower washers were impregnated with a saturated solution of copper sulfate, while the upper washers contained a solution of zinc sulfate.

A copper rod insulated in ebonite plastic held everything in place. Wetting the disks put the element into action. Being very regular, this battery was especially advantageous for telegraphy and medical instruments. As you can imagine, constant and continuous current was critical during surgery, and my batteries achieved that.

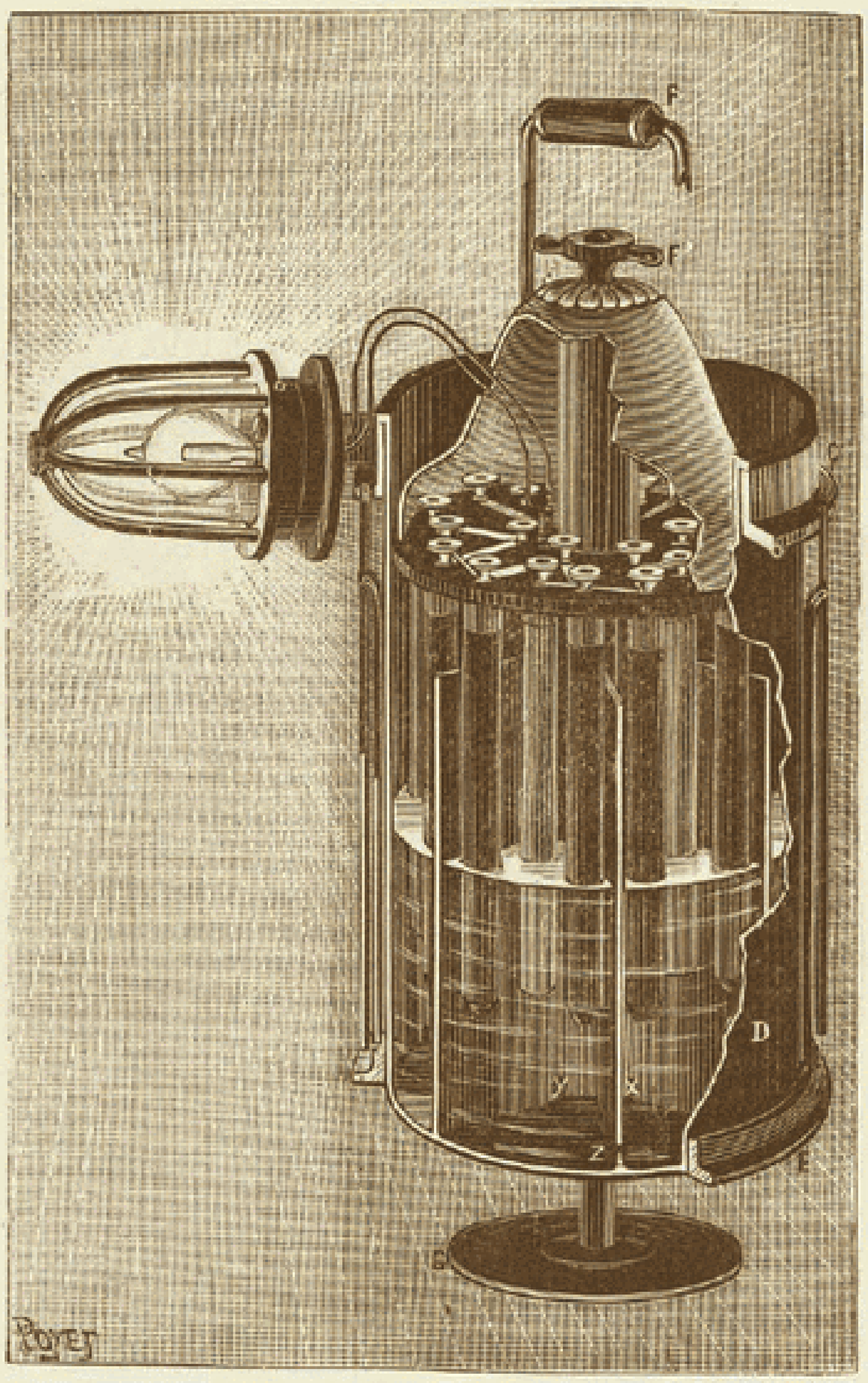
One of the most practical, simple, and well known was the Trouvé-Callaud battery made of copper, zinc, and a copper sulfate solution. It was designed for medical uses. Constructed at a more reasonable cost than other batteries and generating about 1 volt, it also could be employed in alarms, telegraphs, and telephones.

Arthroscopes, laparoscopes, and ultrasound are today's high-tech medical tools. Are such devices really new?
Mais non! I invented polyscopes (illuminated endoscopes) and photophores (medical headlamps) beginning in 1869. Polyscopes let physicians explore inaccessible parts of the human body, and photophores illuminated and reflected more easily accessible cavities. I was the first to light the cavities of the human body by means of platinum wire heated to an incandescent state by an electric current. This made diagnosis more accurate.

Although I developed both petrol- and electric-powered devices, the electric ones came into widespread use during surgery and in physiology laboratories and dentists' and gynecologists' offices. Societies and exhibitions around the world honored me with medals and diplomas.

I also created instruments for removing tumors and extracting projectiles, as well as for cauterizing. I do not wish to describe too graphically the instruments I customized to each organ. (For those interested, I suggest my illustrated *Manuel d'Électrologie Médicale*.)

For my batteries and medical instruments I made cabinets, portable cases, and even a tapestry cover that made a pedal-operated electro-cautery device look like an ottoman.



LIGHT WHERE YOU NEED IT: Underwater lighting with an electric lamp by Trouvé; interior view of his fire-safe universal electric safety lamp.

No sense in frightening the patient — or the neighbors — with the sight of a strange new medical apparatus!

Wasn't there a dispute about who was first?
My polyscope caused a revolution in medicine when it appeared at the World Exposition of 1873 in Vienna. I was awarded the Medal of Progress.

Malheureusement, two foreigners — a physician and a manufacturer — claimed as new inventions things that were merely modifications of my ideas.

I told my wife with a smile, "My dear love, I am redeemed: my invention is good, I have a counterfeiter!'"

Luckily, I encountered eloquent defenders, and in spite of the two German counterfeiters, the use of my electric polyscopes entered medical practice definitively.

In the 21st century, we're getting serious about electric vehicles. You pioneered two?
Using electromagnets, I made dynamo-electric motors. I patented a 5-kilogram motor and envisaged two such motors, each directly driving a paddle wheel on either side of a boat's hull. Then I progressed to a multi-bladed propeller.

In July 1880, I submitted to the Academy of Sciences a new motor based on the eccentrization of the Siemens coil. In 1881, I reported that through numerous modifications I had reduced the weight of all the components and thus obtained remarkable output. The motor was removable and easily lifted off the boat.

On the 26th of May 1881, my outboard motor, with two potassium-bichromate batteries and a three-bladed propeller, powered an 18-foot-long boat down the Seine and back from Pont Royal.

Soon after, I repeated this experiment on the calm upper lake of the Bois de Boulogne, with a four-bladed propeller and a battery charged with one part hydrochloric acid, one part nitric acid, and two parts water so as to lessen the emission of nitrous fumes.

Without noise or smoke, my boat beat all others and reached an unofficial record speed of 10.8 kilometers per hour. *Quelle acclamation!*

As all inventors did, I greatly admired Mr. Alexander Graham Bell. I had named my fast, electric-powered boat *Téléphone* in his honor. It seems the admiration was mutual, for when he visited me in Paris, he said, "I want to import to America a complete collection of all your inventions, because they constitute for me the highest expression of the perfection and the ingenuity of French electrical science." He also expressed great surprise that I wasn't a millionaire many times over like all his colleagues in the United States!

In April 1881, I mounted two battery-powered electric motors on an English-made Coventry Rotary Tricycle. Traveling on the Rue de Valois in Paris at 20 or 25 kilometers per hour (depending upon whom you ask), this *vélocipède* was the first lightweight electric vehicle. It wasn't much, but it was a start.

While my boats became popular among wealthy patrons for pleasurable outings, they were practical as well.

To control opium trade along China's coast, the authorities required stealthy surveillance boats. Though electric motors were two or three times more expensive to operate than steam engines, they were silent and always ready. My small, efficient, 30-horsepower dynamo-electric motor launch provided a solution. This boat made possible the interdiction of many millions of francs worth of contraband.

While you were making waves with the outboard motor, you were also experimenting with aviation. What were you up to?

Since I drew birds and made bird toys from an early age, it is perhaps not surprising that my flying machines were based on birds. In December 1870, I presented two new models to the Academy.

In my first ornithopter, steam or compressed air activated the wings. The second derived its power from gunpowder charges fired into a tube. *Finalement,* even though mine flew 70 meters, mechanical birds did not figure in the future of aviation.

What prompted you to invent military devices?

The terrible days of bloodshed in the 1870 War directed my attention away from pleasant science. My first work for the military involved

> "During my leisure time, I studied architecture, mathematics, chemistry, and physics. But with electricity it was like love at first light."

locating bullets in wounded soldiers. Later, the Geneva Conference recommended to all European governments that my lighting system for locating wounded soldiers on the battlefield be adopted as standard ambulance equipment.

In the portable telegraph system I devised, the sealed battery withstood all sorts of moving about. It became the most-used portable military telegraph at the time. The *Scientific American Supplement* in 1882 called the system "perfect." Others called it "ingenious." That mattered less than the fact that the combination of snap hooks and cables on spools allowed soldiers to establish lines as long as three kilometers over land and streams in just half an hour.

My shipboard light projector for detecting torpedo boats was presented to the Academy of Sciences in 1885. That same year, my underwater lamps were used in the Suez Canal — and drew international press attention — when they helped divers dynamite a sunken dredger that had interrupted navigation.

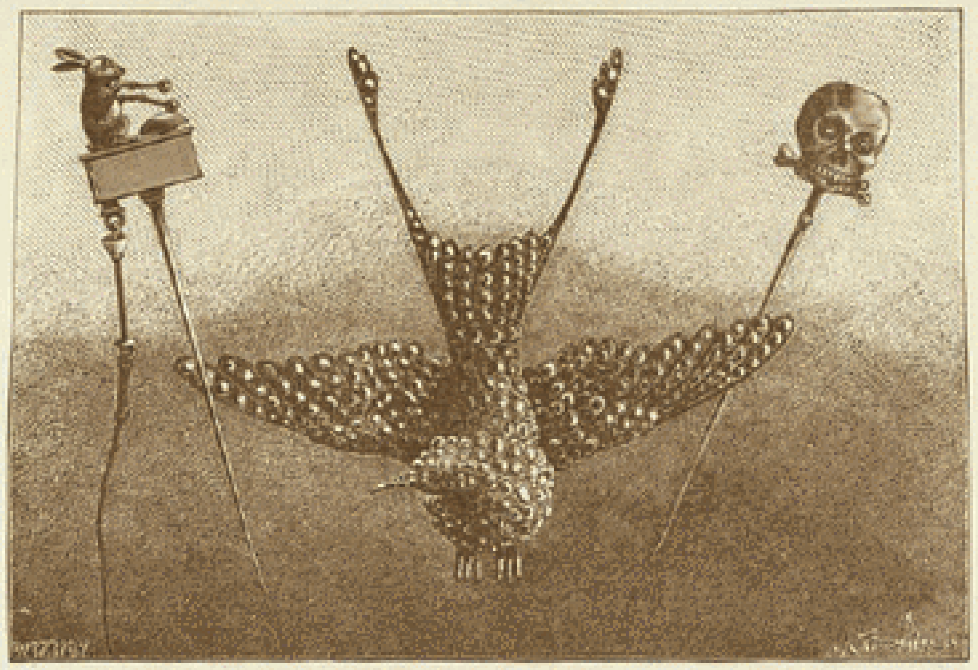
Electricity was transformative, and you lit the way in many ways. Tell us about that.

My battery designs made possible portable lamps that were small, maneuverable, and light.

For vehicles, I developed an extremely simple lantern that functioned instantly and provided illumination five to six times superior to oil or candle lanterns. Doctors and others lit their vehicles inside, to do their work, deliver mail, take notes, read, and dispel boredom! Some people, wanting to light their routes or being in need of publicity, used the lamps on the exteriors of their vehicles.

The public named them *lampes d'Aladin Trouvé*. They burned for about three hours and gave illumination equivalent to four or five candles.

One of my designs enclosed an electric lamp in a double envelope of thick crystal inside a metal



STAGECRAFT TO AIRCRAFT: A living chandelier of dancers adorned in Trouvé's electrically lighted jewelry for *The Chicken That Laid the Golden Eggs*, performed in Paris and Berlin; electro-mobile jewelry by Trouvé included a drumming rabbit, flapping bird, and chattering skull; Trouvé's second "mechanical bird" ornithopter, driven by gunpowder.

lantern. Even if the lamp broke in a flammable atmosphere, no accident would result. It was used for firefighting in Paris and New York, in mining, and for finding gas leaks.

Did you ever invent just for fun?
Of all things, I became an international sensation as a jewelry maker and theatrical designer.

I started making electro-mobile jewelry in 1865 — rabbits drumming, birds and butterflies flapping, decapitated heads talking, a grenadier playing a drum. Everyone wanted them! Mounted on gold or on tiepins, the minuscule creatures were animated with the aid of an invisible wire attached to a cigar-sized, sealed battery hidden in a waistcoat pocket. *Très amusant!*

After the military events of 1870, I made electrically illuminated crystal jewelry in myriad colors and shapes. It, too, was all the rage, but nothing compared to the audience and media acclaim when I incorporated lighted crystals in dance, theater, and opera costumes and props.

Neither language nor images can sufficiently convey the effect on the major stages of Paris, London, Berlin, and beyond. For the time, it was the most considerable application of electrical illumination directly from batteries. Imagine a ballet of illuminated amazons, a bejeweled chandelier of sparkling dancers, Neptune's chariot aglow, and the duel in Faust with lighted swords flashing on a darkened stage. *Quel plaisir!*

Given the many inventions I exhibited at major expositions, it seems fitting that my last spectacle on the international stage appeared in 1889 at the Exposition Universelle in Paris. My enormous lighted fountain, which I would patent in 1893, was a sensation at the end of a transformational century.

With hope that in some small way I lit their paths or electrified their imaginations, I salute all inventors and makers who succeeded me. *Au revoir et bonne chance!*

Karen Hansen makes classical music, stories, and photographs in Minneapolis and on her travels throughout Europe, Asia, and America. She interviews artists, entrepreneurs, gardeners, judges, professors, and makers.

Crib Notes

Modding a baby crib for disabled parents.

By Michael H. Kelsey

Parents with disabilities face numerous challenges when caring for a newborn. Besides the usual sleep deprivation and anxiety about such a small and dependent life, the equipment made for infants and children can present substantial barriers.

Changing tables are built for standing, bathtubs can take two (or more!) hands, and cribs require parents to have substantial flexibility and lifting strength.

My wife, Liz, is a little person; when she's out of the house, she uses crutches and a lower-body brace that doesn't bend. Around the house, we keep most of our storage low to the ground, and our activities are on the floor. (Dinners on a patterned rug with Japanese lacquered-table place settings are a great way to relax after work!)

By the time we brought our daughter, Madeleine, home from the hospital, we'd been thinking about the many adaptations needed to care for her. We consulted several times with Judi Rogers at Through the Looking Glass in Berkeley, Calif., a terrific organization with resources, advice, designs, and uniquely engineered equipment for parents with disabilities.

Some things were easy: a mover's dolly to move stuff around, a padded changing pad on the floor, trays of supplies stored in our coffee table.

But Madeleine's crib posed a challenge: cribs are built to strict regulations, and the railings are all 2½ to 3 feet above the floor, far too high for Liz to use. One of Rogers' designs inspired me to modify a crib to be easy for Liz to use both in and out of her brace (and easier for my back, as well!), while being safe for Madeleine to sleep in unattended.

I started with an inexpensive "Leksvik" crib from Ikea, built of solid wood and easy to alter. It converts to a toddler bed, so the mattress is lower; with the legs cut off, the top of the mattress is just 8 inches off the floor.

CRIB MOD: Raising an infant isn't easy, and it's especially challenging if you're disabled. The author modified an Ikea crib with a sliding railing.

I cut one side panel in half, and attached drawer glides at the top and bottom to rejoin the two halves. With a strip of molding on the end panel as a stop, and the fixed part of the railing screwed to the mattress frame, the panel opens and closes like a patio door and stays solidly in place. I used another strip of molding and a block of foam padding to close the gap between the rail and the mattress. I added a clevis pin underneath to lock the door, and covered the railing posts with a flexible crib bumper.

Now when we open the crib, the mattress is right there, just inches off the floor. Liz and I can both get Madeleine into and out of the crib, day or night, with no extra effort.

+ Detailed assembly instructions and safety notes are available at makezine.com/go/cribmod.

Michael Kelsey is an experimental particle physicist and occasional tinkerer, investigating rare B meson decays at Stanford.

Photography by Sam Murphy

Flight of Fancy

Kazuhiko Hachiya mines cartoons for his real-world inventions. By Lisa Katayama

Kazuhiko Hachiya is famous in Japan for his quirky, entertaining creations. He is also about to become the first person to fly in an anime-inspired jet.

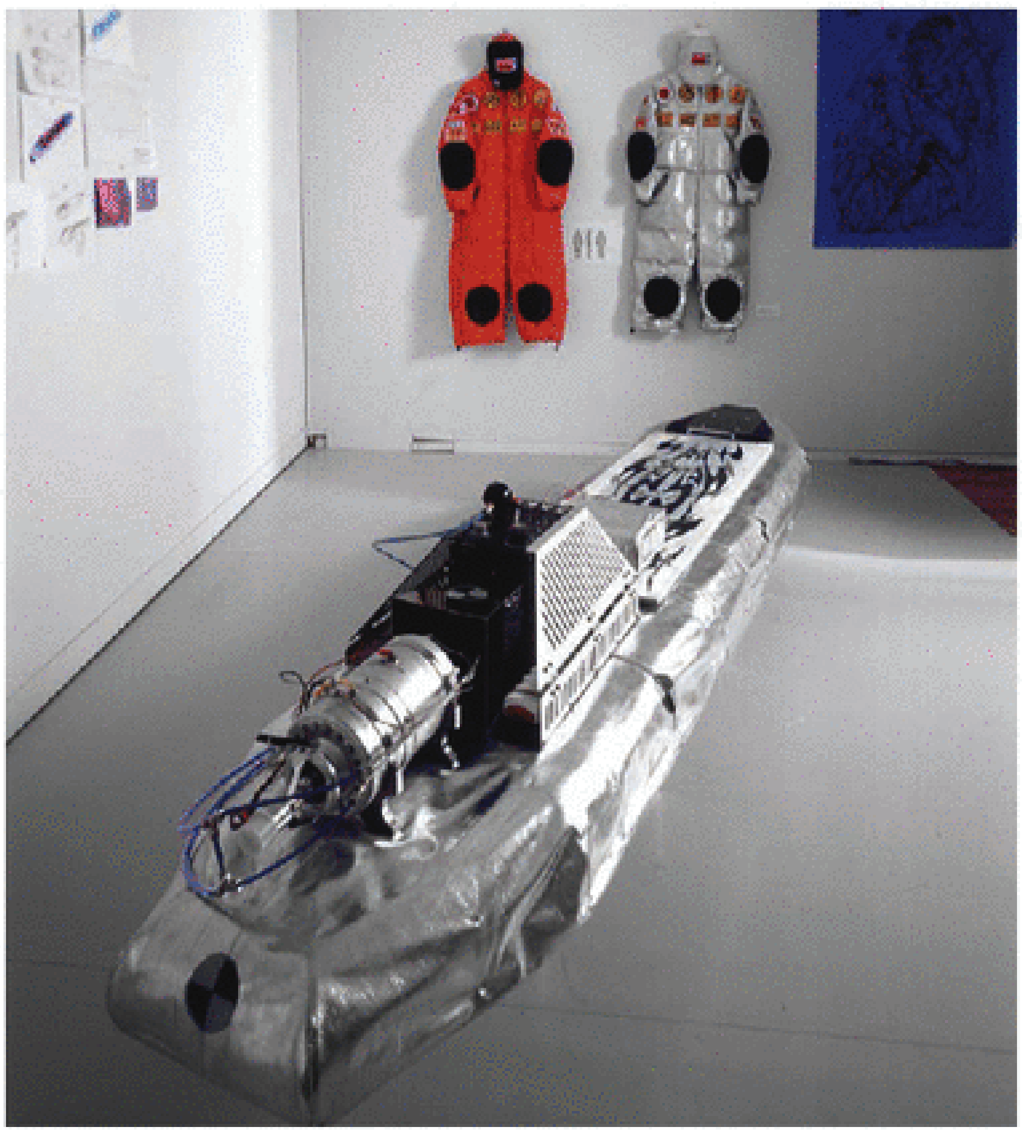
The 42-year-old Tokyo-based artist is in the final stages of making the jet-engine version of *OpenSky*, a one-person glider with a 32-foot wingspan based on a popular Japanese film. "My biggest goal is to create something that moves or bemuses people," he says. "If that meant I only made one big thing, that would be OK."

It took Hachiya three years and a whole lot of spruce wood and fiberglass composite to make the first version of *OpenSky*, inspired by the fictional plane from Hayao Miyazaki's *Nausicaä of the Valley of the Wind*. "It's a hybrid between a vintage wooden glider from the 1930s and today's airplane," he says. His first test flight, which lasted several seconds, took place in the spring of 2006 with the help of a bungee cord and a nearby university soccer field.

To understand factors like weight, wingspan, and control, Hachiya practiced riding hang gliders and trikes, then launched a half-sized remote control version before takeoff. The full-sized *OpenSky* only carries a pilot weighing less than 130 pounds, but this isn't a problem for Hachiya. "I weigh 115," he says. "And I only plan on letting myself and female pilots take the flight."

Hachiya worked full time at a design consulting firm until 1995, when he won a $100,000 fine arts award and decided to go independent. Since then, silliness has become an unofficial requirement in all of his works. "People always ask me if I'm an inventor, but I'm not. Inventions have a practical

Photography by Yuki Yonekura and Toshiaki Makihara (AirBoard)



STRANGER THAN FICTION: (clockwise from facing page) Hachiya poses with *OpenSky*; *OpenSky*'s second 98-meter run; the *AirBoard*, a jet-powered skateboard; a demonstration of *Inter DisCommunication*; a model in a stylish space suit perfectly finishes off the fantasy of *OpenSky*.

component to them; none of my pieces have that."

In 1993, Hachiya made the *Inter DisCommunication Machine*, a simulation game in which two people interact with images of themselves as seen by the other, using two head-mounted video cameras and winged backpacks geared with transmitters.

"You switch perspectives with your partner," Hachiya explains. "Sometimes I tell players to kiss or shake hands; they freak out because they feel like they're kissing themselves."

But it was *PostPet*, a simple desktop application that combines an endearing virtual pet with a person's email inbox, that put him on the map in the growing niche of Japanese media artists. *PostPet* was commercialized in 1997 and has sold more than 1 million copies to date.

Some also know Hachiya for the *Thanks Tail*, a joystick-controlled robotic dog tail that attaches to the rear of any car and wags at other drivers. In Japan, a quick wink of the hazard lights means thank you, and flashing hazards indicate traffic ahead. The tail serves a similar function.

OpenSky isn't the only Hachiya project that looks like it's straight out of a fictional world. *PostPet*'s cute, 3D characters were inspired in part by a manga called *JoJo's Bizarre Adventure*, and the *AirBoard* — a jet-powered skateboard that hovers a few centimeters above the ground — is a lot like the Hoverboard from *Back to the Future II*. "I really get a kick out of turning fantasy into reality," Hachiya says.

» Kazuhiko Hachiya: www.petworks.co.jp/~hachiya

Lisa Katayama is a Tokyo-born journalist living in San Francisco. She is the author of *Urawaza: Secret Everyday Tips and Tricks from Japan* and has guest blogged for Boing Boing.

Thin(k) Ice

A chilly reception for Minnesota's Art Shanty Projects.

By Mike Haeg

A lopsided tin shed creeps along the surface of the frozen lake. Inside, a handful of rosy-cheeked passengers are pedaling their hearts out. The shanty's skipper keeps the little icehouse on its snowplowed track by manipulating a rudder-like steering apparatus. His first mate is feeding small pieces of cedar shake into the miniscule wood-burning stove that warms the shanty's passengers and brings a snow-packed teakettle to whistle.

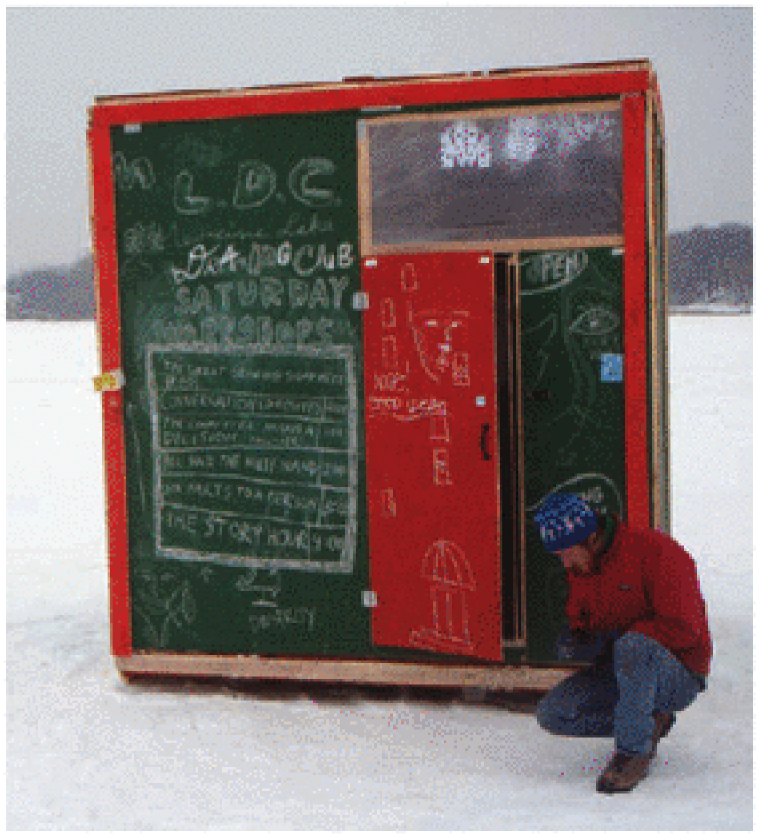
The Mobile Home Shanty circumnavigates the 2008 Art Shanty Projects, a curated community of 20 artist shacks humbly populating a small section of Medicine Lake, just outside Minneapolis. Along its route, the mobile shanty passes a monolithic shanty comprised of inward-facing refrigerator doors, a shanty with clear plastic walls insulated with castoff stuffed animals, a menacing 20-foot robot shanty, an ice museum, a radio station, and a camera obscura.

At the heart of this makeshift community is a small, piecemeal shack sporting a bold, red letter A and a sign proudly exclaiming Auto Ethnographic Guide Service HQ.

Inside is Peter Haakon Thompson, who started the Art Shanty Projects together with fellow artists David Pitman, Kari Reardon, and Alex DeArmond with a single shanty back in 2004. The idea: to transform the traditional ice-fishing shack into a public art space. That year, the team had about 30 visitors, mostly friends and other artists.

The following year, the team was awarded an art show through the Soap Factory gallery, involving ten projects created by 20 different artists on the

Photography by David Pitman



NOT YOUR GRANDPA'S FISHING HOUSE: (facing page) Peter Thompson's Auto Ethnographic Guide Service, the original art shanty; (this page) S.U.R.V.I.V.A.L. Shanty folks conduct an improvisational survival workshop; Chalkboard Shanty of the Medicine Lake Drawing Club; and the little art shanty that could.

lake during the winter. The team put out a small press release, and much to their surprise, 300 people showed up the first day — one of the coldest days in 70 years, around –36°F.

For the 20 teams selected each year to participate, the only limitations are the temporary nature of the exhibit, extreme conditions, respect for the lake, small grants, and state and county regulations for fish houses (they must have at least three walls, a door that opens from the outside, and at least two square inches of reflective material on each side). The rest is up to their imaginations and resourcefulness.

"It's like forts for adults," says Thompson.

Thompson believes that the real magic of the project comes in pushing not only the artists but also their art out of their studios, galleries, and disciplines, and challenging them to be more inspirational and engaging to the bundled-up families, ice fishermen, and occasional game warden who come to visit.

Near what looks to be a crashed plane, the residents of S.U.R.V.I.V.A.L. Shanty (Serious Undertakings Regarding Visionary Investigations into the Vital Attributes of Longevity) are improvising a workshop on the aesthetics of improvised shelters.

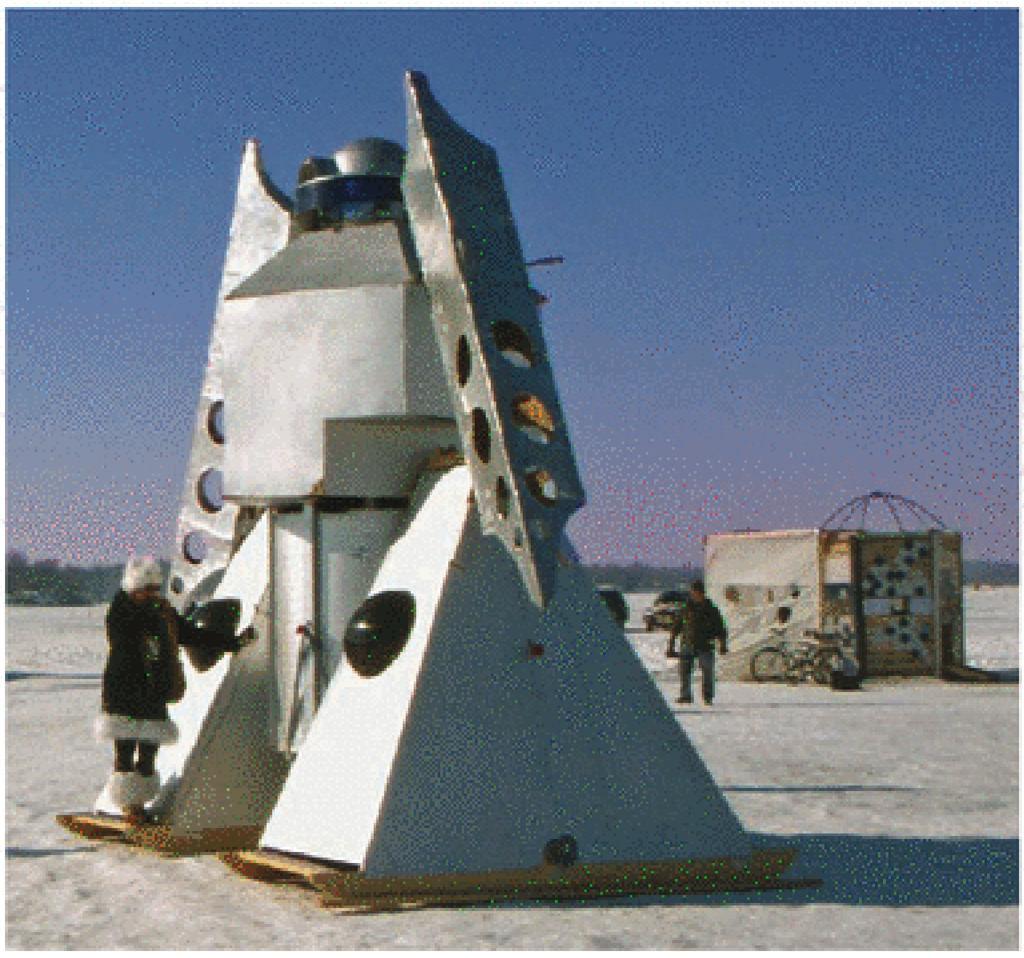
Nearby, a shanty built out of green chalkboard quakes in response to the Drawing While Dancing workshop that's taking place within. A stunningly handcrafted wooden fish breaks through the ice just feet away from the line of people waiting for the Norae Karaoke Shanty. And the Mobile Home Shanty picks up a new group of inhabitants, and lazily (as seen from the outside, at least) takes another lap.

Find the annual Art Shanty Projects on Medicine Lake from mid-January through mid-February. Come on the weekend. Plan on spending the afternoon. Dress warmly.

» For a list of the 2009 shanties and more information, visit artshantyprojects.org.

» Turn the page for more Art Shanty photos.

Mike Haeg is the proud mayor of Mt. Holly, Minn. (pop. 4). He invites all disbelievers to swing by for an ice-cold beer and some free pinball.



CRAFTY LIKE ICE IS COLD: (clockwise from top) Bell guards the International Ice Museum; Prismobot; the solar-heated Vista Shanty; the shanty of K-ICE FM 97.7; and the Shanty of Forgotten Toys.

Giants of the Micros

The two inventors who fueled the rise of the living room helicopter. By Adam Salter

Micro-sized indoor R/C helicopters that launch from your palm and hover in midair never fail to make the uninitiated gawk like cats tracking a moth. Toy stores are filled with these inexpensive miniature marvels, and it got me wondering: how did they come into being? I learned that the story of their development includes years of hard work, hobbyist passion, and an undeniable streak of brilliance.

The giants of the micro R/C scene are Alexander Van de Rostyne of Antwerp, Belgium, and Petter Muren of Nesbru, Norway. These two have made possible the affordable, ready-to-fly indoor R/C helicopters. Van de Rostyne's models from Silverlit Toys and Muren's from Interactive Toy Concepts (ITC) are the market leaders and the original products that started the current micro R/C heli craze.

Van de Rostyne is an electromechanical and computer science engineer who has worked in marketing and management at Motorola and Apple Computer, where he says he "got the bug for simple and user-friendly high-tech products." He's currently CEO of a 50-person web agency and partner in a software company.

Muren is an R&D engineer who studied hydro- and aerodynamics and has experience in mechanical engineering, electronics, and software development. He manages a team of 20 engineers developing videoconferencing systems at Tandberg ASA, does consultant work for the UAV industry, and also runs his own company, Proxflyer.

Of course the two men's "hobby" is their true obsession, and has become a profession in itself. Van de Rostyne explains, "I have been a passionate

Photography by Federica Pischiutta

modeler for more than 40 years now. There is no single topic in my life that I've spent more time on. For me it was always much more than just spending my free time. It became a way of life. When I got bored in a business meeting, I started making sketches of all sorts."

Muren says that his hobby know-how blends naturally with his career skills when he's designing his inventions. "Most of the development work is done in my private workshop as a modeler/hobbyist — but then again, I have experience as a modeler that probably could be classified as professional."

The Incredible Shrinking Heli

In the late 1990s, R/C helicopters were out of reach for casual buyers. You had to build, tune, and learn to fly a model that was large, heavy, dangerous, expensive, and just plain "fiddly." Van de Rostyne explains, "You have to imagine that in those days a typical helicopter weighed 8 pounds or so, and there were no indoor helis at all."

In order to bring the joy of helicopters to a larger demographic, some major problems had to be solved: miniaturization, stability, steepness of learning curve, and price. The first step took place when, despite the warnings of friends who thought it couldn't be done, Van de Rostyne set to work on his Pixel series of miniaturized electric helicopters.

In 1997 the Pixel 1 took flight, weighing 125 grams. He explains why this was such a feat at the time (before the advent of ultra-light Li-Po batteries): "The biggest challenge was (and remains to some extent) energy density, meaning how much energy can I get in what weight of batteries."

As Van de Rostyne continued his series of incredible shrinking prototypes, his work led to the first retail indoor heli in 1999: the Ikarus Piccolo, weighing 280 grams and measuring 20 inches in length. Despite a relatively high cost and sensitive controls, the Piccolo allowed enthusiasts to spend hours perfecting their flight skills in their living rooms. It also had full 4-channel control, a gyro for stability, and the durability to survive the learning process.

Stability Breakthrough

While the Piccolo was amazing heli freaks everywhere, Muren was solving the second daunting problem: the quest for passive stability. The main challenge was bucking conventional wisdom: "All the textbooks I had stated that helicopters by nature are inherently unstable. After years of failure, hundreds of models, and thousands of test flights (most of them ending in spectacular crashes) it was sometimes hard to push on."

However, by combining his theoretical and modeling skills, Muren was able to slowly make progress until, in 2002, he achieved perfectly stable flight. "I still remember that feeling," he recalls. "I am pretty sure it is close to the feeling a sportsman has after winning an Olympic medal."

In his Proxflyer concept, Muren employed two counter-rotating rotors that tilted freely in response to horizontal movement, keeping the craft in the same position relative to its surroundings without the need for gyros or other electronic aids. The result is an almost magically stable, light, simple flying machine.

In videos on his website, a prototype hangs elegantly in space, silently compensating for destabilizing forces, even when Muren tugs the body of the craft with his fingers. This new kind of helicopter also used greatly simplified controls, more akin to an R/C car with an up/down stick added on.

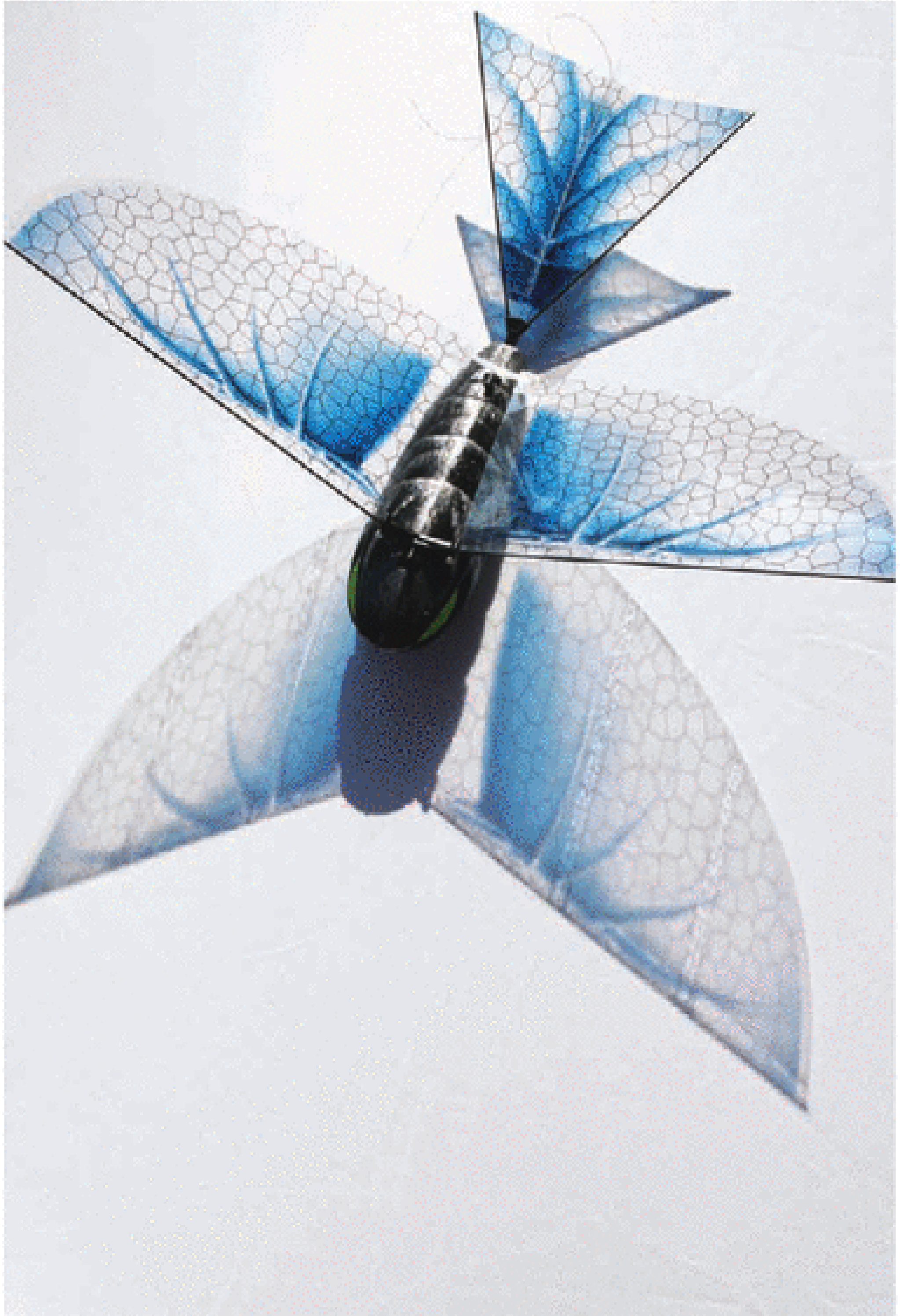
It was only a matter of time until this technology would be brought to the mass market. Muren recounts: "I instantly knew that this could be the start of something very big."

Race to Retail

The process of going from prototypes to a retail product was a new challenge for Muren. He says his years as a development engineer were instrumental in overcoming the obstacles: "Maybe most important of all was that I had learned to never give up — even at times when 20 engineers and 200 workers in a factory in the middle of Asia just sat there and looked at you, waiting for you to tell them how to solve the problems and get this thing to work."

The 50-gram Bladerunner was released in 2004, offering an ultra-light aesthetic and a flying experience more reminiscent of rubber band-powered, balsa-and-tissue planes than of copters that used high-rpm rotors to lift their weighty power source.

Subsequent versions of the Bladerunner offered new options and improved performance, culminating in a new model called the Micro Mosquito. This latest incarnation has a 6-inch rotor and weighs only 20 grams. It also offers a sleeker, uncovered design similar to Muren's prototypes, and green LED "eyes" that accentuate its insectoid appearance.



LITTLE WING: Interactive Toy Concepts' 20-gram Micro Mosquito (above) and iFly series 13-gram Vamp (right)

Van de Rostyne was not far behind in the race to retail, with another groundbreaking helicopter called the PicooZ, the tiniest yet at 10 grams and 6 inches long. Costing around $30, it has a tough foam body, auto-stability, and a simple 2-channel control scheme.

Melding of the Minds

Muren and Van de Rostyne met in 2003 and had a ball flying their models in Van de Rostyne's living room. The fruit of this meeting was a friendly competition between the two, producing successive pairs of impossibly tiny helicopters. Since then, more models have been produced, some less than 2 inches long and weighing as little as 1 gram.

The two designers are constantly releasing new retail versions of their models. Among Van de Rostyne's copters is one notable for its aesthetic appeal. The PicooZ Pluto is a 3-channel, minutely detailed model with a classic bubble canopy and open tail-boom structure. The design is reminiscent of the iconic Bell 47D1, famously suspended from the ceiling of New York's Museum of Modern Art.

One of Muren's latest, the Micro Mosquito 4×4, has mechanical and control innovations that set it apart from previous models. It incorporates four motors and 4-channel control, which now allow the helicopter to "slide" side-to-side while the body remains facing forward. This is accomplished via two separate tails with independent rotors that extend at oblique angles from the body of the craft.

Beyond staying in touch with each other, the two designers communicate with their peers, their fans, and the larger hobbyist community through discussion forums such as rcgroups.com. They also interact with their customers there, offering tips and encouragement to those of us who love tearing into the retail products, modding them to improve their function or appearance.

Their kinship with other enthusiasts is unsurprising, since Muren and Van de Rostyne insist what they value most is bringing joy to users of their technology. Van de Rostyne sums it up: "When designing products is driven by a dream, then that dream will become tangible in the experience of the final product."

Adam Salter (adamulus@gmail.com) is a burnt-out stock trader and former Angeleno. He currently lives in Rome where he writes freelance and enjoys the incomparable victuals.

BY DOUGLAS REPETTO

Putting On a Show

I think you should put on a show. It's great that you're a gastro-innovating, neuro-hacking, nano-fabricating bio-tinkerer. It's wonderful that you've posted pics to your website, made an Instructable, been featured on the MAKE blog, and Twittered every stripped-out screw and hot-glue mishap. But I think you should put on a show, an in-person, be there or be square, get 'em while they're hot, olde-timey, humans-sharing-a-point-on-the-space-time-continuum show.

It doesn't matter if you live in a big city, a tiny hamlet, or a strip-mall dead zone. There are other humans around, and it's time to meet them face to face. Tough love, I know, but it's got to be done.

Great! So now that you're putting on a show, all you need are some projects/artworks/ideas you want to share, an enthusiastic crew, maybe a little cash, and a venue. How about a kite photography exhibition in the public library or a handmade instrument concert at a local park?

We put on the first ArtBots robot art show for $200, but we probably could have done it for $20 if we had really worked at it. And dorkbot-nyc, a regular show-and-tell of creative electricity projects, has been running for eight years now on an annual budget of zero dollars, but with a tremendous amount of support from the community and Location One, our host.

Find venues by riding your bike around the neighborhood looking for empty spaces, sending emails out to local mailing lists, and pestering friends of friends of friends who work at likely spots. Coffee shops and bookstores are common venues, but try local colleges, abandoned storefronts, the courthouse steps, out-of-season campgrounds, etc. A lot of fun can be had showing your work in unexpected places.

Both ArtBots and dorkbot started tiny and have grown large, mostly by accident. Starting tiny is good — if you're going to grow, you get to grow organically, and if you don't want to grow, then you don't have to worry about it!

I've taken the liberty of asking an assortment of veteran DIY, low-budget (or no budget) show makers for show-making advice.

> There are other humans around, and it's time to meet them face to face.

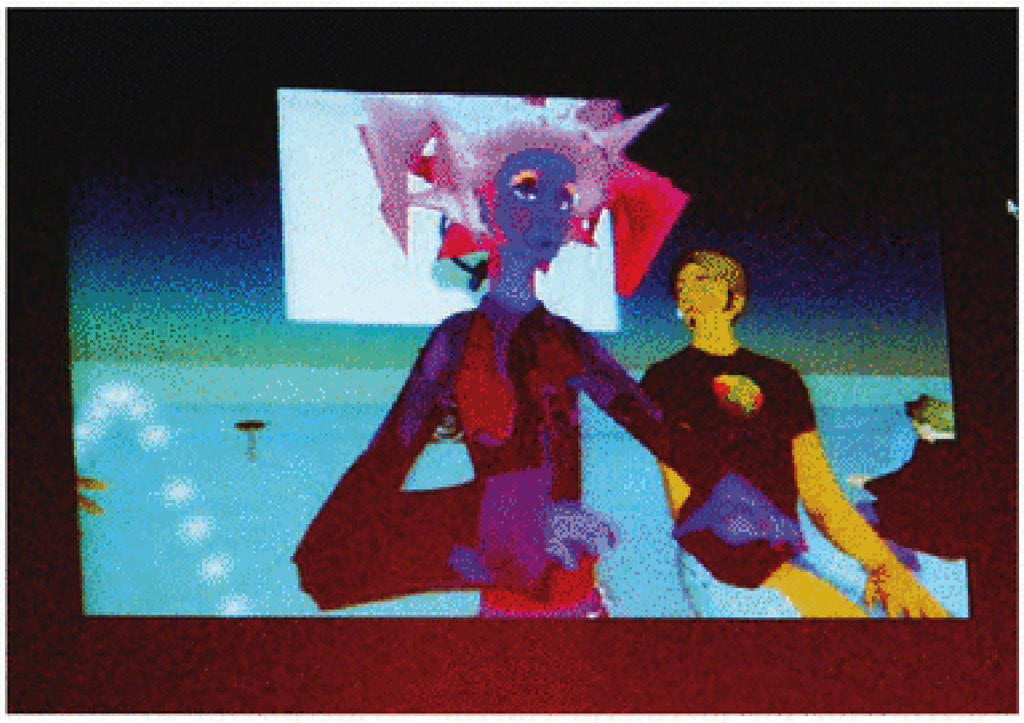
» First off, me! Here's my number-one most important, from-the-heart advice: *strive for diversity*, both in people and in ideas. Be open to, and even pursue, people and ideas that don't quite fit your original conception of the event. The ArtBots call for works states: "If you think it's a robot and you think it's art, send it in!" And dorkbot-nyc is an open forum — we have a vague motto, "People doing strange things with electricity," but beyond that it's anything goes. That means that we've had some really terrible presentations, but we've also had incredible, unexpected wonders. Of course there are often good reasons to make careful selections, but stretch out a little, reach out to someone unexpected. Err on the side of diversity.

» Artist Tali Hinkis organizes La Superette, an annual holiday art show that focuses on functional, affordable art in multiples. Her advice: *learn to delegate.*

"Allow people to contribute; give them responsibility so they feel like real collaborators and want to invest time in helping and promoting," Hinkis says.

"People are the best resources; they have friends, family, and skills. They have jobs with high-end color printers, a boyfriend with an empty office space, a journalist sister, or some mad archiving skills!" She also recommends *an "in progress" attitude*: "Sometimes the hardest thing is just to put something 'out there' in the world. It doesn't have to be a masterpiece, or a revolutionary curatorial project. We learn from doing."

» Wendy Jehanara Tremayne has organized all sorts of DIY events, from collaborative plays to political protests. She's the force behind the giant Swap-O-Rama-Rama events at recent Maker Faires. She recommends *projects with a clear structure, a*



SHOWTIME: (clockwise from top left) Onlookers at La Superette; noise performance at ScrapCycle; Second Life is big at dorkbot-london.

Photography by (clockwise from top left) Evelyne Buhler, Michael Dory, and Rain Ashford

focus on a particular problem or idea, and space for the participants to contribute meaningfully.

"If you feel strongly that a project is relevant," Tremayne says, "you must suppose that some number of others will too, and act on this assumption. Projects that invite others to express themselves invite authentic contributions that are heartfelt and that ultimately resonate through the project when it is produced. Nothing but genuine self-expression can have this same impact. Money, as an obstacle, is an illusion."

» Marie Evelyn is executive director of the art organization Analogous Projects, and produces ScrapCycle, a series of homemade-instrument/noise shows with a novel admission fee — audience members are asked to bring a piece of scrap or found material for barter at the show. Analogous Projects focuses on interaction art and emergent behaviors, interests reflected in her advice.

"Enter into the endeavor with acceptance," counsels Evelyn. "*Accept that you can't directly control any aspect of a social gathering*. You can set up the initial conditions and you can guide things, but a social gathering is a living organism: to try to control it (even in the most caring and well-intentioned way) is to snuff out the life and joy and humanity of coming together. ... And accept the fact that you have absolutely no idea what will happen! People will surprise you in beautiful ways."

» And some wise parting words from Saul Albert, U.K. low-budget rapscallion who co-produces The People Speak events and helped start dorkbot-london: "There is no such thing as a low-budget event! If you've got no cash, you just use different currencies to get the job done. Sweat, flattery, passion, and flirtation are all good ones, and can improve the atmosphere more than the most expensive canapés. The real key to your cheapo event's success is *making sure it hits an unfulfilled need for different groups of people*."

What could be simpler? Embrace the chaos, be prepared to improvise, con your friends into helping, find your niche, and keep an open mind. You made it, now show it.

Douglas Repetto is an artist and teacher involved in a number of art/community groups including dorkbot, ArtBots, organism, and music-dsp. He lives in New York City with Amy, Pokey, Sneezy, and many plants.

BY FORREST M. MIMS III

How to Photograph the Solar Aureole

The purpose of the Country Scientist column is to provide projects that will encourage readers to do science. Whether you're a student looking for a good science fair project, or an adult wanting to begin a personal science study, I hope that you'll find this or a future project worthy of pursuing.

The Solar Aureole

Dust and other kinds of particulate matter cause the sun to be surrounded by a bright glow in the sky known as the solar aureole. The aureole is often faint or even nonexistent when the sun is viewed from a mountaintop. But it's almost always present at lower elevations, especially during spring, summer, and fall.

The diameter and brightness of the aureole is related to the scattering of sunlight caused by particulate matter. This means a record of solar aureole photographs can provide a good indication of the transmission of sunlight through the atmosphere. The color of the sky beyond the aureole also provides clues about stuff in the air.

Since 1990 I've made almost daily measurements of the ozone layer, solar ultraviolet radiation, haze, total water vapor, and other sun and sky measurements from a field adjacent to the small farmhouse that serves as my South Texas office. In 1998, I bought my first digital camera, a 1.5-megapixel Fuji MX-700. To date this camera has provided 4,465 images (1,280×1,024 pixels) of the solar aureole and the sky over the north horizon. While the resolution is low by today's standards, it's more than adequate for a record of sky images.

These solar aureole images provide important information about my electronic sun and sky measurements, for they quickly reveal the presence of thin clouds or haze that might have affected the measurements. They also provide a visually convenient way to compare the clarity of the sky across the seasons and years.

Photographing the Aureole

Solar aureole photos can be made with virtually any kind of digital camera. For serious studies, you'll want to use a camera that allows you to set the same exposure duration and f-stop for all your aureole photos. This will provide a record of the sky without unwanted automatic adjustments by the camera that alter or even remove the changes in sky brightness and color caused by dust, smoke, and other forms of air pollution.

The aureole is washed out if the sun is photographed directly. Worse, your eyes and a digital camera's image sensor can be permanently damaged by the focused image of the sun. Therefore, it's necessary to design an occulting device that blocks the direct sun when making solar aureole photos. To protect your eyes, it's also necessary to use a method that does not require you to look anywhere near the sun.

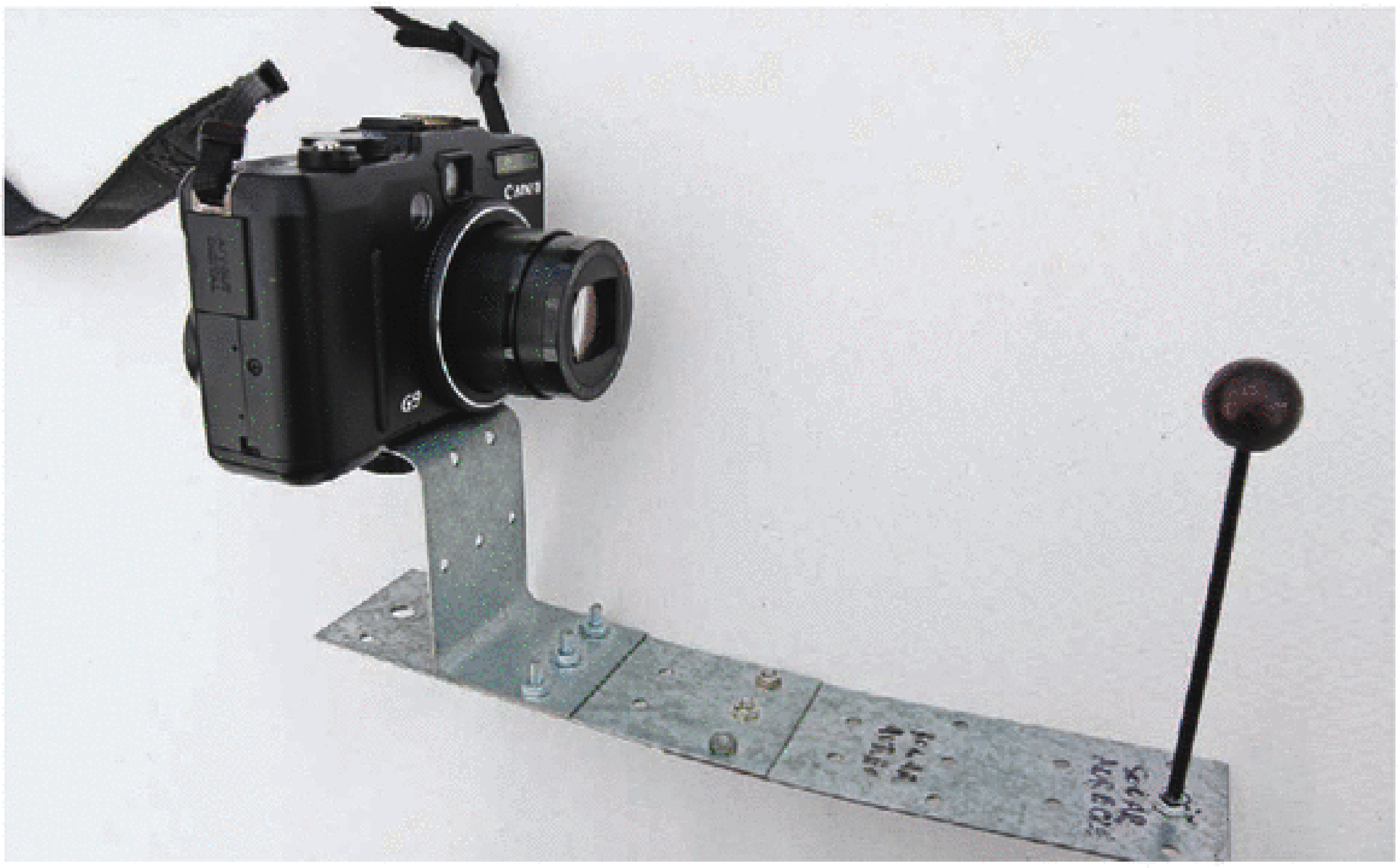
I've developed various methods for photographing the solar aureole in which you need only look at your camera. My favorite occluder rig is a simple camera platform that keeps the sun and occluder in the same position for each photograph. This greatly simplifies the comparison of photos.

You can design your own platform or you can try my simple version, the Solar Photography Occluder Rig, explained in the DIY on the following page.

Making a solar aureole photo with the occluder in place is simple. If the sky is not overcast, put on sunglasses and a hat and go outdoors with your camera mounted on the occluder. If it's awkward to sit in a chair or on the ground, brace the occluder rig against a stable object such as a fence or wall.

Switch on the camera, point it toward the sky *away from the sun*, and adjust its position so that the occluder is centered in the display. Then look at the front of the camera — *not* at the sun — while pointing the camera toward the sun. When the shadow of the occluder ball falls directly over the lens, press the shutter button and quickly move the camera away from the sun.

DIY SOLAR PHOTOGRAPHY OCCLUDER RIG



MATERIALS

- **1¾"×5" steel mending plates (3)** or equivalent
- **#6-32 screws (6)**
- **#6-32 nuts (8)**
- **¼-20 bolt**
- **⅛" threaded rod**
- **Wood ball slightly larger than the diameter of the camera's lens** Found at craft or hobby stores, wood balls may come with or without a hole bored partway or entirely through.
- **Black ink or paint** A black marker pen works fine.
- **Drill and drill bits**

» Join 2 of the mending plates end-to-end with three 6-32 screws and nuts, as shown in the photo above. (You may need to slightly enlarge the holes in the mending plates.) Drill out the center hole near the end of the third plate to ¼" diameter, to accept the ¼-20 bolt that will secure the camera. Bend the third plate twice as shown above and fasten it to the center of one of the 2 base plates with 3 more 6-32 screws and nuts.

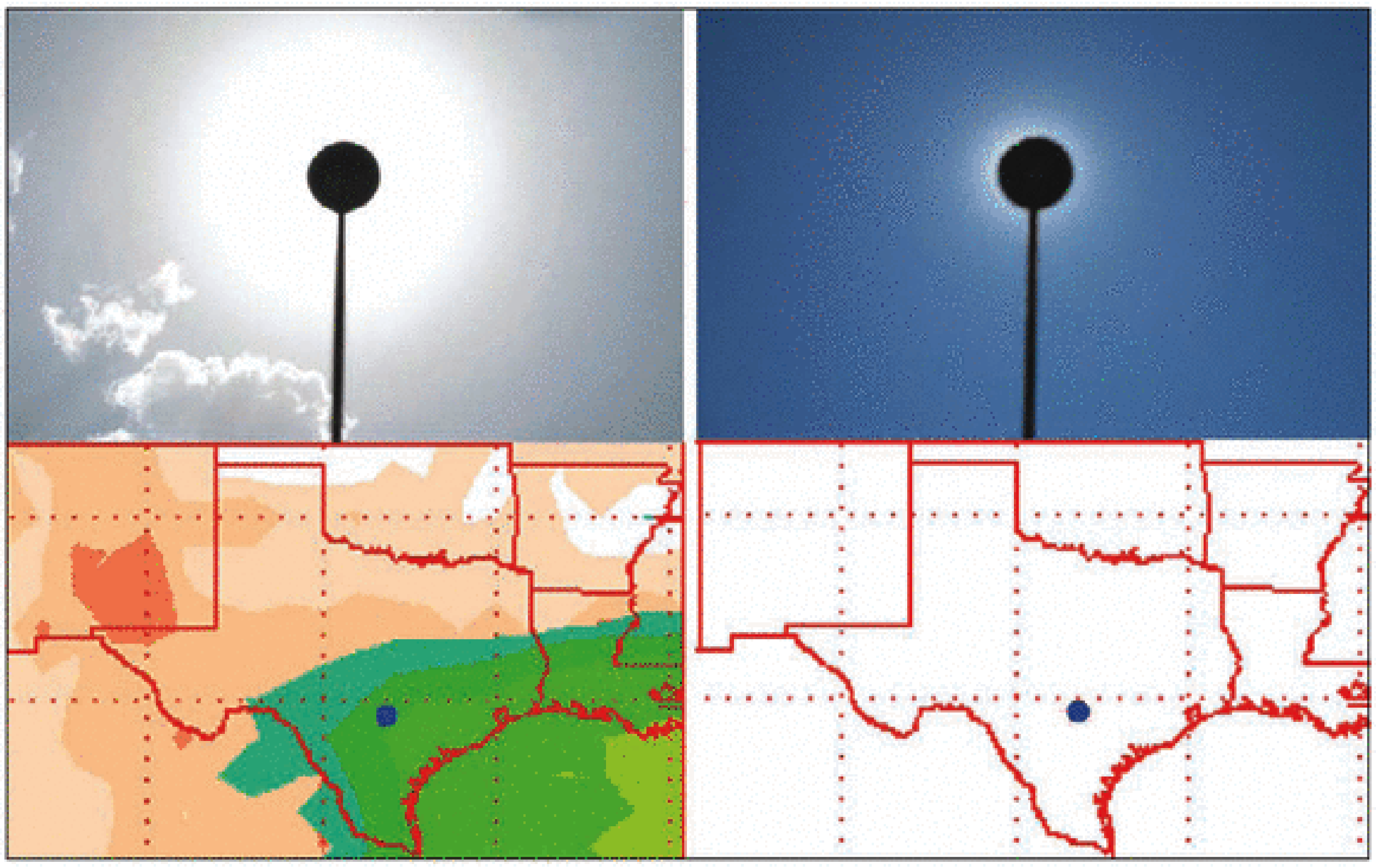
Next, determine how high the wood ball needs to be so that it's in line with the camera lens. Mount your camera atop the bent plate with the ¼-20 bolt. Hand-tighten the bolt to avoid damaging the camera; if it's loose, insert a few washers to take up the slack. Now measure the distance from the base plates to the center of the lens. Add to this distance ⅛" plus half the diameter of the wood ball. Use a hacksaw to cut the threaded rod to this length.

Twist the cut end of the rod into the wood ball. Turn a 6-32 nut onto the uncut end of the rod until it's about ⅛" from the end. Remove the camera and set it aside. Insert the end of the rod through the center hole in the end of the base plate opposite the camera mount and secure it with another 6-32 nut.

Complete the occluder by coating the ball and the threaded rod with black paint or ink.

29 Jun 2008. African dust. Sunlight transmission at 525 nm (green): 60.1%

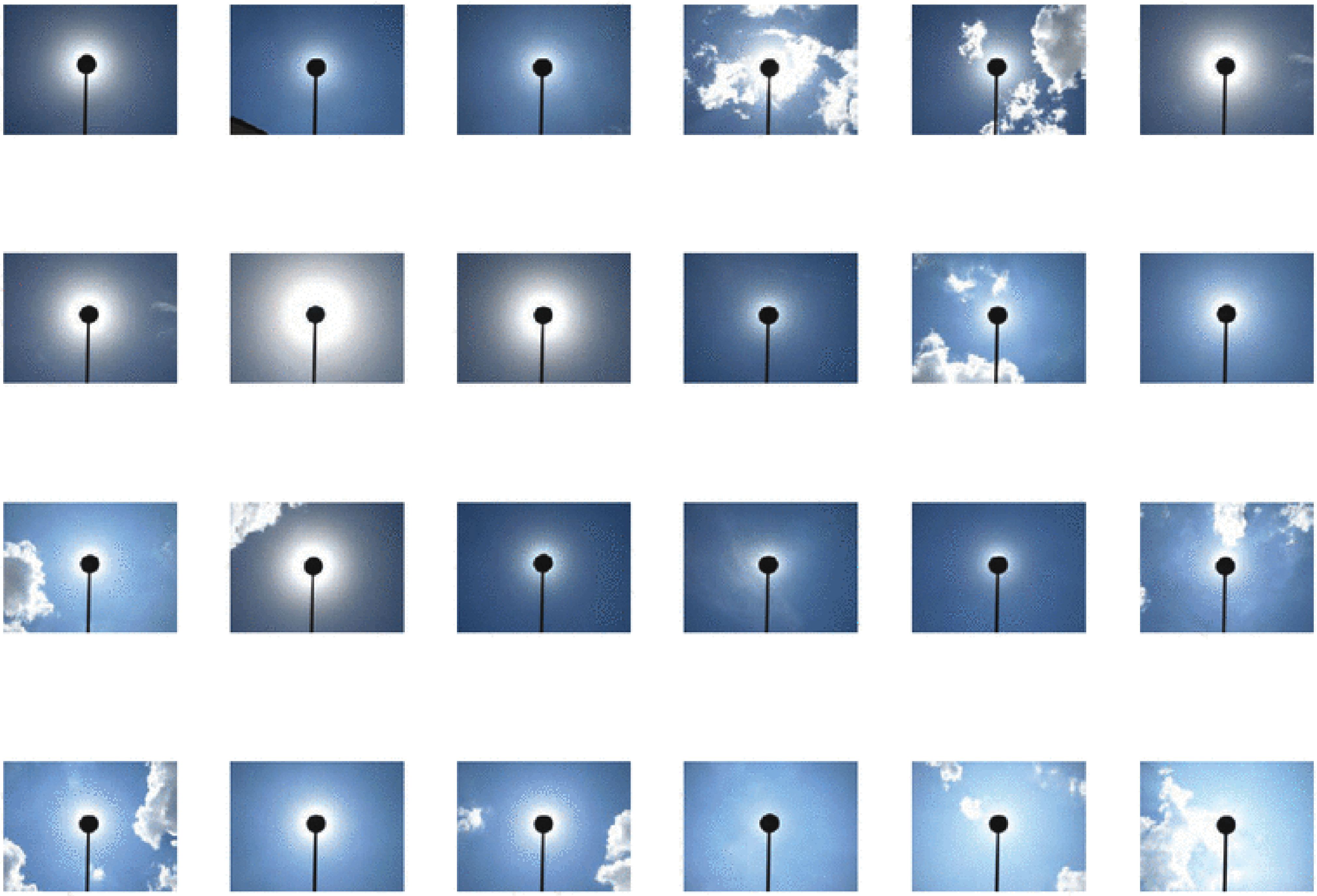
08 Oct 2008. Clear sky. Sunlight transmission at 525 nm (green): 94.3%



Photography by Forrest M. Mims III

TOP: The author's Canon G9 mounted on a simple occluder platform that blocks direct sunlight from entering the camera lens.

BOTTOM: The solar aureole photographed from South Texas on a day with thick dust from the Sahara (left) and a very clear day (right). Both images confirm the Naval Research Lab's aerosol forecasts for the same days (nrlmry.navy.mil/aerosol).



SOLAR JOURNAL: A recent series of solar aureole images made with the author's sun occluder.

⚠ CAUTION! Always wear sunglasses and never look at the sun while making aureole photographs. To avoid sunlight damage to your camera's image sensor, you must work fast. You may void the camera's warranty if you damage it by pointing it at the sun.

Doing Science with Your Images

For serious scientific purposes, it's best to make solar aureole photos at the same manual settings (I use 1/1,600 at f4) and at the same time each day the sun is visible.

Since 1990, I've made 2,392 aureole photos at or near local solar noon. Solar noon varies during the year, in accordance with the equation of time. You can find solar noon calculators and tables for your location online. Just search Google under "solar noon." Some sundial sites also have solar noon tables.

An even better choice would be to photograph the aureole when the sun is at the same angle in the sky. Again, the web has various sites that provide solar angle calculators. A good choice would be to select the sun angle at noon on the winter solstice when the sun reaches its lowest point in the sky.

Going Further

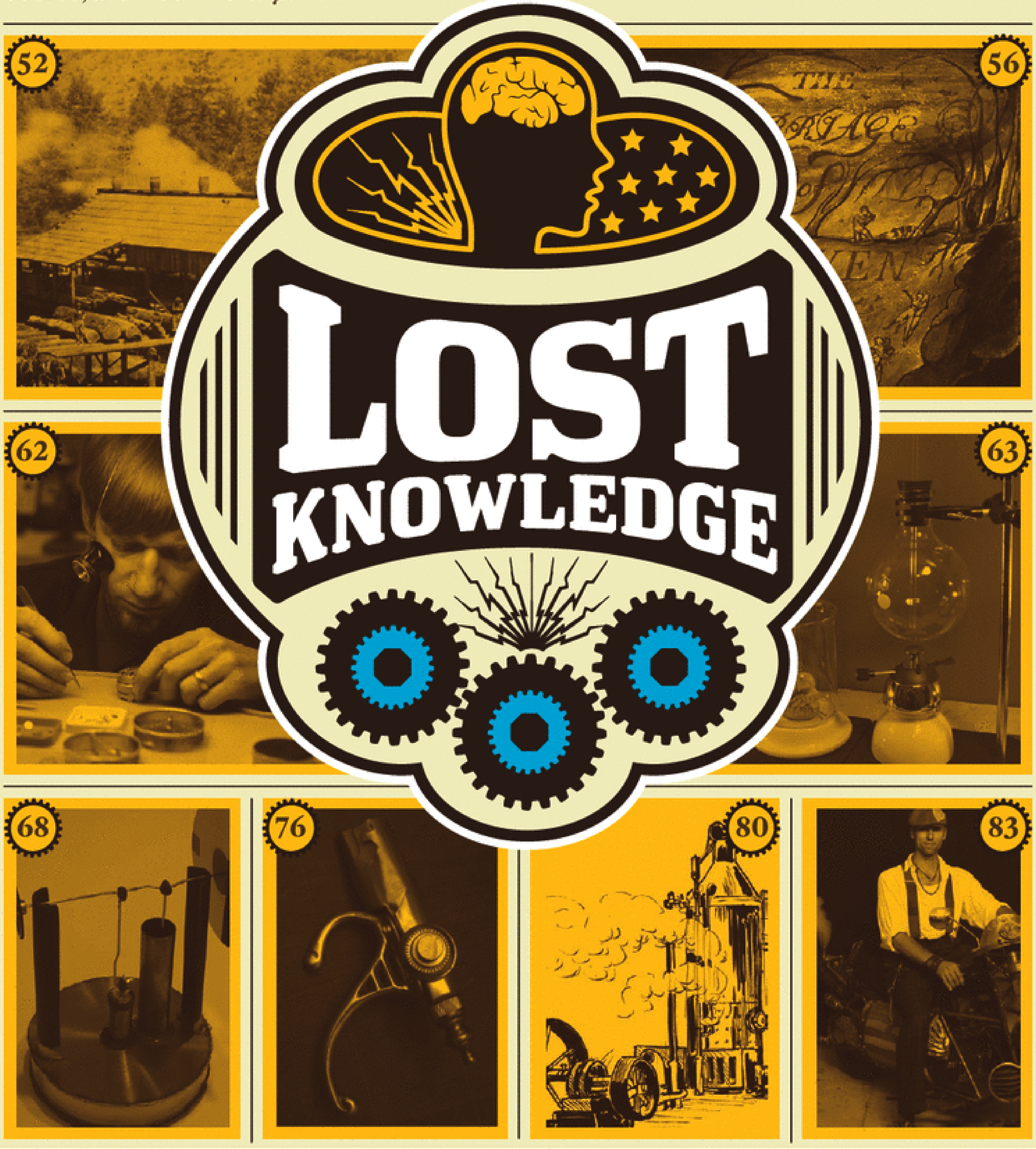
Next time, we'll use a free image processing program to analyze your solar aureole images and other kinds of photographs.

Forrest M. Mims III (forrestmims.org), an amateur scientist and Rolex Award winner, was named one of the "50 Best Brains in Science" by *Discover* magazine. His books have sold more than 7 million copies. He also edits The Citizen Scientist (sas.org/tcs).

Technologies from the dusty attic of the past can have as much mystery, excitement, and allure as those we imagine are just over the horizon. Today's amateur techno-historians don't just want to read about the gadgets of yesteryear, they want to build them, to interact with their constituent parts, right down to the rivet heads and hand-blown triodes.

Perhaps because modern technology seems so gray-box drab and utilitarian by comparison, retro makers like to bring the hand-built sensibilities of the past into their technosphere, re-casing their gadgets in highly ornamented forms of wood, brass, leather, and copper.

There's no end to how we can revive, recast, and refashion the machinery of the past, and meld it with the technology of the present. In this issue, we explore "**steampunk**" and the **revival of steam power**, **relief-etched illuminated printing**, the **art of mechanical time-keeping**, and **brilliant makers of centuries past**. We'll demonstrate how to build **a parlor-proven electrostatic generator**, **a vacuum siphon coffee brewer**, **an engine with a teacup power source**, and much more.

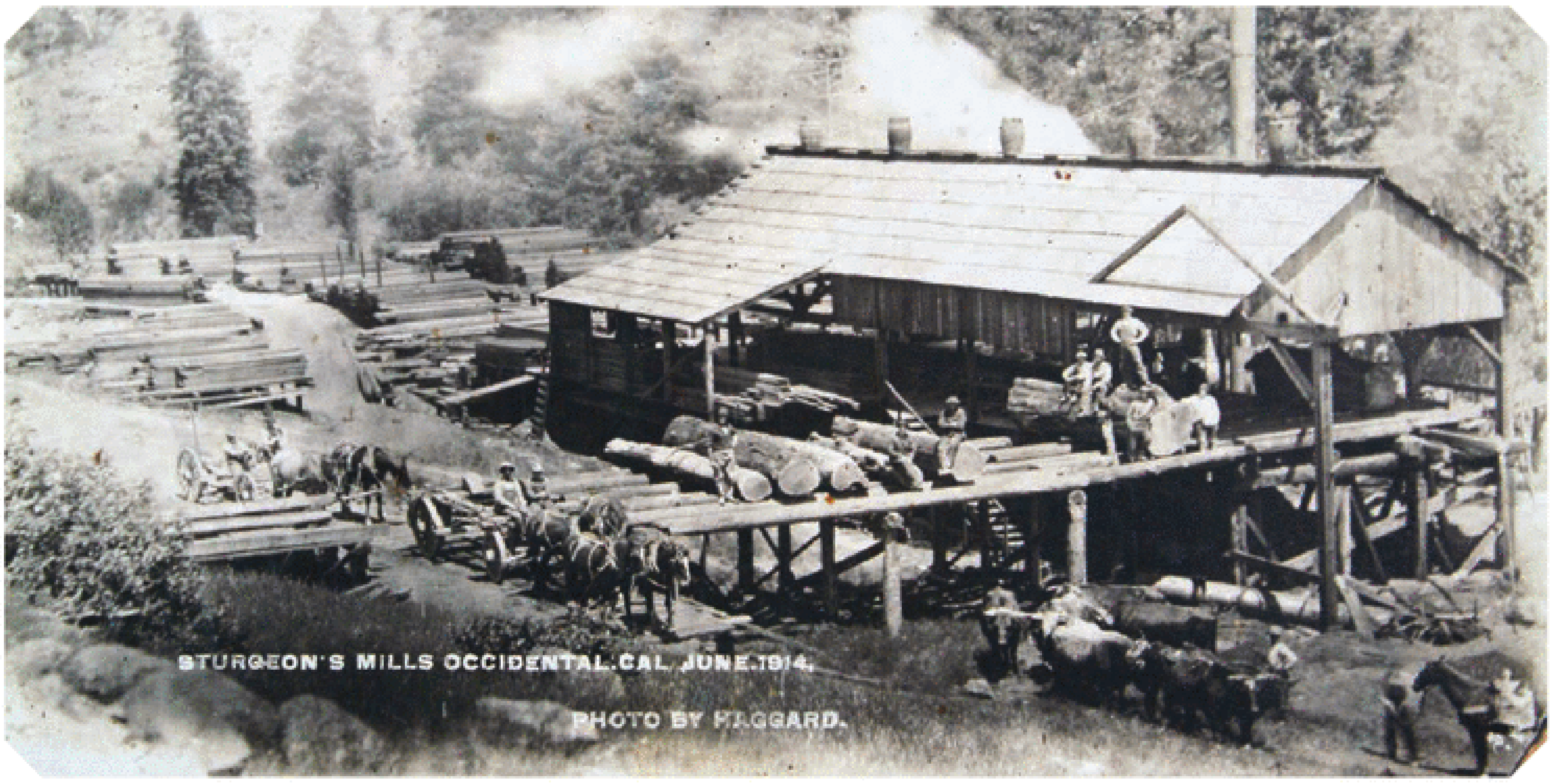


LOST KNOWLEDGE

THE Power of Steam

A steam-powered sawmill survives. [BY DALE DOUGHERTY]

Plumes of steam rise from a rusted tin roof and from side vents underneath the wooden building. They float among the redwoods that line the canyon and merge into a low, morning fog that has rolled in from the coast. A portal to the past has opened to reveal Sturgeon's Mill.



It's a world of steam whistles and forged iron, rumbling wooden floorboards and rhythmically pulsing, gleaming machinery, filled with moist air and piles of wet sawdust. At its center is a beast of a circular blade, with huge teeth, ripping through a giant log. Everywhere, men are working, unable to speak to each other above the noise, each one tasked with keeping the newly restored California sawmill alive.

Photography courtesy of Sturgeon's Mill (top), and by Dale Dougherty (bottom)

ABOVE AND RIGHT: The falling and bucking of a tree creates logs that are typically 16–20 feet long when delivered to the mill's landing. These logs are dogged to the sawmill carriage one at a time. BELOW: The *blocksetter* (Jay Meyer, below left) rides the carriage that holds the log as it passes the *head rig* — the 60" circular saw blade. The operator of the head rig is the *sawyer* (below, at right). The sawyer controls the direction and speed of the carriage and communicates with the blocksetter via hand signals.

Photography by Branca Nitzsche

ABOVE: Power to the main blade is controlled by the *engineer,* or *fireman,* who works on the ground floor below. The sawyer communicates with the fireman via short toots on the *signal whistle*. Two short toots means "Let's go!"; three short toots means "Run slow"; one long toot means "Stop!" BELOW: After the logs are cut into slabs, the *offbearer* handles the slabs coming off the main saw. Then the *edgerman* directs the slabs through the edger, which trims them further. Finally, the *trimsaw man* cuts the slabs into boards, in common lumber sizes like 2×4s or 2×6s, cutting out ruts and knots.

ABOVE: Beneath the main mill deck, the *boiler* and the *engine room* are run by the fireman, who is responsible for controlling the steam pressure. There are two main engines: an 1850s Atlas main engine and a late-1800s Erie steam engine. The boiler has an automatic pop-off valve if the pressure gets higher than 150lbs. The original boiler burned wood as fuel, creating a lot of smoke, which often filled the canyon. Today, the boiler is heated by diesel fuel. BELOW LEFT: Oilers slowly drip oil through petcocks into the operating crankshafts. BELOW RIGHT: The fireman, Tom Schaeffer, opens the valve or throttle on the 6" black iron steam line. Schaeffer is Ralph Sturgeon's grandson and he's also the *millwright*, the mechanic who maintains the machines at the sawmill.

Photography by Branca Nitzsche (top), and Dale Dougherty (bottom)

About a dozen workers are needed to operate the sawmill, each one with a very specific function. "It is very clear when you look at this old mill that it was very labor intensive," says Harvey Henningsen, who is leading efforts to restore the mill. "That was the economic downfall of the mill as the 1950s slipped into the 60s and 70s and modern equipment replaced workers." He believes the mill is worth maintaining so that future generations can see "how water was converted to steam, how it powered an engine that converted reciprocal motion into rotating power, and then how this rotating power was transferred throughout the mill by the use of belts and jack shafts."

Sturgeon's Mill (sturgeonsmill.com) is located near Sebastopol, Calif. (about four miles from MAKE's offices). Henningsen's father, James, and Ralph S. Sturgeon bought the mill in 1943. It operated in various locations from the late 1880s until 1964.

LOST KNOWLEDGE

William Blake: Patron Saint of Makers

The mad Englishman was on a mission that makers can relate to. [BY GARETH BRANWYN]

The Marriage of Heaven and Hell (Copy I, 1827), an early example of Blake's invented technique of illuminated printing and something of a proto-zine, with different writing styles, voices, postures, rants, and aphorisms.

Photograph courtesy of Fitzwilliam Museum, Cambridge

For the past 25 years, nearly every day, I've interacted with "the mad English poet" William Blake in some fashion. I poke my nose into one of the dozens of books I've lovingly collected, or I whisper (or shout to the rafters) a poem, or I chew on some gristly hunk of his ridiculously complex poetic psycho-mythology.

For someone with the attention span of a 4-year-old, having anything captivate me to such an extent is downright alarming. Equally strange is the fact that I rarely explain my obsession with Blake to anyone.

Why am I so fascinated by this apocalyptic, outsider artist (in his day) whose work still defies comprehension? What keeps me coming back?

In this article, I'll explain a little of Blake's invented printing method, and make my case for him as patron saint of makers.

William Blake, 18th-Century Zine Publisher

I was introduced to William Blake in British Lit class in high school, but ironically, it was during the desktop publishing revolution of the mid-1980s that I started to understand what he was really all about.

I came to the real Blake by way of the cyberneticist Gregory Bateson. Bateson was fascinated by how Blake famously "mixed up" modes of perception in his work; Blake claimed he had something called "fourfold vision" and that he could see things on different levels of awareness simultaneously.

Bateson had studied schizophrenia for the Veterans Administration and discovered that, similarly, schizophrenics confuse and conflate, for instance, the literal and the metaphorical; they don't organize thoughts, communication, and perceptions into logical categories the same way that non-schizophrenics do.

Blake also seemed to leak at the margins separating these logical types. Of course, one can argue that all artists do this, but it's the extremes of the leakage in Blake's work, the sheer quantity, and its complexity (and its surprising coherence, if you stick around long enough to sort it out) that makes Blake so compelling. Bateson was also intrigued by how functional Blake was while living in his world of perceptual and categorical mashups.

As I began to delve deeper into Blake, one day I had something of an epiphany. I'd gotten a lovely two-volume set of his most popular works: *Songs of Innocence* and *Songs of Experience*, two of his masterpieces of "illuminated printing," a technique of free-form engraving, painting, and printing he'd invented.

Up until his discovery, illustration engraving and book printing were two separate disciplines, with the engravings etched, printed, and later, tipped into the books as plates. By combining these two arts on the page, Blake's technique freed him to write text, compose pages, design typography, and paint illustrations, right on the copper printing plates.

I was reading about all of this while working on a zine publishing project, using an Apple Mac SE running PageMaker layout software. I was doing a lot of the writing, designing, even some of the illustrations, right in PageMaker, and printing out my zines on the Canon copier sitting next to my Mac. I realized that Blake had experienced the power of a different, but surprisingly analogous, set of media tools and felt a similar sense of creative freedom, more than 200 years earlier. William Blake was a zine publisher! William Blake was a multimedia artist![1]

"On England's Pleasant Pastures Seen"

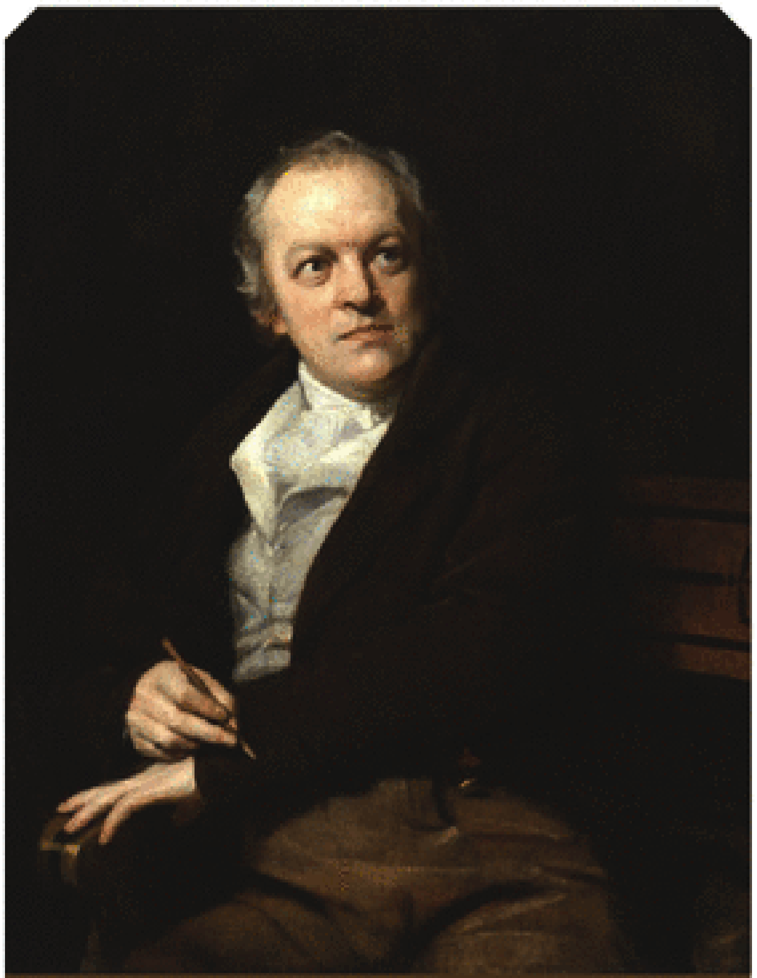
William Blake was born on Nov. 28, 1757, in Soho, London, in a modest apartment above his father's hosiery shop. His parents were devoutly religious, but they were Dissenters, nonconformists who opposed the established Church of England and its hierarchy. From an early age, Blake proclaimed religious visions, that he could see angels and other nonphysical entities. His father tried to beat such nonsense out of him.

Aside from punishment for seeing apparitions, Blake's early childhood was rather peaceful, even

1. Some scholars have even argued that Blake was a hypermedia artist. *Songs of Innocence* and *Songs of Experience* are not only two poetic cycles connected to each other, with a poem relating to youth and innocence, and a complementary one to age and experience, but they also contain additional images and textual passages that thread together in ways similar to linked content in a modern hypermedia document.

bucolic, as he wandered through fields on the outskirts of London, swam in farm ponds, haunted printmakers' shops, read the classics and the Bible, and studied as much art as he could find.

The rest of his life found him living through some of the most tumultuous times imaginable, including the American and French revolutions, great scientific and naturalistic discoveries, the dawning of the Industrial Revolution, and all the intellectual ferment and cultural activity excited by these seismic shifts.



William Blake by Thomas Phillips, 1807

It's no wonder that Blake's subject matter was so epic, so apocalyptic — all fire, upheaval, and psychic magma on one hand, and Eden-like dreamscape on the other. He saw tremendous potential in humanity and in the power of big ideas — and he dreamed of all of it coming to flower in his beloved Albion.[2] But he also saw the horrors of war, of poverty and class division, of state and religious intolerance, and of the shortcomings of science and reason when divorced from imagination and wonder.

Blake showed artistic promise at a very young age and was enrolled in drawing school at age 10. At 14, his father, ever the pragmatic tradesman, wanted his son to know a durable trade, so he signed him up as an engraver's apprentice, where he labored for seven long years. It was as an engraver that Blake developed a lifelong love for Gothic art and architecture and for the nobility of the engraver's and printmaker's arts (though he resented being forever identified solely in that trade).

In 1779, at 21, Blake was accepted into the recently formed Royal Academy of Arts. He quickly found himself at odds with the teachings of the school and its first president, Sir Joshua Reynolds. Reynolds would become a lifelong artistic foil for Blake, a two-dimensional symbol of everything he found wrong about establishment art and art that generalizes, abstracts, and handily categorizes; art that no longer "rouses the faculties to act."

Blake Dreams a New Method of Printing

In 1788, Blake claimed he'd been visited in a dream by his dead brother Robert (who'd recently died of consumption) and shown a revolutionary new printing technique.

Unlike traditional engraving, where the image outline is scratched into a plate prepared with an acid-resistant waxy "ground" and then the lines are exposed to acid, Blake's technique worked in reverse. The area to be printed was painted over with the acid-resist ground and then the plate was exposed to acid, eating away everything that was not the image.

After etching, he would touch up the image and clean the copper plates with his engraver's tools before printing the pages on a rolling press and then (usually) coloring the printed pages with watercolors.

For Blake, "illuminated printing" was the artistic breakthrough of a lifetime, "a method of combining the Painter and the Poet."

Anyone who's looked closely at traditional engraving tools and techniques can appreciate how painstaking, labor-intensive, and constraining the process is (a square inch of engraving can take hours). Now, imagine a method of engraving that combines text and artwork, where creation happens right on the plate, using pens and brushes, traditional artist's tools.

Imagine how excited Blake must have been by this discovery. Unlike traditional engraving, which was largely a copyist medium, a means of reproduction, illuminated printing was a means of original production where you could compose your ideas, and paint them, right on the printing plate.

2. Albion is the ancient name for Britain. In Blake's mythology, it also represented the "cosmic man," the being who splinters through space-time, falls from grace, and yearns for unity in a new Jerusalem.

To give you a better idea of how illuminated printing worked, here are a series of photos taken by Todd Weinstein in 1979 in the New York studio of Blakean scholar Joseph Viscomi. They were part of Viscomi's attempt at preparing, executing, and printing a relief-etched facsimile of plate 10 from *The Marriage of Heaven and Hell* (1790). Blake wrote little about his technique, so his process is not exactly known. Few of his plates survive. Tragically, they were mainly sold for scrap metal after his death. Scholars such as Viscomi have managed to reverse-engineer the process and they think it went something like this.

From the Heart of Los' Forge: **Preparing the Metal**

In Blake's psycho-mythology, his inner poet/creative man was named Los (likely "Sol" spelled backward). Los is a blacksmith, and given the preparations required to create the plates that Blake worked on, it's not hard to see how he would have made the connection between this prep work and the roots of his creations, both literally and figuratively. Copper sheets had to be hammered and cut into smaller plates, planed, washed, oiled, and polished.

Raising Up His Voice: **Painting the Text and Art**

Once the plate was prepared, Blake painted the text and artwork onto the copper surface with quills and brushes, using an "impervious fluid" that would resist the acid to which the plate would then be subjected. For this, he used "stop-out," an asphalt-based varnish found in traditional engraving, used to cover already-etched lines to prevent them from being further "bitten" into during successive etchant baths.

Because the designs would be transferred onto paper in an engraver's press, the art and text all had to be painted in reverse. While Blake was already used to reverse composition in engraving, he raised free-form mirror writing and mirror painting to an art form in itself. (For a man who believed it was a mission for each of us in life to do everything in our power to keep our minds awake, our imaginations expansive, and to look at things from multiple points

Fig. A: Copper plates were hammered, chiseled, and split to size, then polished with charcoal, pumice, oil, and water to create a smooth working surface. Fig. B: Stop-out varnish mixed with lampblack made an acid-resistant "ink" for creating the artwork on the copper plates. Fig. C: Blake could compose his work, in mirror images, right onto the copper plates. Fig. D: Blake would build a vessel of wax around the plate and constantly stir the acid like a cauldron brew.

of view, conceiving and visualizing everything backward must have been a great "mind hack" in support of this worldview.)

"Melting the Metals into Living Fluids": **Etching**

With the image painted onto the copper with impervious liquid, Blake would then create a dike around the outside edges of the plate with walls of soft wax. This allowed him to pour a bath of "aqua fortis" (nitric acid) onto its surface. As the corrosive acid bit into the exposed metal, Blake would hover over the plates like some Shakespearean witch, using a big bird feather to keep the acid agitated and to stir away bubbles that formed.

The process, with its noxious fumes, was not a

Fig. E: Ink is carefully added to the raised areas of the plate using an engraver's dabber. Fig. F: Blake would add color in the printing process by inking different areas of the plate with different inks before printing. Fig. G: An approximation of Plate 10 from *The Marriage of Heaven and Hell*, first copies probably printed in 1790. Fig. H: Plate 10 of *The Marriage of Heaven and Hell*, from Copy I, printed in 1827 and completed just months before Blake died.

pleasant one (some have suggested that the liver failure that finally took Blake's life may have been the result of "chronic copper intoxication"). It's no wonder that he called this an "infernal process," and that in his satirical masterpiece, *The Marriage of Heaven and Hell*, he located his print shop in hell.

With his penchant for leaking margins between modes of perception, Blake proclaimed that what he was really doing in his artistic process was "melting apparent surfaces away, and displaying the infinite which was hid."

After the etching was complete, he would remove the acid and the wax dike, rinse off the ink with turpentine, and polish the plate before inking.

"Without Contraries Is No Progression": **Inking**

Ink was applied to the etched copper plate with a flat-bottomed linen dabber wetted with engraver's ink. The ink was made of a powdered pigment mixed with burnt linseed or walnut oil. For multicolored prints, Blake would use smaller dabbers or brushes to apply spot colors to desired areas on the plates.

"In Which Knowledge Is Transmitted from Generation to Generation": **Printing the Plates**

Blake's wife, Catherine, was his assistant in hell's printing house and she was especially adept at printing, and in hand-coloring the printed pages. They used an engraver's press (with the plate and paper on a bed that passes between two heavy rollers when the press is cranked). Blake would ink and deliver the plates to the bed and Catherine would then place the paper, blankets, and backing sheets.

Given the metalwork, caustic chemicals, oily inks, and other "infernal" parts of the process handled by Blake, and the pristine and expensive white paper delivered by the lovely Catherine, it's no wonder that he saw their extreme roles as a symbolic expression of the dynamic, two-toned life process, his "marriage of heaven and hell."

"Exuberance Is Beauty": **Hand-Coloring the Prints**

For his illuminated books, Blake and Catherine would hand-color the printed pages with water-colors to complete an edition. Some editions, and individual copies, were painted very simply, others far more elaborately.

Over the years, Blake also changed, sometimes dramatically, the ways he colored the manuscripts. This could depend on his mood, or whether he desired to bring out some aspect of the work in a specific copy he was creating. This has allowed connoisseurs of Blake's work to enjoy, interpret, and heatedly debate multiple versions of the same work from countless perspectives, something Blake surely would have been thrilled by.

Create! The End Is Near!

During his lifetime, Blake was uncompromising in his work and what he wanted to say with it. His art is so dramatic, so muscular and apocalyptic, because he felt an overwhelming sense of urgency. One can almost picture him as a crazy man on a street corner, wearing a sandwich board, waving around dirty fistfuls of doomsday pamphlets.

But instead of proclaiming "Repent, sinners! The end is near!" Blake's message was more like: "Wake up! There's an artist asleep inside of you! Don't let the world lull you to sleep. Create!"

And that message, steadfastly encoded like a fractal equation, reiterating at every level of his work, is what makes William Blake a worthy saint of makers. He called his illuminated prints "windows into Eden." They were designed to function something like stained glass: you can see through them, to something on the other side. What he hoped you'd catch a glimpse of there was your own creativity, your own "poetic genius." Blake didn't want to create work for you to passively consume; he wanted to create work that would inspire you to make something yourself!

Blake's early biographer Alexander Gilchrist said: "Never before surely was a man so literally the author of his own book." Blake was self-taught in every discipline but engraving; during his lifetime, he was a painter, poet, essayist, author, inventor, philosopher, engraver, printer, calligrapher, graphic designer, bookbinder, singer, songwriter, and metalsmith (to name a few). One of Blake's best-known quotations is, "I must create my own system or be enslaved by another man's." There is no more ultimate "maker" statement than that.

SPECIAL THANKS: Information about Blake's printing technique used in this article comes from the article "Illuminated Printing" by Joseph Viscomi, available at the William Blake Archive (blakearchive.org). Many thanks to Professor Viscomi for providing these images.

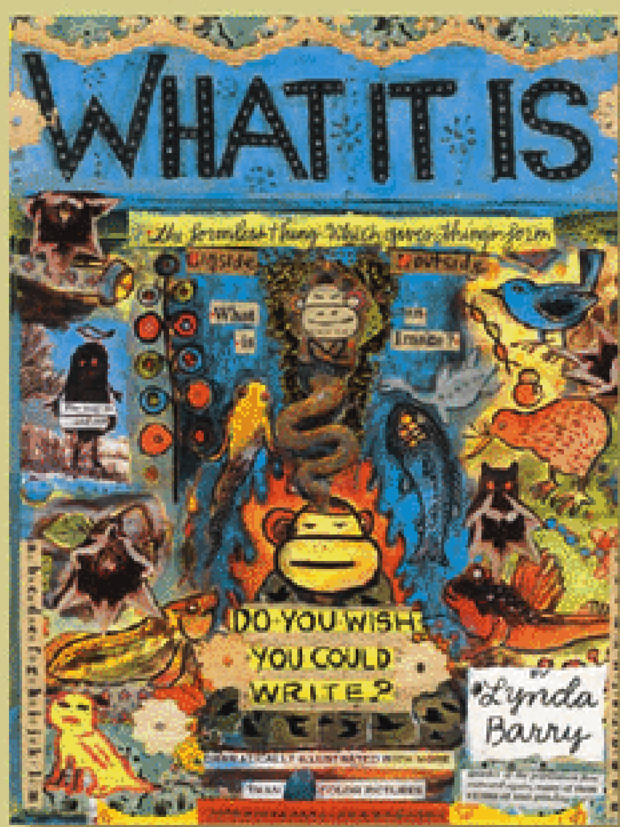
+ See larger versions of the illuminated printing process photos, and check out our own experiments in recreating the technique, at makezine.com/17/blake.

Gareth Branwyn is a contributing editor for MAKE, an editor at Make: Books, and part of the MAKE blog team.

Channeling Your Magic Cephalopod

I can't think of a better example of a real-life Blakean character, someone who's cultivated a similar self-modeled universe and who sees things from many unique angles, than contemporary comic artist and memoirist Lynda Barry.

This is impressively evident in Barry's new book, *What It Is* (Drawn And Quarterly, 2008). This densely collaged work is utterly uncategorizable — so many simultaneous modes of expression: a textbook/workbook on inspiring creative writing and cultivating creativity of all kinds; a memoir-comic of Barry's personal struggles with creativity and self-expression, especially as a child; a stunning, intense, and challenging piece of collage/altered book art; and a sort of extended fever dream on the nature of memory, imagination, play, and creativity.



Like Blake, Barry's message is also about rousing yourself from creative slumber. It's an extended pep talk on finding your sources of inspiration and using your senses and memories of life experiences to express yourself in ways that can truly enrich your life.

When you open up this book and poke your head into its dream-like sea of memory-ticklers, imaginative ideas, creative inspiration, and surreal imagery, it's hard not to want to put it down and go make something on your own. As if to drive home the beastly, manifold nature of primal creativity, Barry introduces the Magic Cephalopod (aka squid), a sort of creature from your id who swims through the murky depths of the text, its many appendages in constant creative motion, gently guiding you to swim off on some grand adventure inside the Mariana Trench of your own creativity.

This is Blakean art, and Blakean inspiration, for the 21st century. *—G.B.*

See more: makezine.com/17/watch

Teaching Time

The nation's premier watchmaker's college, in the heart of Amish country.

BY ERIN KELLY-PARK

CLOCKWISE: Ficklin assembles and lubricates a cleaned watch. A watchmaker's tools: Tweezers, hand installers, pin vises, movement holders, hammer, truing caliper, aperture plate, etc. Some of the 220-plus components of a Rolex wristwatch movement.

Twist the crown of a mechanical watch and you're winding a tiny spring, which powers a gear that runs until the spring is completely unwound, some two days later. Maintaining these miniature ecosystems is a skill that takes hours to learn — 3,000 hours, if you're as obsessed with keeping time as they are at the Lititz Watch Technicum or "LWT" (lititzwatchtechnicum.org).

Based in the Amish country of Pennsylvania, this watchmaker's college accepts just 12 students a year. After a two-year program, graduates can repair anything that ticks, and even fabricate parts.

Jordan Ficklin (watchmakingblog.com), a 2006 graduate of LWT, originally got a degree in computer science but now fixes watches. "Watchmaking tools haven't changed much in a hundred years," Ficklin says. "A few have become motorized, but the tweezers, lathes, and files haven't changed much."

"Probably the hardest skill to master is manipulating the tiny hairspring that controls the rate of the watch," Ficklin says. "The slightest mistake can ruin the work piece."

The LWT, funded by Rolex, aims to prevent a watch-repair crisis, as watchmakers have declined in recent decades. Rolex covers tuition, while students are responsible for their own tools, which can run up to $5,000.

Ficklin muses about traveling back in time 150 years. "Watches from that period would have had custom-fit components instead of manufactured pieces with the tolerances we have today. With a modern watch I can just order a replacement and put it in." Still, he notes, "Every day I have to adjust parts so that the play between them and the next component is within 0.01 or 0.02 millimeters."

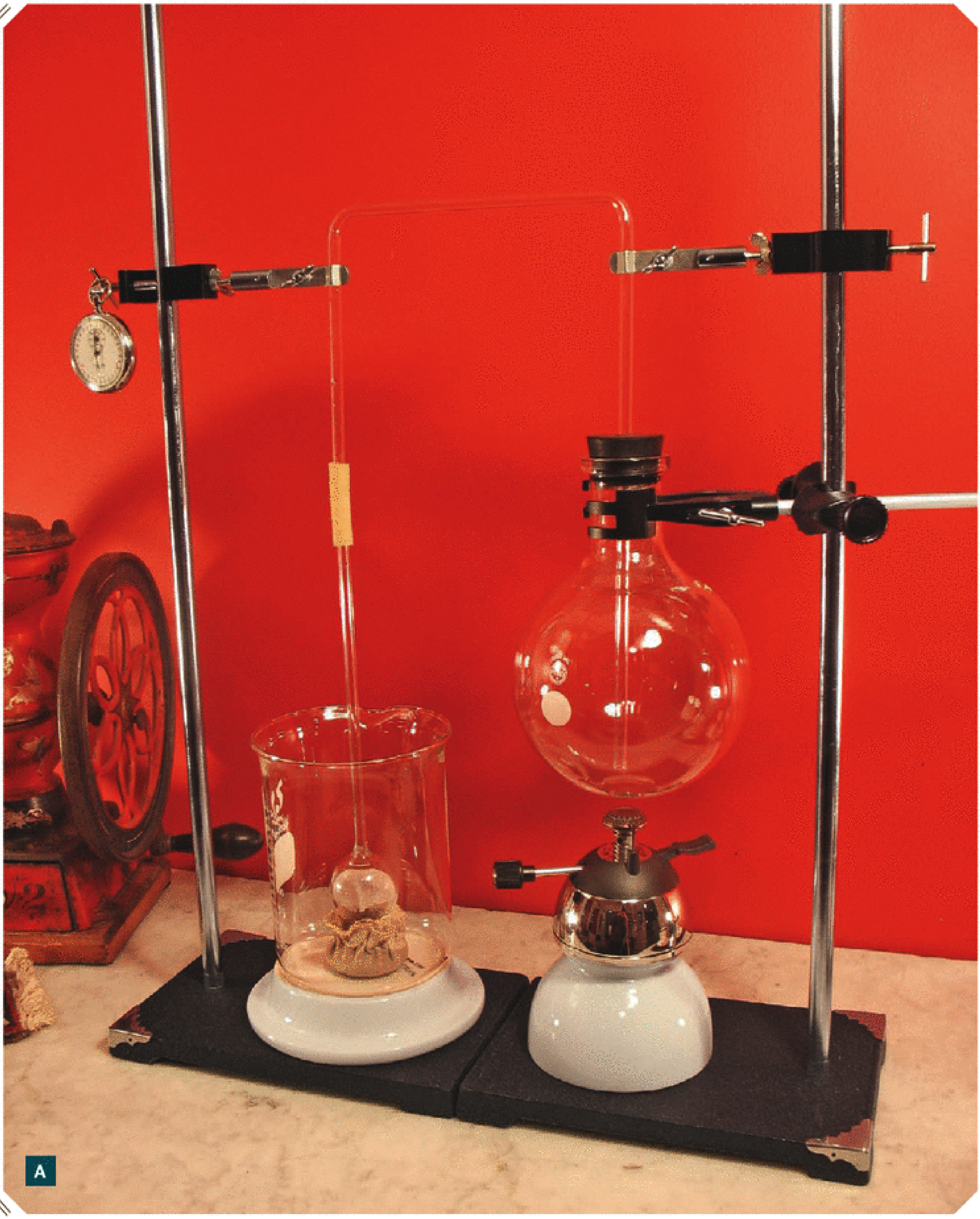
Your grandfather's Datejust will reap the benefits of this new generation of watchsmiths.

Erin Kelly-Park is wife to a maker and momma to two little makers. She lives in Southern California.

Photography by Ryan Heffernan

THE Florence Siphon Arabica Brewing & Extraction Apparatus

Make your own mad-scientist coffee machine. {BY J. EDGAR PARK II}



A

Photography by J. Edgar Park II

Aboard the dirigible Aeroship Phaedrus, two men are seated at a table in the onboard laboratory:

"Doctor Liepold, would you kindly prescribe something to lift my depressed spirits?"

"Why of course, Captain Heffernan. What is it that ails you?"

"My mind feels sluggish and there is still much work to be done before daylight. I am drawing up charts for the expedition."

"Ah, yes, I have just the thing. Sit a moment while I extract the invigorants from these wondrous beans."

"Very good, thank you. What is that strange device, Herr Doktor?"

"I call it the Florence Siphon. It is an arabica brewing and extraction apparatus. Allow me to demonstrate. First, I fill this boiling flask with a quantity of pure spring water. It is a vessel of my own devising that can withstand great heat and pressure. I heat the flask, which causes the water to vaporize, passing through this tube here, through a filter, and into the beaker to my left. Here, the water commingles with precisely roasted and ground fruit of *Coffea arabica*. I give the slurry a rapid stirring to fully saturate the grounds, then wait.

"As my boiling flask cools, a vacuum is created, causing the very atmosphere of the Earth to push the liquid through the filter, leaving the grounds and all unsavory particulate matter behind. Thus the liquid, now filled with essences, oils, solubles, flavors, and vital invigorants, is returned to the flask. Allow me to unstopper it and pour you a dose."

"Doctor! You have outdone yourself! I feel revitalized by this most miraculous potion."

The vacuum siphon coffee brewing method dates back to the 1840s. It produces some of the cleanest, smoothest-tasting coffee of any method. Commercial vacuum pots are available, but I wanted to heighten the drama of vacuum brewing by taking it into the realm of the mad scientist's lab. Thus the Florence Siphon was born!

After studying original patent drawings and existing devices, I identified these key features:

» Water is heated in a boiling flask that has a tube leading to a second vessel containing ground coffee.
» The tube must have a filter, to allow the water to flow through but not the grounds.
» The filter must be submerged during brewing, so as to maintain a seal with the boiling flask.
» The second vessel must be accessible for stirring the slurry.
» The boiling flask must be large enough to create a sufficient vacuum as it cools to "pull" the coffee back through.

One drawback to early vacuum brewers was the constant danger of exploding glass. Today, we have plenty of high-quality borosilicate glassware that's up to the task — it just happens to be found in the lab, not the kitchen.

Filtration was another challenge. I tinkered with a few options (including an unfortunate foray into shower heads) before arriving at an inverted thistle tube. This is a type of bulbed funnel that's easy to cover with filter cloth. (Thanks to Dr. Jim Callan from Avogadro's Lab Supply for this suggestion.)

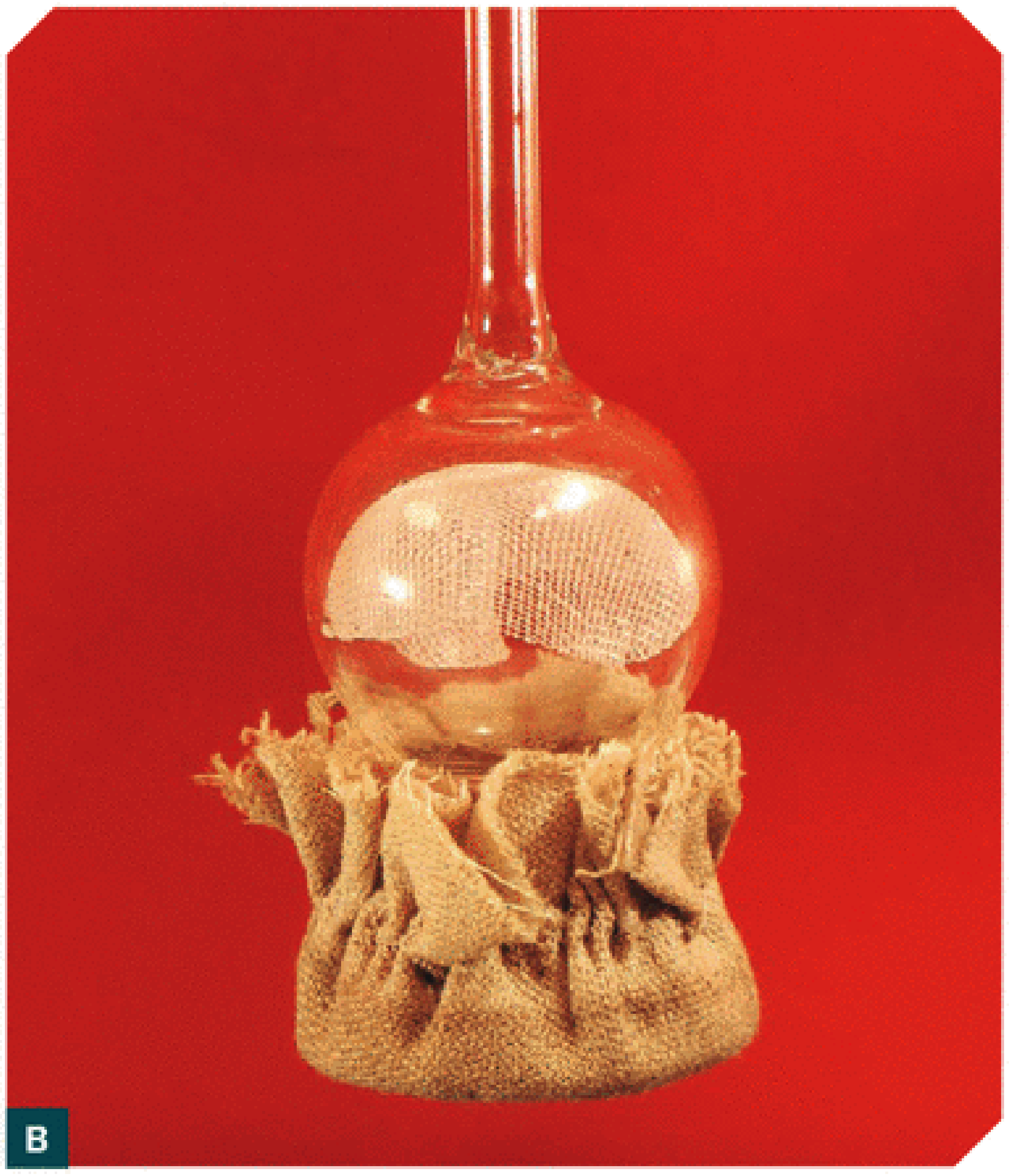
I assembled my funnel, stopper, tubing, filter, and a beaker for the grounds. I filled my flask with preheated water (small burners can take a while to boil 500ml), poured 38g of medium-ground coffee into the beaker, donned my goggles, and lit the burner.

The water began to bubble quickly, and soon went straight up the glass tube and over to the grounds. After about a minute, the flask was nearly empty and I extinguished the flame. At this point, there was an abundance of expanded water vapor (steam) inside the flask, which prevented the water from returning.

I stirred up the slurry with a stick and then waited with great excitement. Would the siphon be able to draw the coffee back up? At just about the 2-minute mark, I saw the gorgeous brown liquid begin its ascent. This is due to the vacuum created by the cooling and contraction of water vapor in the boiling flask. It was tentative at first, but as the boiling flask continued to cool, the coffee started to move quickly up the tube, over and then back down to the flask below. Within another 20 seconds, the journey was complete: 420ml of coffee made it back, leaving 80ml of water behind with the grounds.

I removed the stopper and poured myself a cup. It was perfect! Smooth, bright, clear, and clean. Vacuum coffee is a step above a French press, and leagues above drip. Plus, when you brew with the Florence Siphon you get to don your lab coat and cackle maniacally. What more could you want from a cup of coffee?

Here's how to build your own Florence Siphon. »



B

C

MATERIALS

I purchased all the lab supplies from Avogadro's Lab Supply (avogadroslabsupply.com).

CAUTION: Use only brand-new lab equipment. Used glass can contain seriously scary things that can kill you.

- 1000ml Florence flask, Pyrex or Kimax brands only
  aka round bottom flask or boiling flask
- Rubber stopper sized for Florence flask
  Mine was a #8.
- 1000ml Griffin beaker
- 4mm O.D. glass tubing, 12" length
- Glycerin
- Latex connection tubing, 2" length
- Thistle tube with 4mm tube O.D., 1½" funnel mouth
- Cloth filter **I used a Yama vacuum pot filter from sweetmarias.com/prod.brewers.vacuum.shtml.**
- Rod stands (2)
- 4-fingered clamp for Florence flask
- Tube clamps (2)
- Butane burner
- Stopwatch or other timer
- Grease pencil or crayon
- Optional: Flask tongs, cork flask stand, pouring funnel

TOOLS

- Drill or stopper borer **to create a 4mm hole**
- Thick leather gloves **for heating and bending glass**
- Safety goggles

Build It

1. Wash the glassware with a small amount of dish soap and warm water.

2. Assemble your stands and clamps as shown in Figure A on page 63. Put the burner, Florence flask, and Griffin beaker in place. To connect the 2 vessels, you'll need to put two 90° bends in the glass tubing. Measure the height of your Florence flask, then add 3". This is the length from one end of your glass tubing to the first bend. Place a mark there with a grease pencil or crayon. Measure the distance between your tubing clamps. This will be the distance between the two 90° bends. Mark this distance from the first bend on the tubing.

3. Turn your butane burner on high heat, don your gloves (or optional mad scientist gauntlets), then place the glass rod at the first bend mark. Roll the tube in the flame, putting gentle pressure on it so you can tell when it begins to soften. When it's soft enough, gently bend it to 90°. I'd never done this before this project, and it sure is fun!

CAUTION: Wear thick leather gloves and long sleeves when bending or inserting glass tubing.

D

E

4. Using the same method, bend the glass tubing at the second mark. It's important that the bends are aligned on the same plane, so you may need to reheat and adjust.

5. You should also heat the ends of the tube and roll them in the flame to round off the sharp tube edges. Don't overheat them and close off the ends!

6. Using either a drill bit or a stopper boring tool, make a 4mm hole through the center of the rubber stopper. Lubricate the hole with glycerin and very carefully push the long end of the glass tube into the top of the stopper hole. This can be dangerous if done too quickly, so take your time, think happy thoughts, and wear gloves and long sleeves. The stopper should hold the glass tube about ½" off the bottom of the Florence flask when properly seated.

7. Cut a 2" length of latex tubing, and use it to couple the glass tubing and the thistle tube.

8. Place the cloth filter over the end of the thistle tube's funnel mouth, then pull the drawstring tight and tie it off (Figure B, previous page). (I had also inserted a Teflon screen that proved unnecessary.)

9. Attach the filter/tube assembly to the 2 tube clamps, so that they hover above the Florence flask and Griffin beaker (Figure C). You should test pushing the assembly down so that the stopper is in place and the filter rests about ⅛" above the beaker floor. You can adjust these heights with a greater length of latex tubing, or use a stand to prop up the beaker, as I did. I found a disused wine bottle holder that did the job nicely.

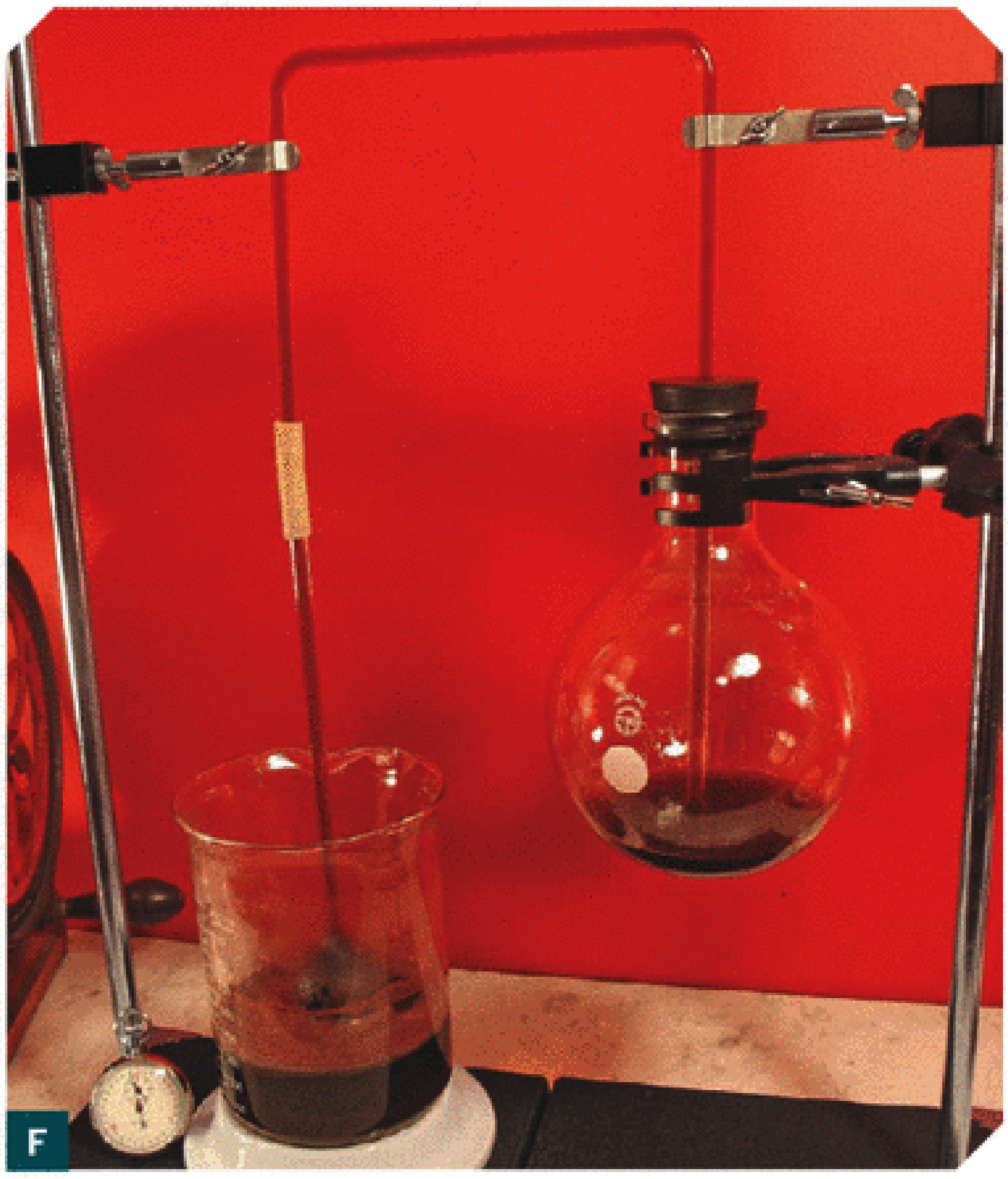
Brew It

1. Preheated water can be a timesaver. Raise the filter/tube assembly, then pour 500ml of hot water into the Florence flask.

2. Grind fresh coffee beans on a medium-fine setting, somewhere between a drip and an espresso. You'll fine-tune this over time. Pour the grounds into the Griffin beaker.

3. Lower the filter/tube assembly until the rubber stopper is firmly in place. The stopper must have a good seal all the way around. The filter end will be dug down into the grounds at this point.

4. Don your safety goggles, then ignite the burner (Figure D). It should take a few minutes for a butane burner to bring the water up to temperature. Watch



F

G

for the water to rise up the tube, defying gravity. It's a very exciting moment!

5. Once nearly all of the water is in the Griffin beaker, start your timer. Lower the heat enough to maintain a low, bubbling roil in the small bit of water that remains behind in the Florence flask. This will keep things from progressing too quickly.

6. Give the water-saturated grounds a few stirs with a spoon or rod (Figure E). If your coffee is fresh you'll see it "bloom" as gases are released.

7. After 1½ minutes have passed (you'll learn to adjust this timing, so keep notes), turn off the burner and remove it. As the flask cools, steam will contract and draw the coffee out of the grounds and back to the flask (Figure F).

8. When the coffee has stopped flowing, carefully unstopper the flask and raise the filter assembly tube (Figure G). Remove the flask of coffee. Pour yourself a cup of the most delicate, nuanced coffee you've ever brewed. Drink and enjoy madly.

J. Edgar Park II is a digital automata builder for cinema theatricals, and the host of the Maker Workshop on *Make:* television.

The Method Behind the Madness

Why is siphon coffee so good? Two reasons: Ideal water temperature and optimal contact between the grounds and the water. Water turns to vapor prior to boiling, and then heads out of the boiling flask and into the ground coffee. This means your water is right around 200°F when the brewing begins. Electric drip brewers are notorious for their wildly inaccurate brew temperatures (and the sour brews they can produce as a result).

All of the water in a siphon brewer is in contact with all of the grounds during the entire brewing process. This gives the water the greatest chance to extract the things we want out of the coffee grounds. In all but the best drip brewers, a tiny stream of water flows quickly through the center of the grounds, leaving behind much of the flavor.

Once you get the hang of your siphon brewer, you can brew for a very precise amount of time. When the vacuum pressure is great enough, it will pull the coffee back into the flask rapidly. You can instigate this by cooling the flask with cold water, or even a wet cloth, although I'd be careful not to shock the glass too much with an ice bath.

THE Teacup Stirling Engine

Turn the heat from tea, coffee, or candles into piston power!

BY JIM SHEALY

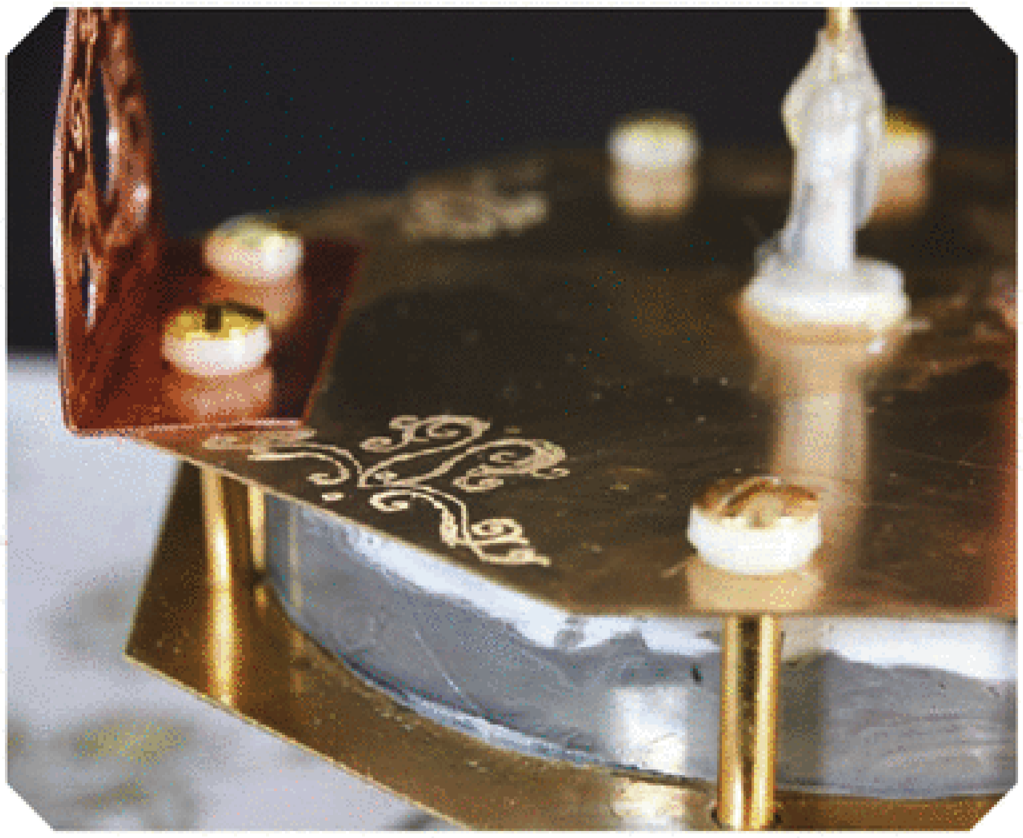
Photography by Sam Murphy

There's energy all around us, just waiting to be tapped. Whether it's a hot cup of coffee on a cold day, light from the sun, scented candles, or waste heat wafting from electronics, it's all potential power waiting to be harnessed! This is the world of the Stirling engine.

Have you ever tried this fun experiment? Put a tightly filled balloon in the freezer. When you return, you'll find it shrunken. Bring it out into the warm room again and it will expand!

What if we could use these expanding and contracting states to move a piston? This is the principle behind the Stirling engine, invented and patented by the Reverend Doctor Robert Stirling, in 1816. It's a simple idea, for a very simple engine. Let's build one!

Jim Shealy is a 17-year-old who enjoys building engines. He's built everything from pulse jets to turbines, and is currently enrolled at Georgia Tech.



MATERIALS

- CD or large plastic jar lid such as a peanut butter lid
- 10"×5" piece of aluminum or steel plate, at least 1/16" thick Two 5"×5" pieces are fine.
- Plastic CD spindle case from a stack of blank CDs
- Wire rod, 1/8" steel or 1/16" stainless steel Welding rod is preferred, and stainless steel is best; it must be smooth and straight!
- 3/4" PVC pipe, 7" length
- 10"×5" piece of foam board or two 5"×5" pieces
- 3/4" copper pipe
- 1" length of any type of pipe, C-stock, or L-angle stock
- Epoxies: J-B Weld or J-B Kwik, and cheap 5- or 15-minute epoxy If it says "non-shrink," don't get it!
- Hot glue gun and glue (optional)
- Fan weights or pennies (optional)
- Double-sided tape (optional)

TOOLS

- Hacksaw
- Utility knife
- Drawing compass
- Ruler
- Marker
- Electrical tape or glue
- Drill and drill bits: 1/16" or 1/8", 5/32", 1/2"–3/4"
- Needlenose pliers (2 pairs)
- Wire cutters
- Hair dryer
- Plastic cling wrap
- Window cleaner
- Cooking spray

COMPLEXITY: DIFFICULT

Before starting, read the tips on page 75 so you know what you're getting into.

1. Cut the displacer ring.

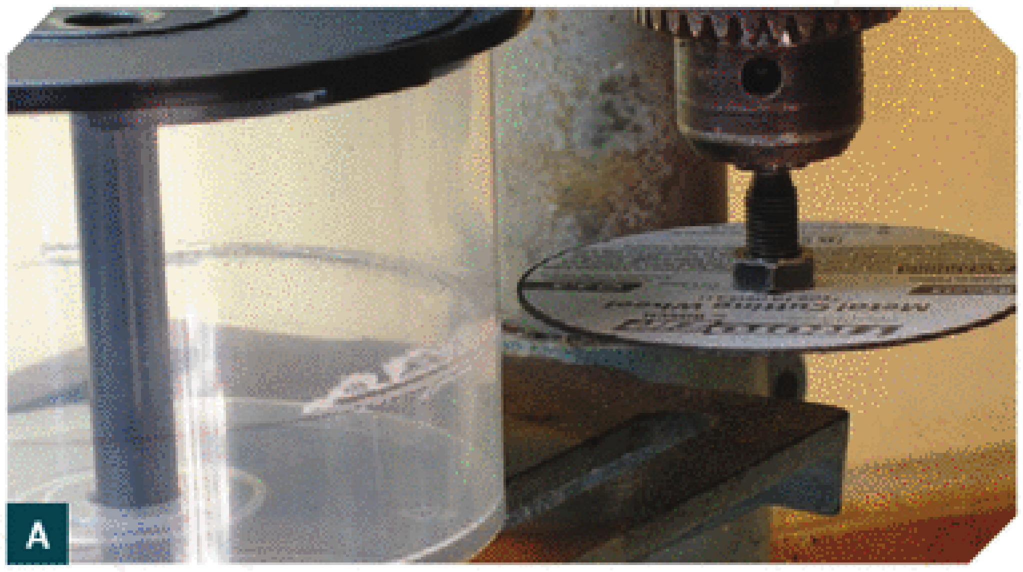
Mark a CD spindle case 1" below the top, all the way around. You can fill it with CDs up to your mark and use them as a guide. Remove the CDs and cut the case in two, along your mark. I used a drill press and cutoff wheel and made a level cut by spinning the case (Figure A, following page). A hacksaw works, too. Next, cut the top off the case, leaving a ring.

2. Make the displacer.

Using the cut top of the CD case as a guide, span your compass from the center of the case to 1/4" from the edge — 2 1/4" in my case.

Draw 2 circles with this radius on your foam board (make sure to mark the center points!). Cut them out roughly, then use a jigsaw, foam cutter, or utility knife to finish the cuts (Figure B).

Stack the 2 circles, then tape or glue them together around their circumference. I used white electrical tape (Figure C).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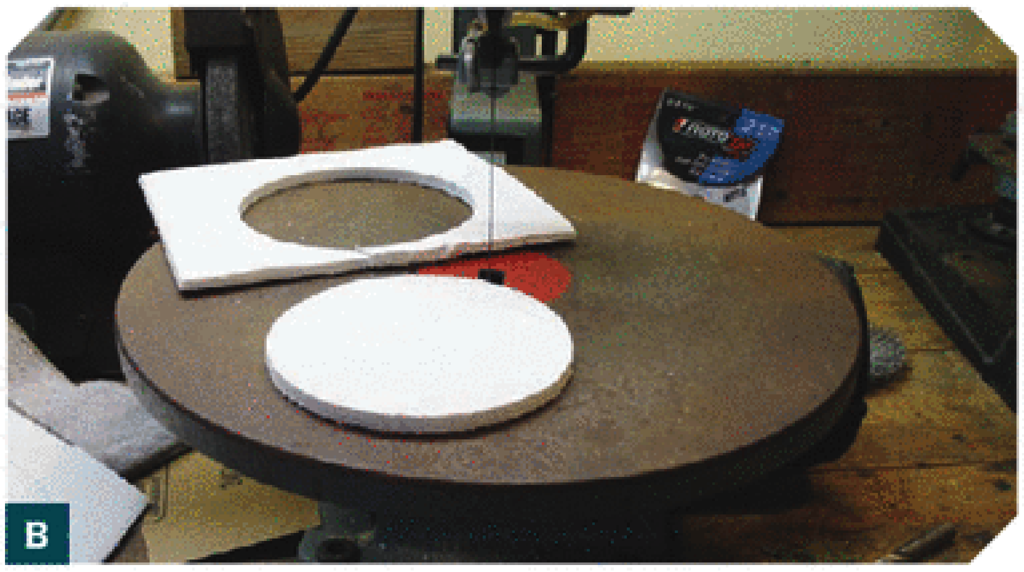
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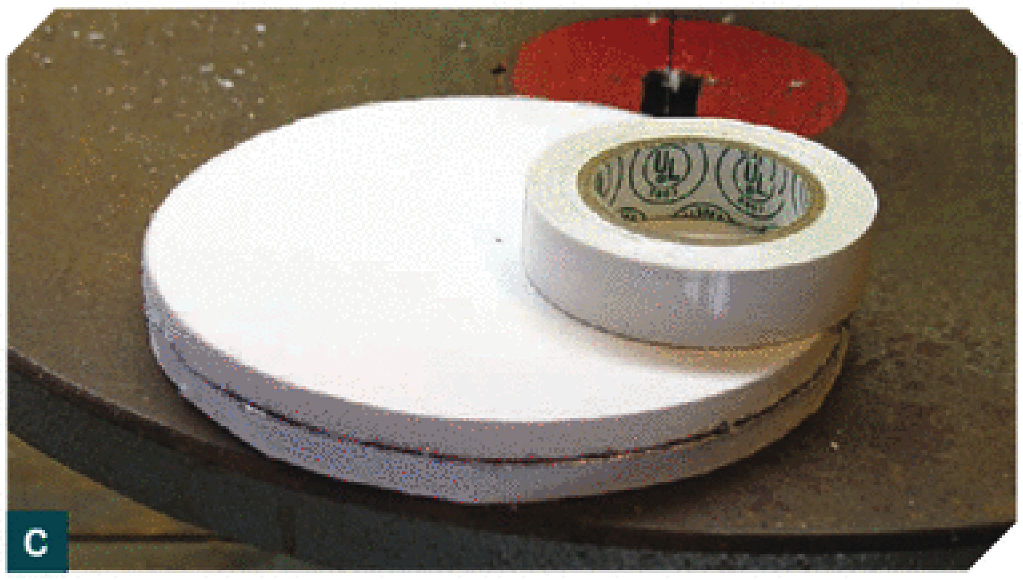
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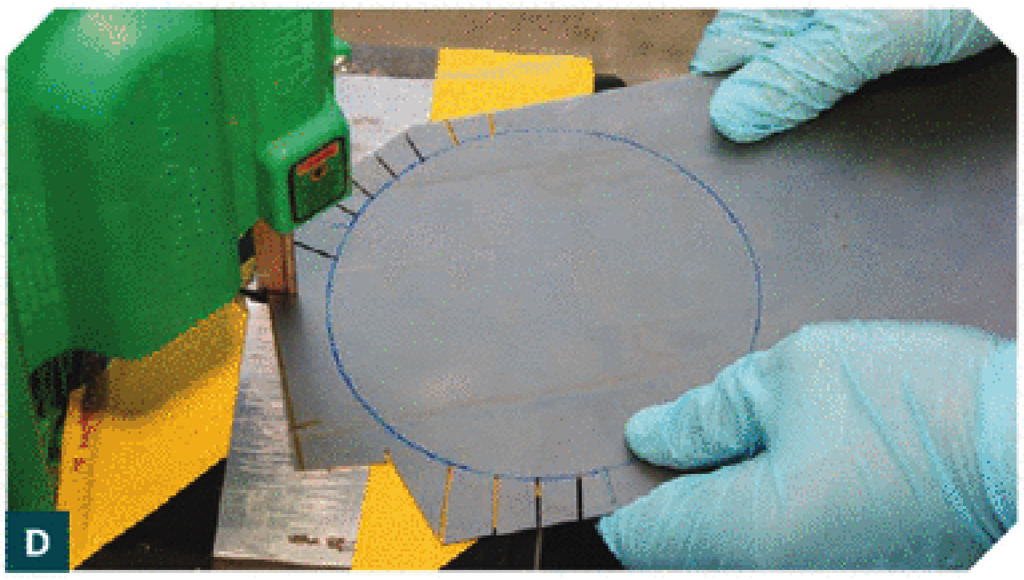
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3. Cut the aluminum hot and cold plates.

Draw two 5" circles on your aluminum stock. These are the top and bottom plates (cold and hot, respectively) that power your engine. Use a hacksaw or band saw, take it slow, and cut out the circles (Figures D and E). They don't have to be perfect; just make sure they cover the displacer ring completely.

4. Drill the top plate to fit the rod.

Here's where problems can arise — not critical ones, but extremely annoying ones. Using your small drill bit (the one that matches the diameter rod you're using, in my case 1⁄16"), drill through the exact center of 1 plate (Figure F). This will be your top/cold plate.

Test-fit the rod in the hole and make sure it's a smooth fit. In order to maintain thermal efficiency, we need this passage to be as airtight as possible, but still allow the rod to run smoothly in and out of the plate. If you wiggle the wire around, you may notice that it tends to stick at any angle. Keep it perpendicular to the plates.

If the rod isn't running smoothly, try this: Run the bit through the hole again to make sure it's clear. File or sand down the edge of the wire rod to make sure it's not causing any binding. If it still doesn't fit, try wiggling the plate around a bit to widen the hole.

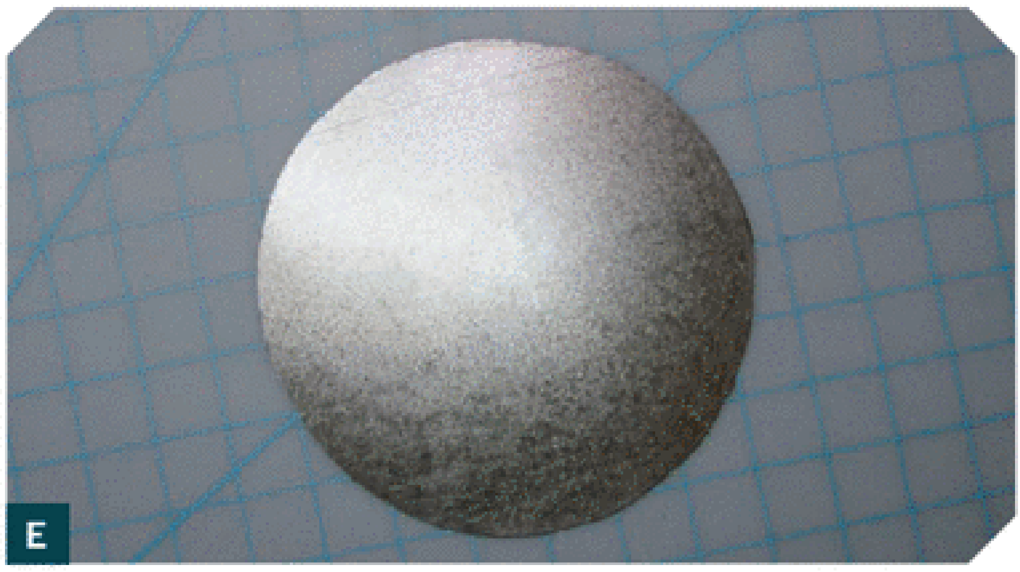
5. Build the top plate standoff.

Once the rod runs smoothly, cut a 1" piece of pipe, C-stock, or angle stock (I've used both angle stock and pipe for this), and cut a small square (or circle, if you're using pipe) of metal from the scraps you cut while making your plates. Drill a hole in the exact center of the small square (or circle). This will act as a standoff to keep the displacer rod perpendicular to the plates.

Center the piece of angle stock (or pipe) over the hole and glue it down to the top plate with epoxy (Figure G). Poke the wire rod through the holes in the plate and the standoff, making sure it slides smoothly, and glue the standoff to the angle piece. As the epoxy cures, check periodically that the rod still moves freely in the hole, and adjust if necessary. If the rod "freezes," redrill the top hole with the next-larger bit.

Finally, near the edge of the top plate drill a ½"–¾" hole (Figure H). Bigger is better, but just make sure the pipe you're using for the piston cylinder is slightly bigger than this hole (the pipe should not fit inside this hole).

Photography by Jim Shealy (A–C, G, H) and Ed Troxell (D–F)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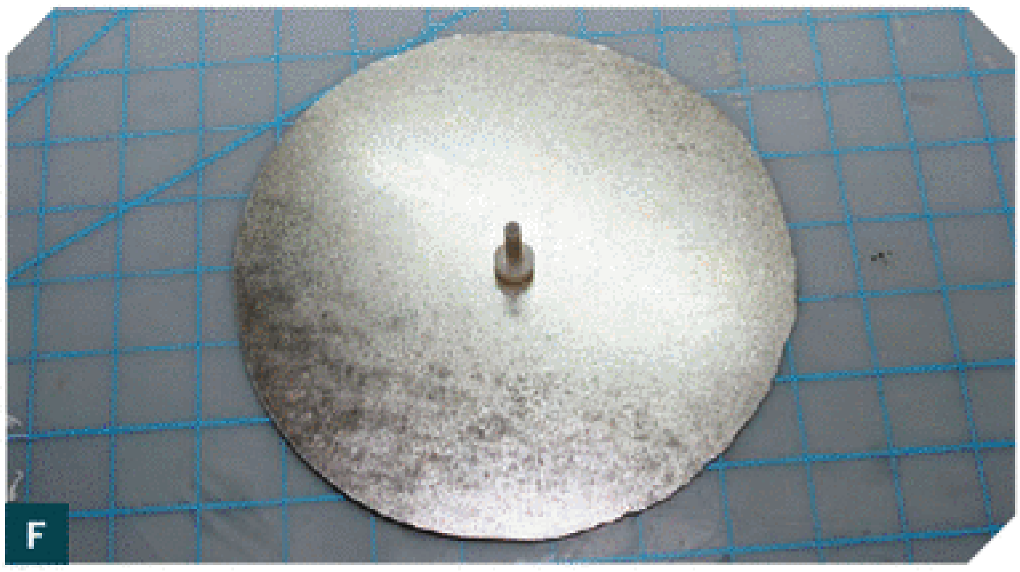
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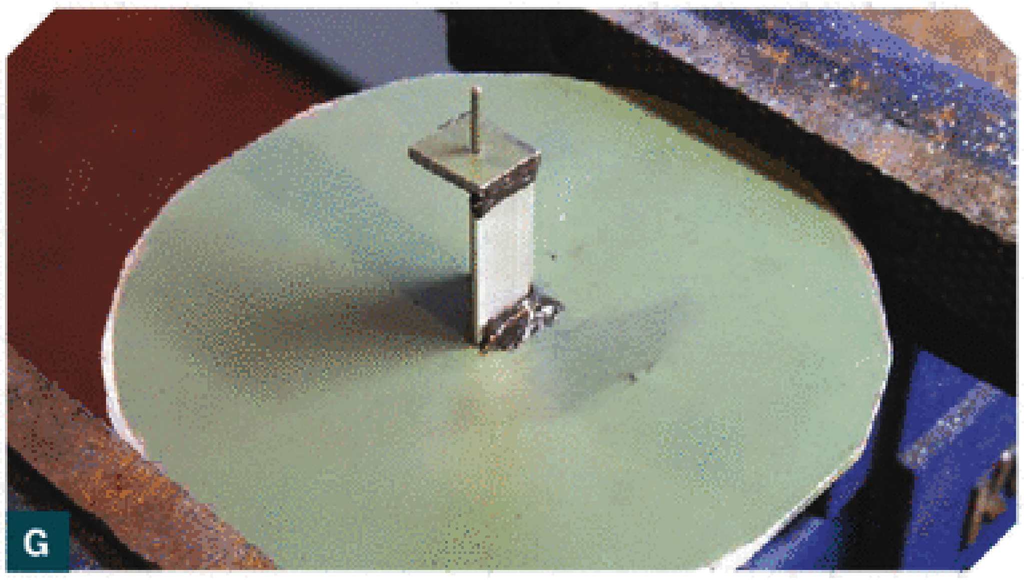
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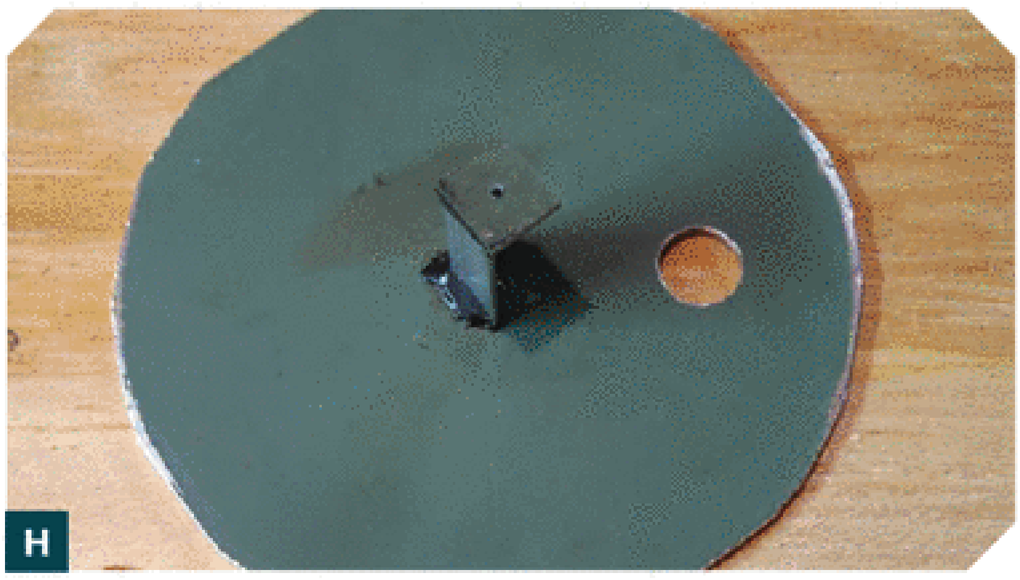
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6. Cast the piston.

I've tried using nearly everything under the sun as a piston. Nothing worked. Without machining one, you're left with few options. So, we'll cast a piston.

6a. Cut 3" of copper pipe; this will be your cylinder. Deburr the inside edge with a utility knife. Don't use sandpaper; you're smoothing the pipe so you can push out the cast piston. Clean the inside until it's nice and shiny. Window cleaner helps.
6b. Wrap the base of the pipe with plastic wrap and secure with a rubber band. Then oil the inside of the pipe (Figure I, next page). Cooking spray works fine.
6c. Pre-warm your 15-minute epoxy components using a hair dryer. You want it nice and runny. Mix enough epoxy to fill ½" of the pipe or so. Fill the pipe. Once the epoxy is fully cured, remove the plastic wrap. Your cast piston should push right out (Figure J). Before you push it all the way out, mark the piston and cylinder so you can match them exactly later (see tip on page 72).
6d. Cut 1" of wire and bend the end into a hook. Drill a hole in the center of the piston and glue the hook in place (Figure K).

While you're waiting for the piston to cure, use J-B Weld or J-B Kwik to glue your plastic displacer ring to the bottom metal plate (Figure L).

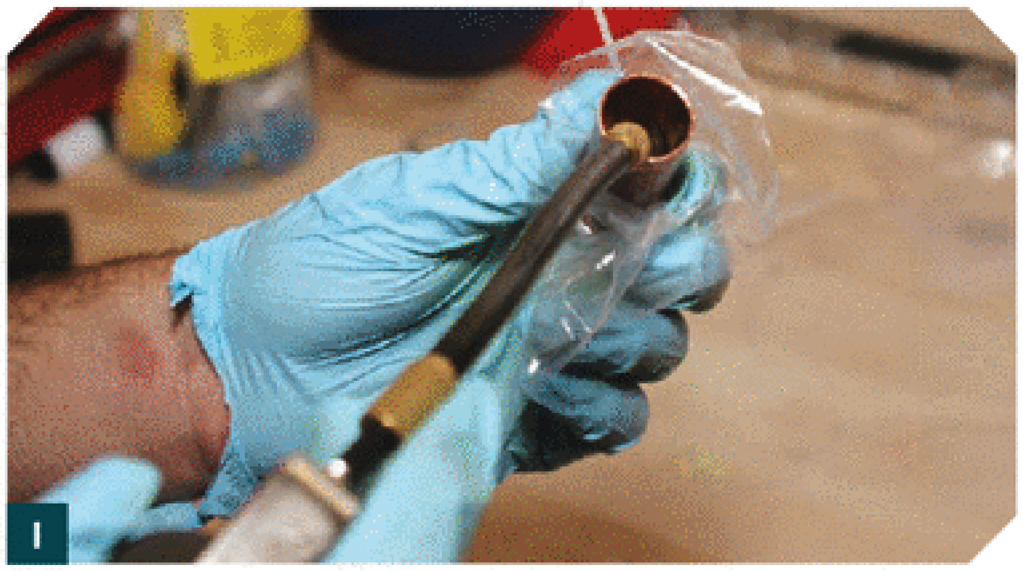
NOTE: For the best piston-casting results, don't mix the epoxy in the cylinder. The oil seems to contaminate it and keeps it from hardening. Mix on wax paper or plastic wrap. Don't use 1-minute epoxy; it can shrink too much or get too hot. Also, don't use extra-time epoxy; it probably won't shrink enough.

7. Make the displacer rod and 2 lever arms.

Here's a critical step: correctly bending the wire rods. Take some more wire and bend a hook in 1 end. Cut the other end at about 5". This is your displacer rod (Figure M). Sand the end and make sure it fits through the hole in the aluminum top plate. Fill the hook with epoxy (Figure N). Go ahead and fill the piston hook, too.

To cut the displacer rod to length, first lay the top plate on top of the bottom displacer assembly that you glued, so that its small center hole hangs over one edge. Put the 5" displacer rod through the holes until its hook is resting on the standoff. Mark where the rod meets the edge of the bottom plate. Remove the rod and cut it where you marked.

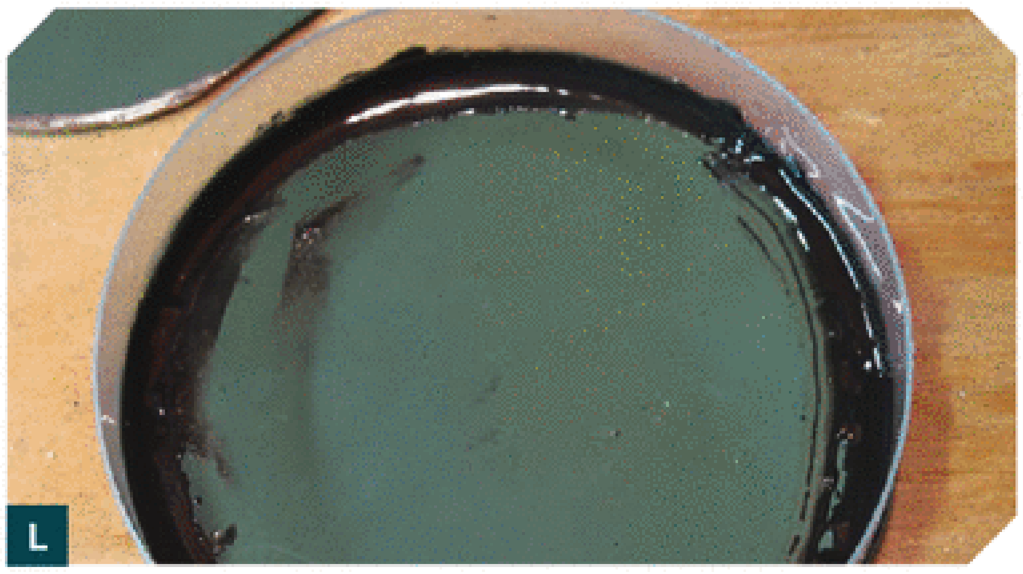
Now create the 2 lever arm rods. Bend a hook onto a length of wire, mark the wire 2" from the base of the hook, then cut it 2½" from the base of the hook (½" from your mark).



I

J

K



L

M

N

At your mark, bend a 90° angle, then bend a bit of the end as well (to keep the piston and displacer rod hooks from sliding off). Make another rod in the same fashion (Figure O).

Fill the hooks on the lever rods with epoxy as you did on the previous 2 hooks.

8. Mount the piston cylinder.

Again, clean the inside of your copper cylinder very well. Center it over the large hole you drilled on the top plate and epoxy it in place (Figure P).

Once cured, wipe the inside of the pipe with an oiled towel. Test the piston in it. Align the marks on the piston and cylinder, then move the piston up and down until it travels freely in the cylinder.

TIP: The inside of a copper pipe is extruded, meaning it has small ridges that run its length. These need to be matched with your piston, which was cast with these ridges as well. Just move the piston up and down, slowly twisting until it moves freely.

9. Bend the crankshaft.

The crankshaft is probably the most critical part of your engine. It must be as straight as possible, and its 2 cams must not be too deep. Its piston cam must be 0.15"–0.20" deep, and its displacer cam must be a little less than 0.25" deep.

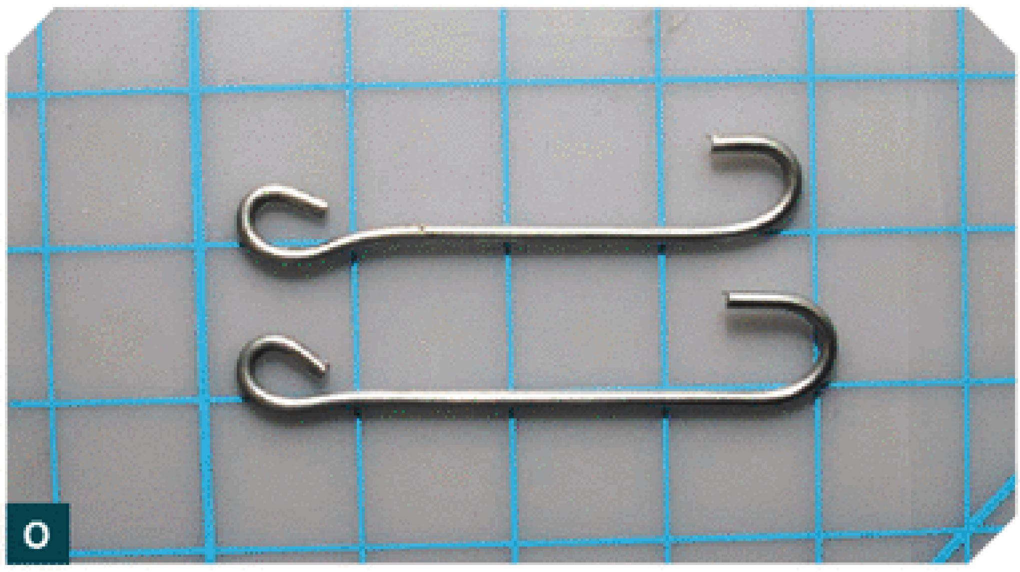
Also, the cams need to be 90° out of phase from each other: if one is lying flat on the workbench, the other should be standing straight up. You probably won't get it right the first time, so don't sweat it.

Measure the distance between the piston rod and displacer rod (Figure Q) and mark their locations on a sheet of paper; these indicate where the cams will go (Figure R).

Cut an 8" length of rod. Bend the first cam, using both sets of pliers to hold and shape the wire. Bend the second cam offset 90° from the first. Make sure the wire still lies flat and the cams are where you want them after bending. Roll the wire to make sure it's still straight, and straighten it if necessary.

NOTE: The cams can be bent in trapezoidal shapes rather than rectangles.

Photography by Jim Shealy (L, P, Q) and Ed Troxell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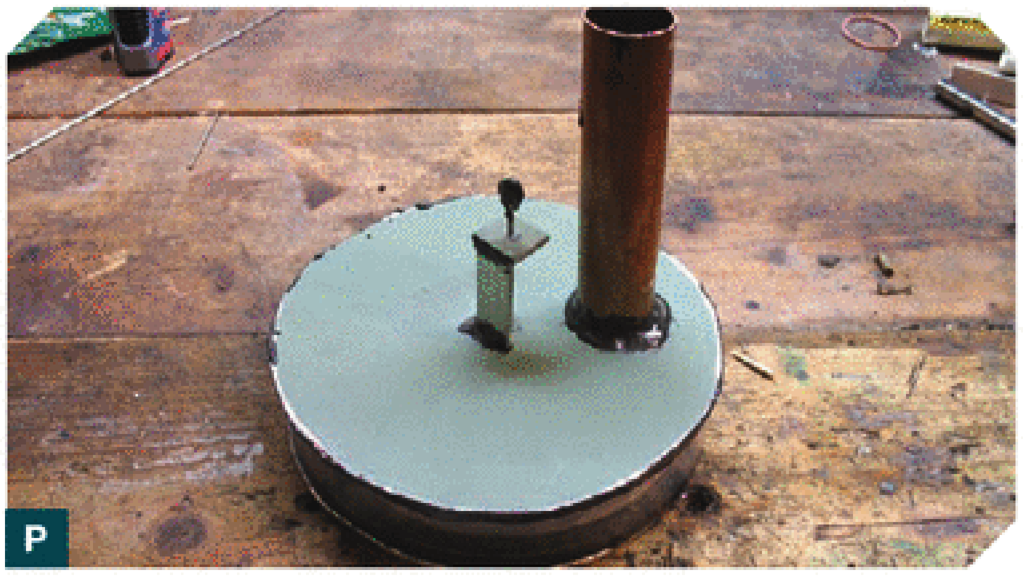
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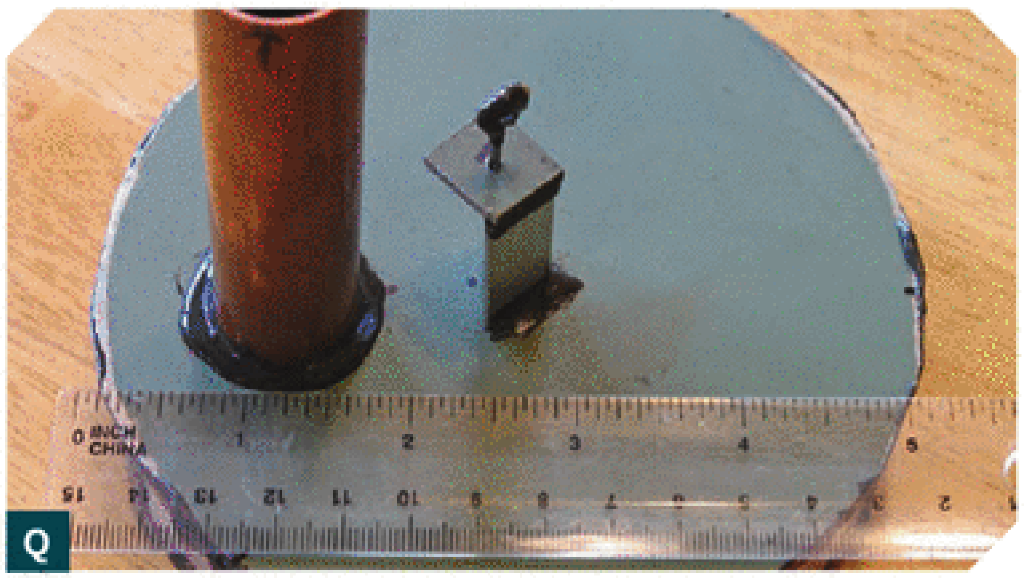
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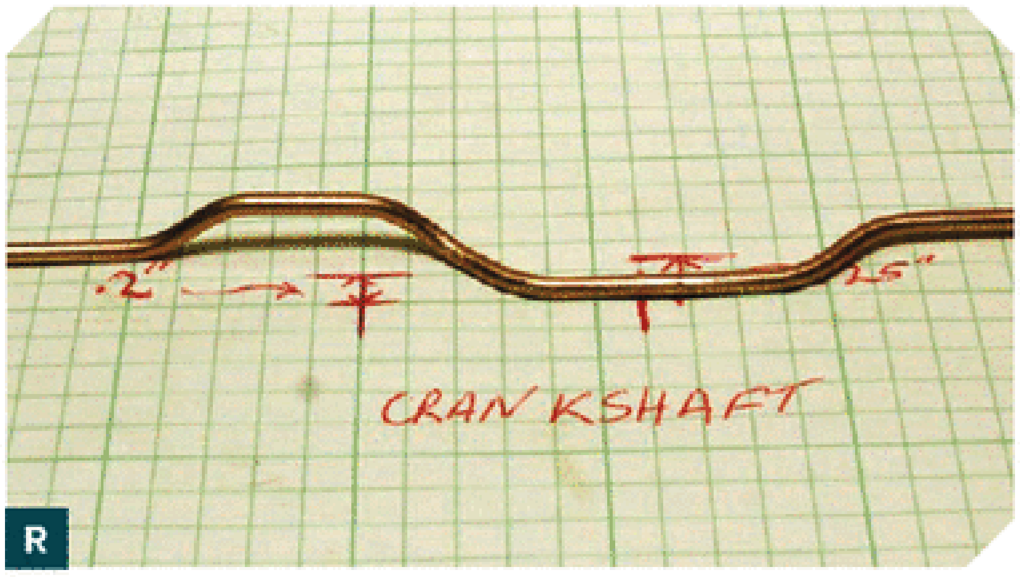


R

10. Glue up the displacer and the crankshaft.

Drill a $\frac{3}{32}$" hole (or one size bigger than your wire) in the center of each epoxied rod hook. Put the displacer rod through the standoff and center hole again. Drill (or poke) the rod into the exact center of the foam board displacer disks and epoxy it in place (Figure S). Make sure it's attached really well. It's a royal pain if it falls off after you've glued the displacer assembly together. Now glue the top plate onto the displacer ring. I suggest using hot glue. (Don't use hot glue on the bottom plate, as it will melt during operation of the engine.)

Cut a 5" length of PVC pipe, then cut it in half lengthwise (Figure T). These pieces become our crankshaft stands to hold the crankshaft and flywheel in place. Measure how high the shaft will need to be — so that when the displacer rod is raised halfway, the lever rod hole is level with the shaft — and drill a hole in each stand at that height. I'd suggest drilling holes just above and below this one, just in case the height of the crankshaft needs to be adjusted during engine tuning.

Finally, epoxy one crankshaft stand right behind the piston cylinder, lined up with the piston and displacer rods. Don't glue the opposite crankshaft stand in place yet!

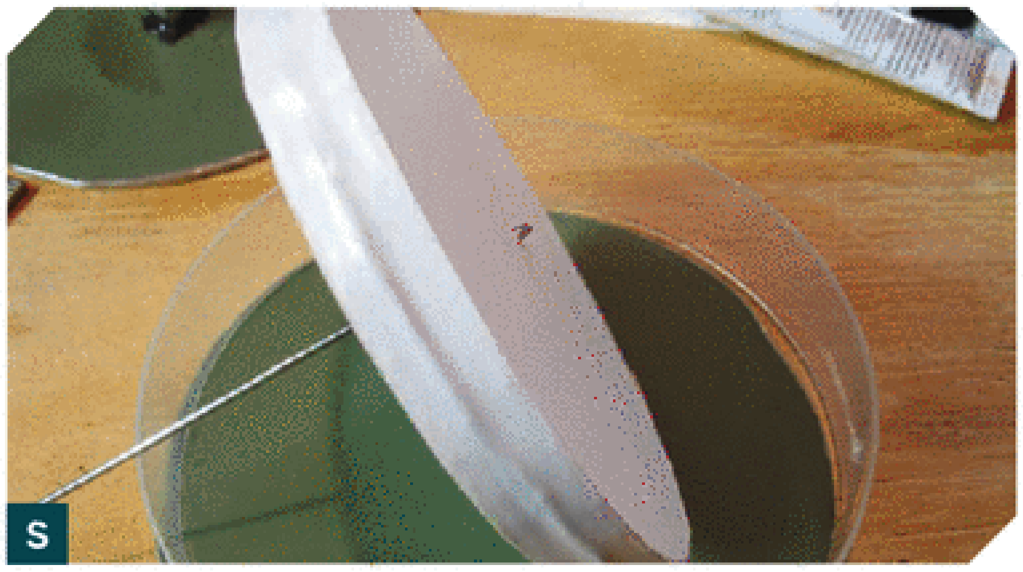
11. Final assembly and testing.

Attach the piston to its lever arm, and slide the lever arm into position on the crankshaft. It'll take some wiggling. Slide the crankshaft through the middle hole on the crankshaft stand you glued down. Next, slide the lever arm for the displacer rod onto the crankshaft, and attach it to the displacer rod (you may need to bend the bottom hook). Slide the second crankshaft stand onto the shaft and line it up. We still don't want to glue it in place until we're done tuning the engine.

Turn the crankshaft. Does anything hang up? If the piston isn't pumping properly, is it lined up where you marked it? If not, remove it and twist the lever arm until it lines up.

When turning the rod, can you complete a full rotation? If not, check the displacer disk. Does it move all the way up and down? If it's trying to go too high, move the crankshaft down 1 hole on the stand. If too low, raise it 1 hole. If it doesn't make a complete turn because it's trying to go too high and too low, bend shallower cams on the crankshaft. Bend deeper cams if there's too much of a gap.

If it turns over nicely, drill a hole the same size as your rod in the center of your peanut butter lid. This is your flywheel. Push it onto the end of the crankshaft closest to the piston cylinder. It should be a snug fit. Don't glue it yet.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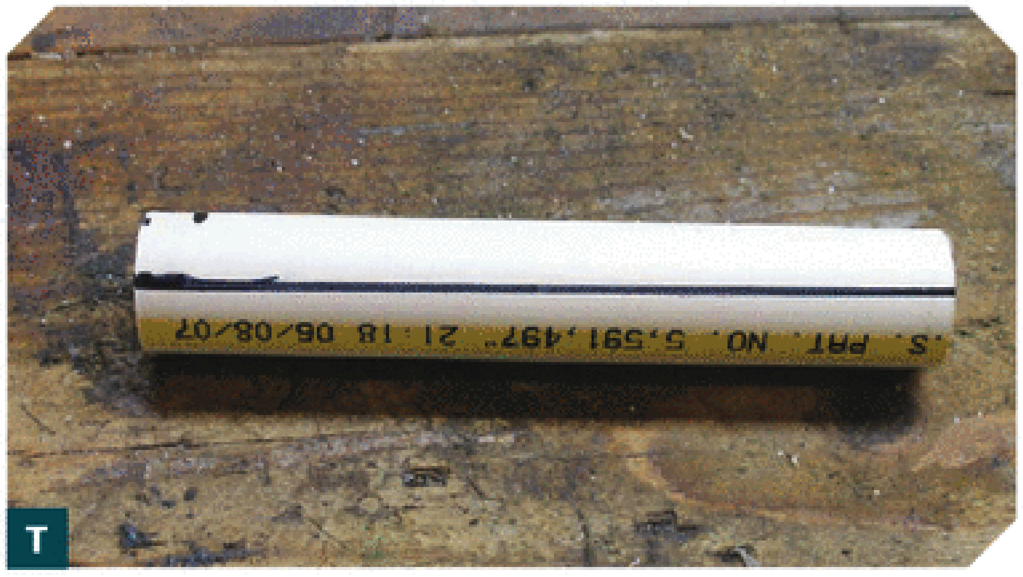

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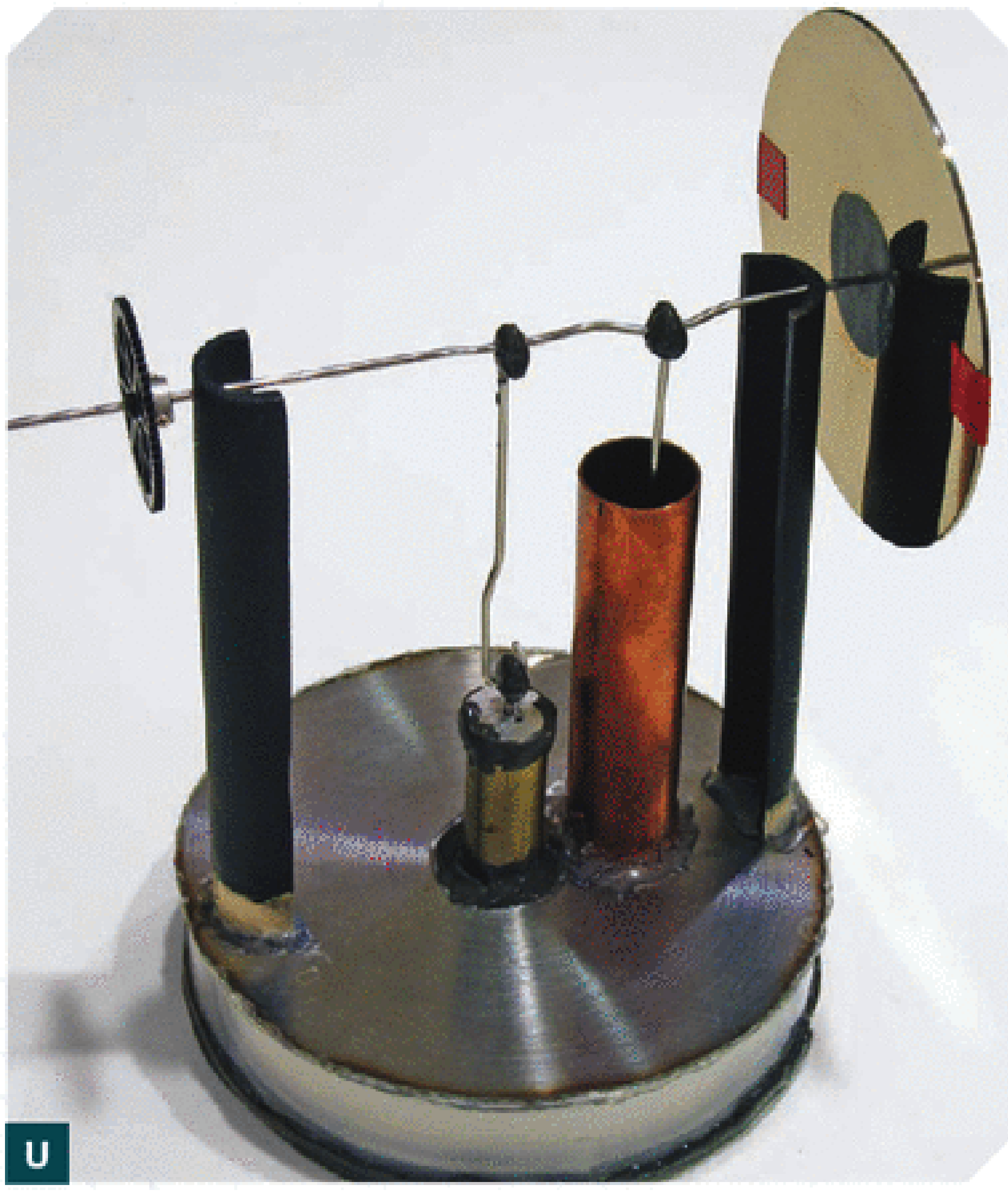

U

NOTE: You can also use a CD for a flywheel. Just mold an epoxy disk in the center, and drill out an attachment hole.

Now, the moment of truth. Apply heat to the bottom of the displacer assembly. Does it work? Try different heat sources: hot tea, coffee, votive candles, a tin filled with alcohol. Obviously, don't melt the plastic displacer ring with too much heat. Turn the shaft and see what happens. One direction should be significantly easier than the other; this is the way your engine runs. After the metal heats for a bit, your engine will either not run at all, or it will kind of move but the piston won't move as high and low as it could. Or it'll run perfectly.

If performance is sluggish, make sure all your glue joints are airtight. Also, make sure nothing is snagging or hanging up. Add oil to the moving parts and try again. And finally, try making the piston's cam shallower. You can also put ice cubes on the cold plate to increase the temperature differential.

Tune It

It works! Basically, you're done, but let's tune things up a bit. Check for these problems: friction, hang-ups, overstressed parts (trying to make them do more than they want to do), and leaks.

Add oil where needed (not much), adjust any parts causing problems, and keep everything sealed tight. Also, you need to counterbalance the displacer. First, glue the second crankshaft stand down, and glue the flywheel to the crankshaft. Get your fan weights (or pennies) and stick them to various spots on the wheel (use double-stick tape) until you find the right spots that offer the best performance (Figure U).

You're done! Steampunks, start your engines!

How It Works

Start off by pushing the air into the hot side of your engine, by spinning the flywheel to raise the displacer.

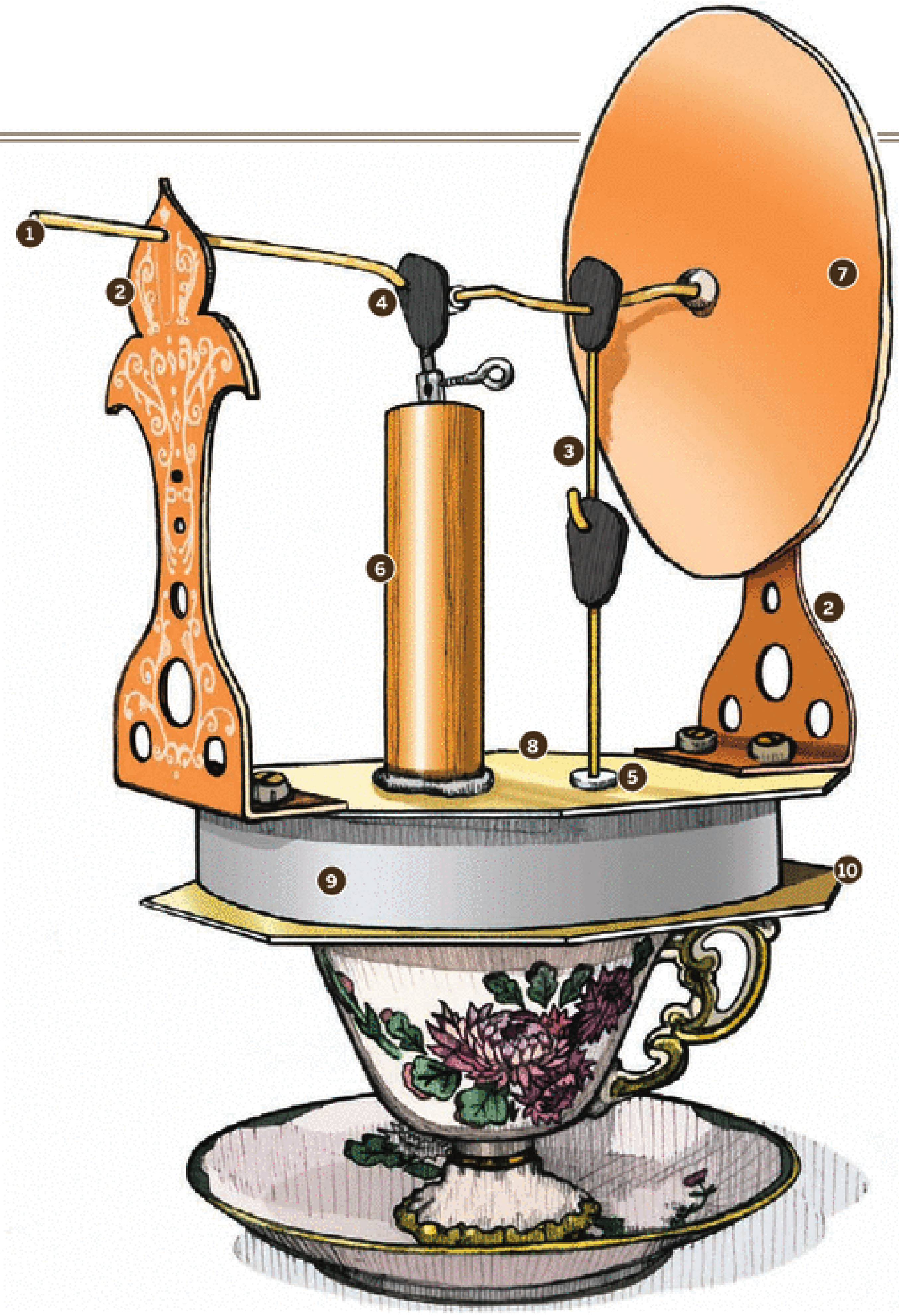
1. The air is heated and expands, raising the pressure inside the engine and forcing the piston upward (a stroke).
2. The displacer falls, moving the air to the cold side.
3. The air is cooled and contracts, lowering the pressure in the engine and sucking the piston back downward (a stroke).
4. The displacer rises, moving the air back to the hot side again.

And the cycle repeats. The displacer isn't really doing any work, it's just taking up space to move the air to one side or the other, so that the heating and cooling can do the work.

Photography by Jim Shealy

PARTS OF THE TEACUP STIRLING ENGINE:

1. Crankshaft
2. Crankshaft stand
3. Displacer lever rod, and beneath it the displacer rod
4. Piston lever rod
5. Displacer rod standoff
6. Piston cylinder (with piston inside)
7. Flywheel
8. Top displacer plate (cold side)
9. Displacer ring (with foam displacer disk inside)
10. Bottom displacer plate (hot side)



Building and Operating Tips

Building a Stirling engine can be a real challenge. If you undertake this project, take your time. Be patient. Go over all instructions carefully, watch the video, and read the discussion of the Instructables version (makezine.com/go/stirling) before you start work. Here are some tips to increase your chance of success:

» The piston can be difficult to cast. Don't try mixing the epoxy in the cylinder. Mix it outside, then pour it in. It may take several attempts.

» Grease the cylinder before casting.

» The piston should fit snugly in the cylinder but not too tightly, and should not slide loosely. Remember, the copper pipe has casting grooves in it that the cast piston must travel in.

» Leaks are your enemy. Make sure everything — the displacer chamber, the piston cylinder — is as airtight as possible.

» Friction is your other enemy. Make sure the crankshaft and lever rods travel as smoothly and frictionlessly as possible.

» You want the 2 displacer plates to have the greatest possible temperature differential (around 200°F). Try putting ice on the cold plate.

NOTE: The photos on pages 68 and 69 are for illustration purposes only, to show how you can decorate your engine to make it look more old-school. The brass rods connecting the top and bottom displacer plates are probably not a good idea, unless they're completely insulated to prevent heat transfer.

A version of this project was originally posted on instructables.com.

Illustration by Damien Scogin

LOST KNOWLEDGE

The "Discreet Companion" Ladies' Raygun

A pocket butane raygun for steampunky cosplay. {BY MOLLY FRIEDRICH}

First invented in 1885 for use by the daring ladies of the Cloud Frontier, the Discreet Companion has been a staple of purses and garter belts ever since.

Torch lighters are handy, cheap, and easy to find. They come in a wide variety of shapes and styles, so there's room for customizing to your personal taste.

I normally modify mine with antique parts, but here I chose parts that you can get in most hardware and home stores. The finished raygun works well as a prop; simply pull the "trigger," and an inch or so of fire shoots out the barrel!

This project uses a $10 Dodo brand lighter. If you use a different lighter, you may need to change the size of the pattern to accommodate it. You need to use a lighter that, when installed into the barrel of the raygun, will shoot forward.

Some point in other directions — obviously, avoid these, unless you specifically want a booby-trapped gun!

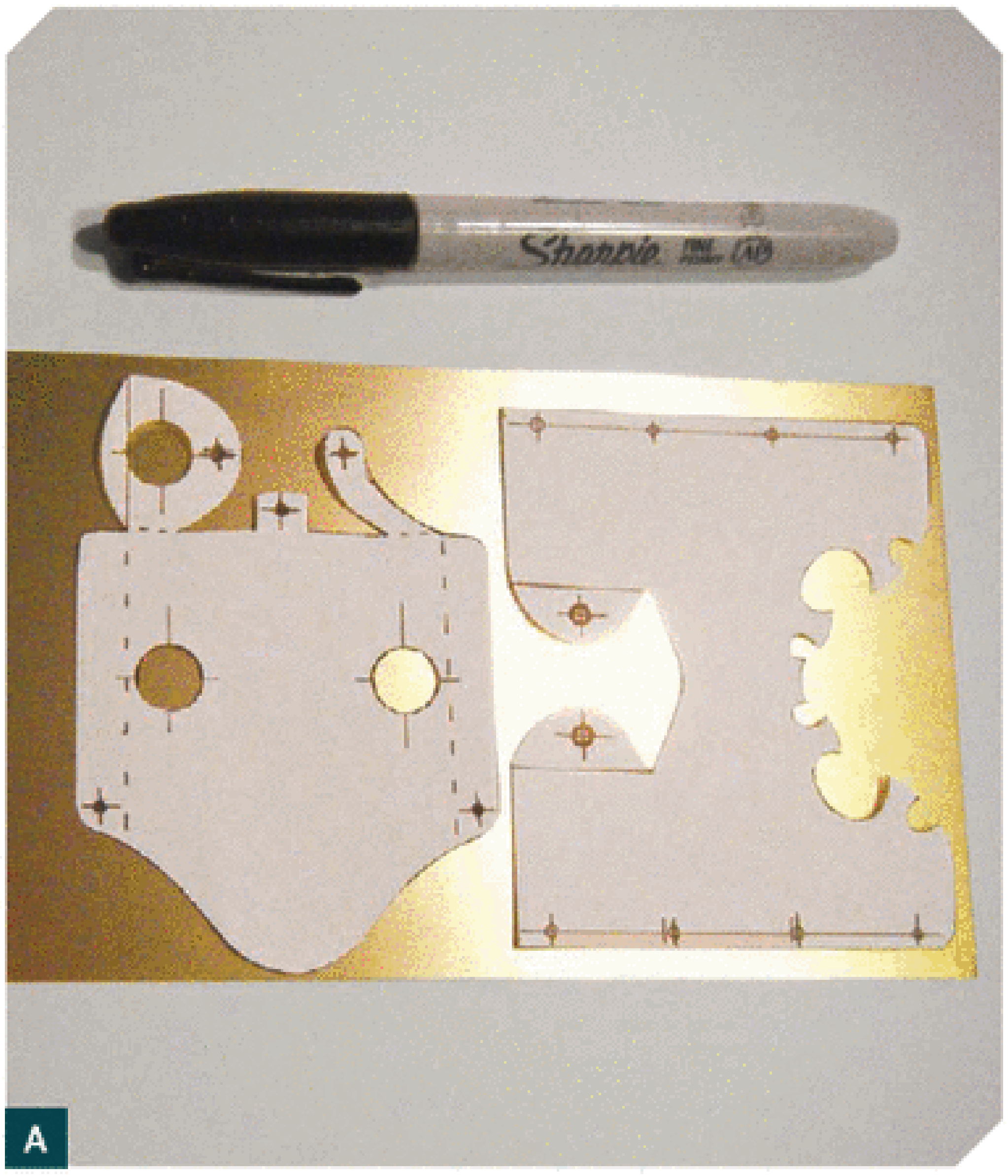
You might try a different ornate coat hook for a different-looking handle. The handle can also be mounted forward or backward.

The lamp parts are easy to customize — you can change the look just by using different finials and other decorative elements — and the design on the front of the barrel can be almost any shape you want.

This project is fairly easy to do, takes a few hours, and costs about $30–$40 in parts (less if you have some stuff already on hand).

In this dimension, Molly "Porkshanks" Friedrich is a freelance costume, prop, and jewelry designer. She's also an infamous pan-dimensional smuggler and freelance artist.

Photograph by John Keately



A

Photography by John Keately (left) and Molly Friedrich

Torch-style cigar lighter
Ornate stamped brass lamp check rings, 1⅛" diameter (2)
Brass lamp washers with fixture seat and ⅞" opening (2)
Steel 1¼" washers (2)
1" lamp knob finial
Brass ¾" knurled locknuts (2)
Brass 9/16" bracket caps (2)
Nickel-finish 1¼" washer
Brass ⅛F hex locknuts (2)
Brass ⅜" to ⅛IPS reducer
⅛IPS lamp nipples (2): 1" long and 2" long
4-40×⅜" slotted round machine bolts (2)
4-40 nuts (4)
Tiny 2-part decorating rivets (5)
Hall tree hook **B&M Hardware part #B&M1901**
Brass sheet 0.010"×4"×10"
Patterns (2) **Download at makezine.com/17/raygun.**

Scissors
Marker
Small flathead screwdriver
Needlenose pliers
Metal snips
Hole punch
Hammer
Scrap wood
Metal rod or pole less than ¾" diameter
Rivet setting tool

1. Build the body.

1a. Print the 2 patterns, cut them out, and trace them onto the brass sheet with a marker. Be sure to mark carefully the dashed lines (where the metal folds) and all holes (Figure A).

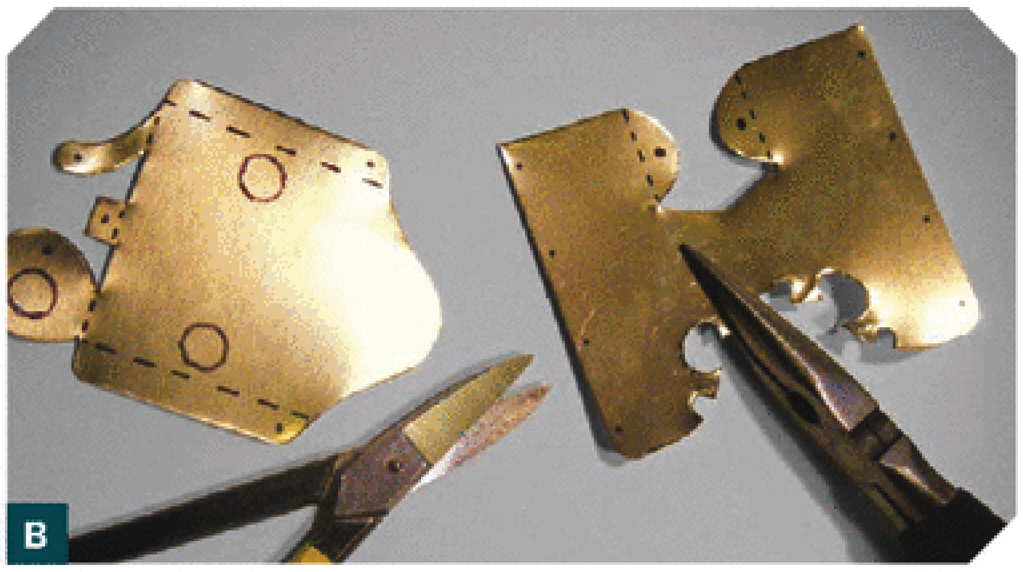
1b. Use a pair of metal snips to cut out the shapes. Take your time. Don't worry if the edges bend a little; this is normal. When you're done cutting, use your pliers to flatten the edges out again (Figure B).

CAUTION: Be careful not to cut yourself when cutting and bending sheet metal. I never use gloves, and my poor fingers hate me for it. Don't be like me!

1c. Set the metal shapes on a scrap of wood and use a hammer and hole punch to punch holes where marked. For larger holes, do a few punches and then cut the hole with snips. If the metal deforms as you cut, use your pliers to flatten it out afterward (Figure C).

1d. Bend both pieces on the dashed lines. Bend the rounded tabs away from the marks on the barrel piece (Figure D), and bend the long sides and the back in toward the marks on the body piece.

1e. Bend both parts over to round them into tubular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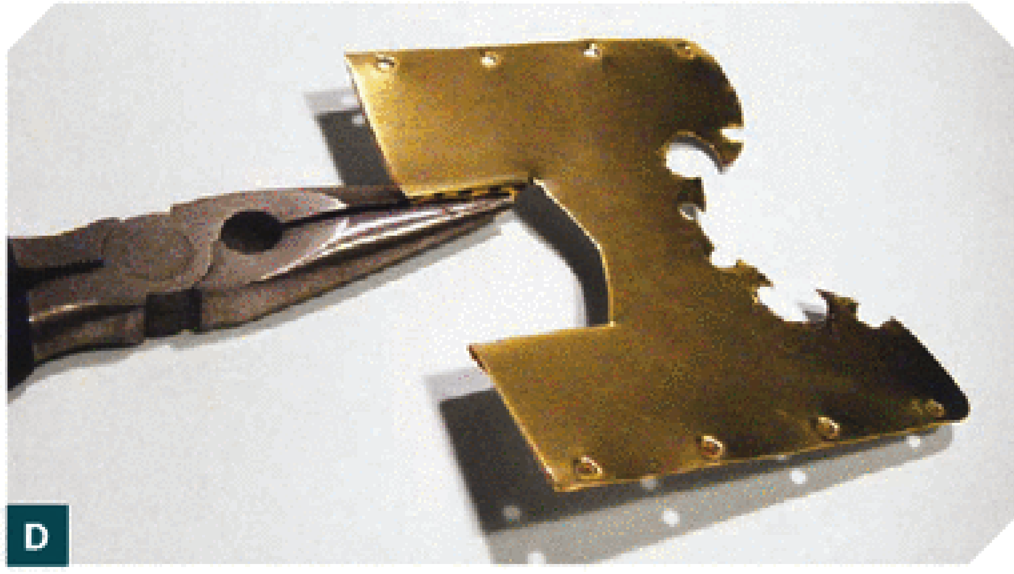
C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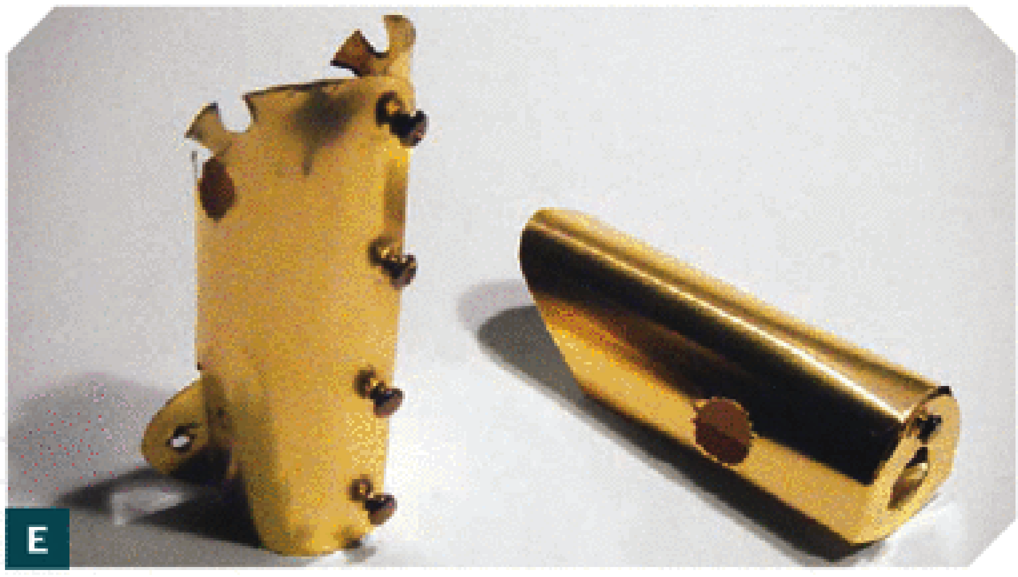
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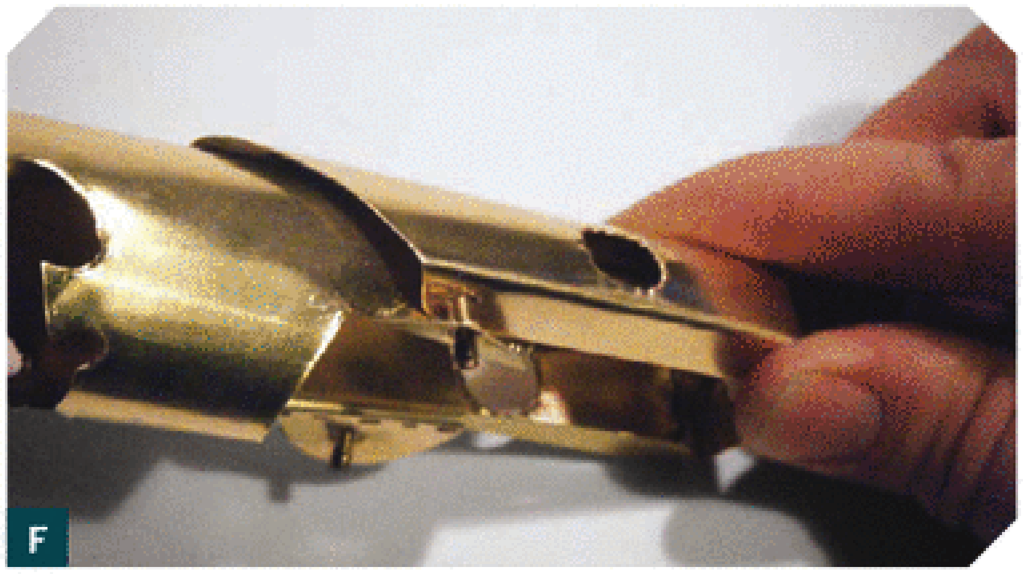

F


G


H

shapes as shown (Figure E). Insert the rivets into the holes of the matched-up ends of the barrel piece. Don't forget the single rivet that goes through 3 holes on the backside of the body piece.

To pound the rivets into the barrel piece, you'll need a metal rod. Slip the piece over the rod and hammer the rivets. Use the rivet setting tool to reach the inside of the single rivet on the body piece.

1f. Slide the open end of the body piece over the end of the barrel at the rounded tabs. The holes from the folded sides of the body should line up with the holes in the rounded tabs on the barrel. From the inside, insert a 4-40×⅜" slotted round machine bolt through each set of lined-up holes (Figure F).

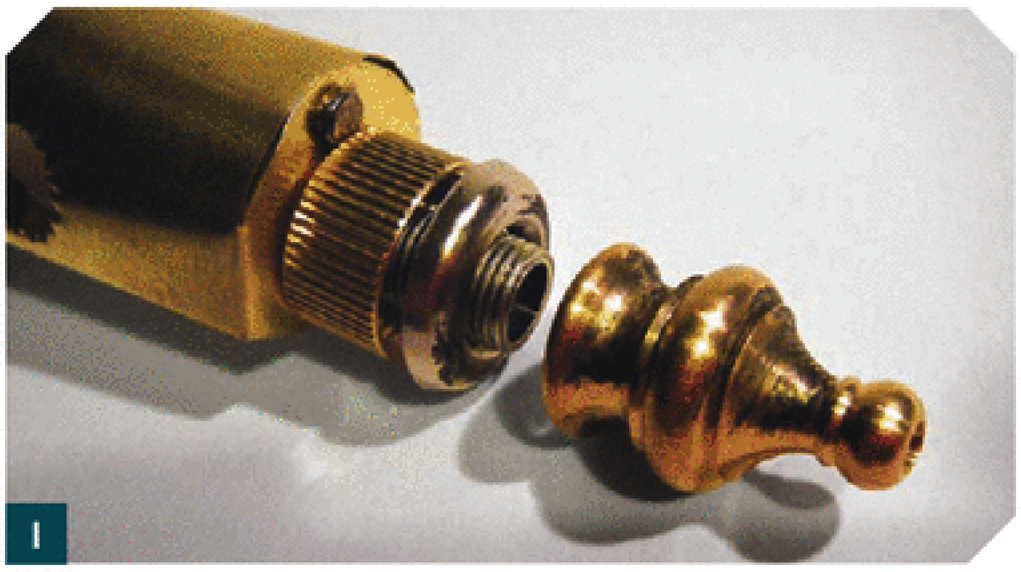
2. Add the back.

2a. Put the hex nuts on one end of the 1" lamp nipple, tightening them against each other so they don't slide around (Figure G).

2b. Slide the other end of the nipple through the large hole on the back of the body (Figure H). Add the ⅜" to ⅛IPS reducer, the nickel-finish washer, and the 1" lamp knob finial (Figure I). The center of my washer was too small for the nipple, so I used the metal snips to cut the hole a little larger.

3. Attach the handle.

3a. This is the trickiest part and takes patience.



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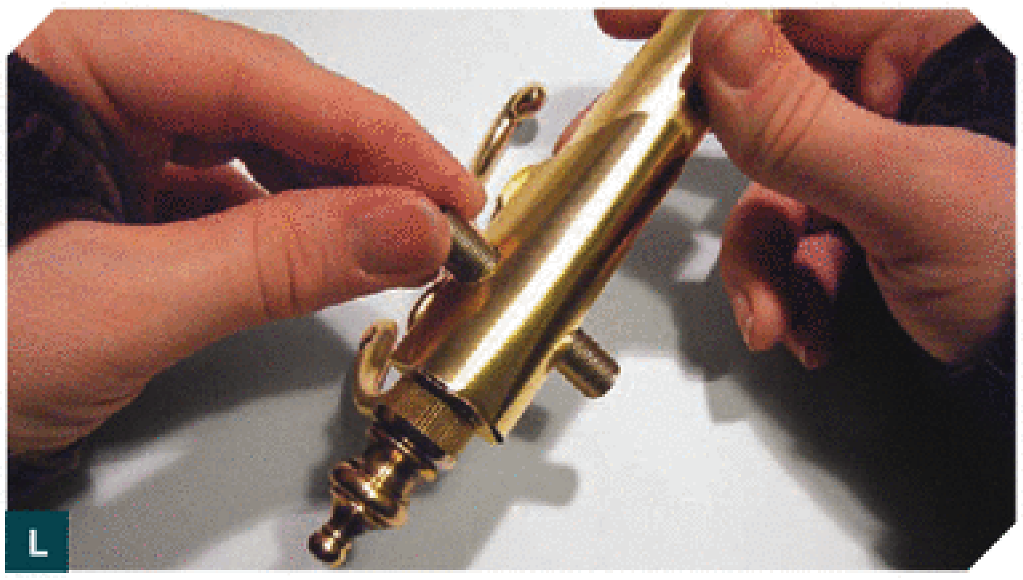


L

M

N

Pressing in on the sides of the gun body at the bolts (friction will help keep them in place), navigate the bolts into the holes on the base of the B&M hall tree hook, aka raygun handle (Figure J). If you have a hard time getting the bolt to go through the holes, use a small screwdriver to push it down and guide it in.

3b. Once you have enough of the bolt showing through, slide a nut on and tighten it down with pliers (Figure K). Do this for both sides, then add a second nut to each bolt to lock everything down.

4. Add finishing touches.

4a. Slide the 2" lamp nipple through the side holes so that equal amounts stick out on each side (Figure L). Add to each side, in order, 1 brass lamp washer with fixture seat and ⅞" opening, 1 steel 1¼" washer, 1 brass lamp 1⅛" check ring, 1 brass ¾" knurled locknut, and 1 brass 9⁄16" bracket cap (Figure M).

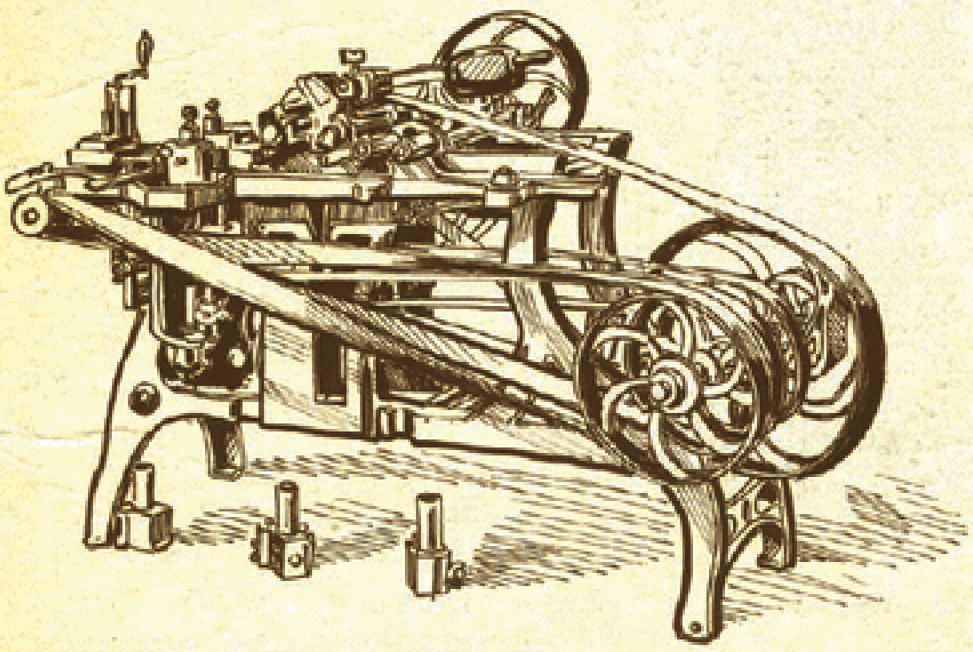
4b. Slide the lighter into place. You may have to press in the sides of the gun barrel slightly to fit. Friction should hold it; in fact, I usually have a hard time pulling the lighter out to refill it. If it gets stuck, use a screwdriver to push on it from the back, where the gun barrel drops down near the handle base (Figure N).

5. Fire away.

Don't smoke, kids! Use your raygun to light devotional incense, airship lanterns, or cartoon dynamite only!

THE Lost Knowledge Catalog

Amazing & confounding techno-artifacts, unearthed for your *edification & amusement*, in the interest of their most timely preservation. [BY GARETH BRANWYN]



Monstrous Machines that Eat Wood!

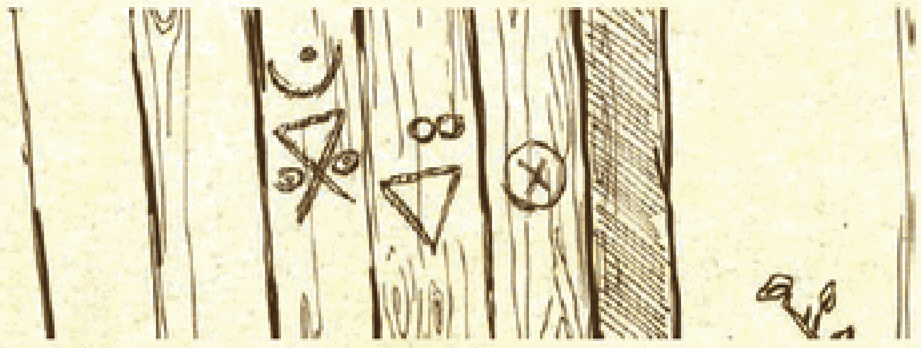
OLD WOODWORKING MACHINES

OWWM is a labyrinthian online library of photographs, histories, operating instructions, and restoration tips covering vintage woodworking equipment. The site has hundreds of PDF scans of old catalogs, manuals, parts lists, adverts, and historical documents from dozens of manufacturers. If you're an enthusiast of "old iron," you'll go giddy clicking the corridors of this impressive collection.
.... **owwm.com**

Coin Carving for Fun and Profit

HOBO COINS

"Hobo nickels" are coins whose faces have been carved to create new imagery. Because it's inexpensive and portable, the hobby became popular with hobos; nickels are the favored denomination because of their size, thickness, and relative softness. While coin carving is still practiced today, fans in the Original Hobo Nickel Society are primarily interested in coins made in the era of the Indian Head ("Buffalo") nickel (1913–1940), the most popular coin to carve. .... **hobonickels.org**



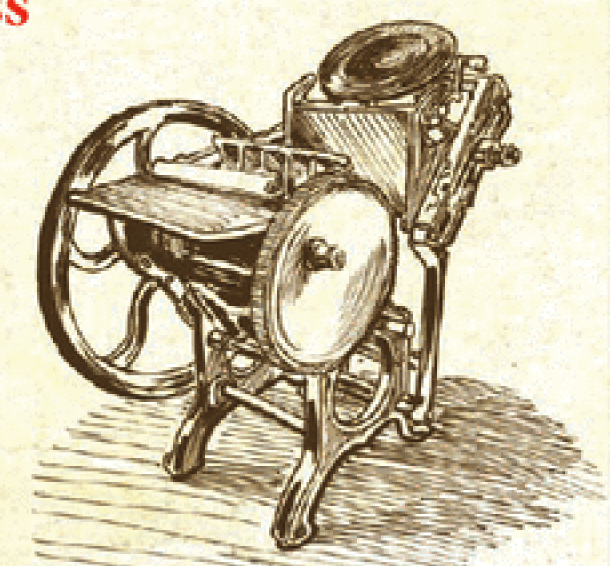
Strange Codes Revealed!

HOBO CODE

To help fellow train hoppers and vagabonds, hobos developed a secret language of symbols to communicate dangers, available food and work, safe places to sleep, and townspeople's susceptibility to grift. While some hobo signs are simple (a smiley face indicates friendlies or a safe place to sleep) others are complicated and esoteric (two interlocking rectangles, one with a squiggly bottom, means: Cowards! They'll give you food/money just to get rid of you).
.... **tinyurl.com/mk77**

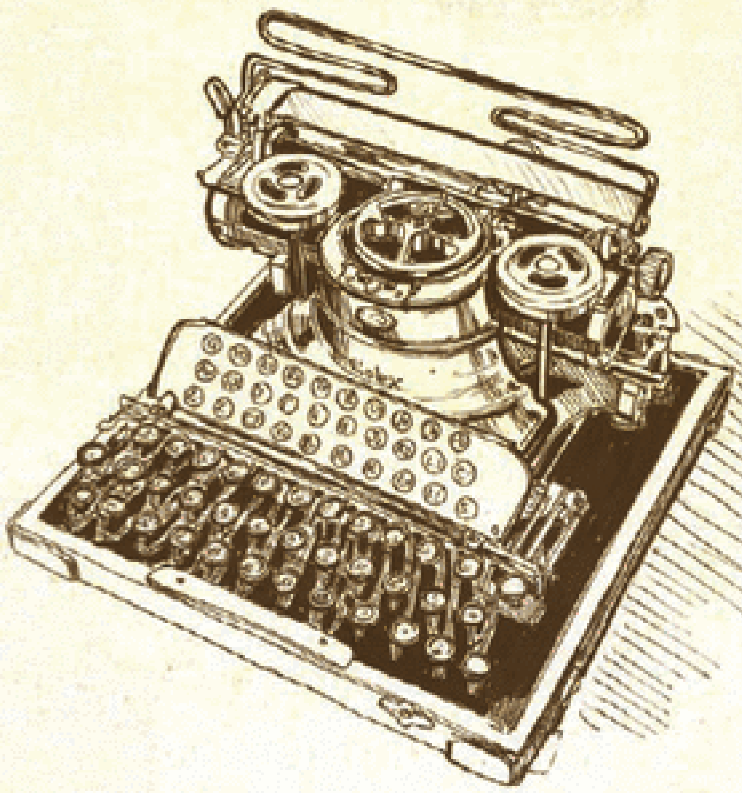
Make a Forceful Impression

LETTERPRESS



Fueled by boutique-press publishing, the new craft movement, and high-profile endorsements in places like *Martha Stewart Weddings*, letterpress printing is enjoying a revival. Suddenly, antique letterpress machines, casting type, type drawers, and anything else to do with letterpress printing are in great demand. There is something undeniably awesome about typography and artwork visibly pressed into a gorgeous piece of high-quality paper stock. Green Dolphin Press is the keeper of the venerable Letterpress FAQ (**greendolphinpress.com**). Also, check out the Briar Press Letterpress Museum (**briarpress.org**). .... **aapainfo.org/lpress.html**

Illustrations by Suzanne Rachel Forbes



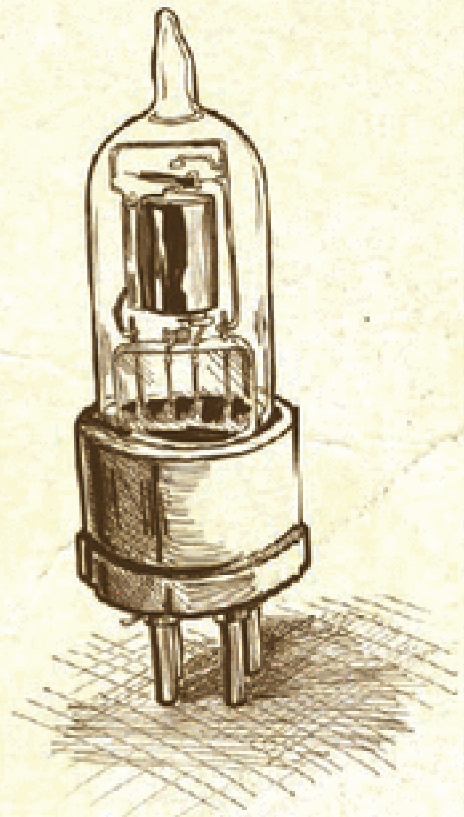
Amaze Your Friends with Manual Labor!

CLASSIC TYPEWRITERS

As computers, phones, and other modern digital machines do more, some people desire less — a machine that only does one thing: dutifully hammers out the written word. Typewriter repair shops are experiencing a small upsurge in business and inquiries about purchasing manual typewriters. The Classic Typewriter page will take you back in time and bring you up to speed ... er ... so you can slow down again, with a fine analog word processor of yesteryear. **tinyurl.com/55dhl**

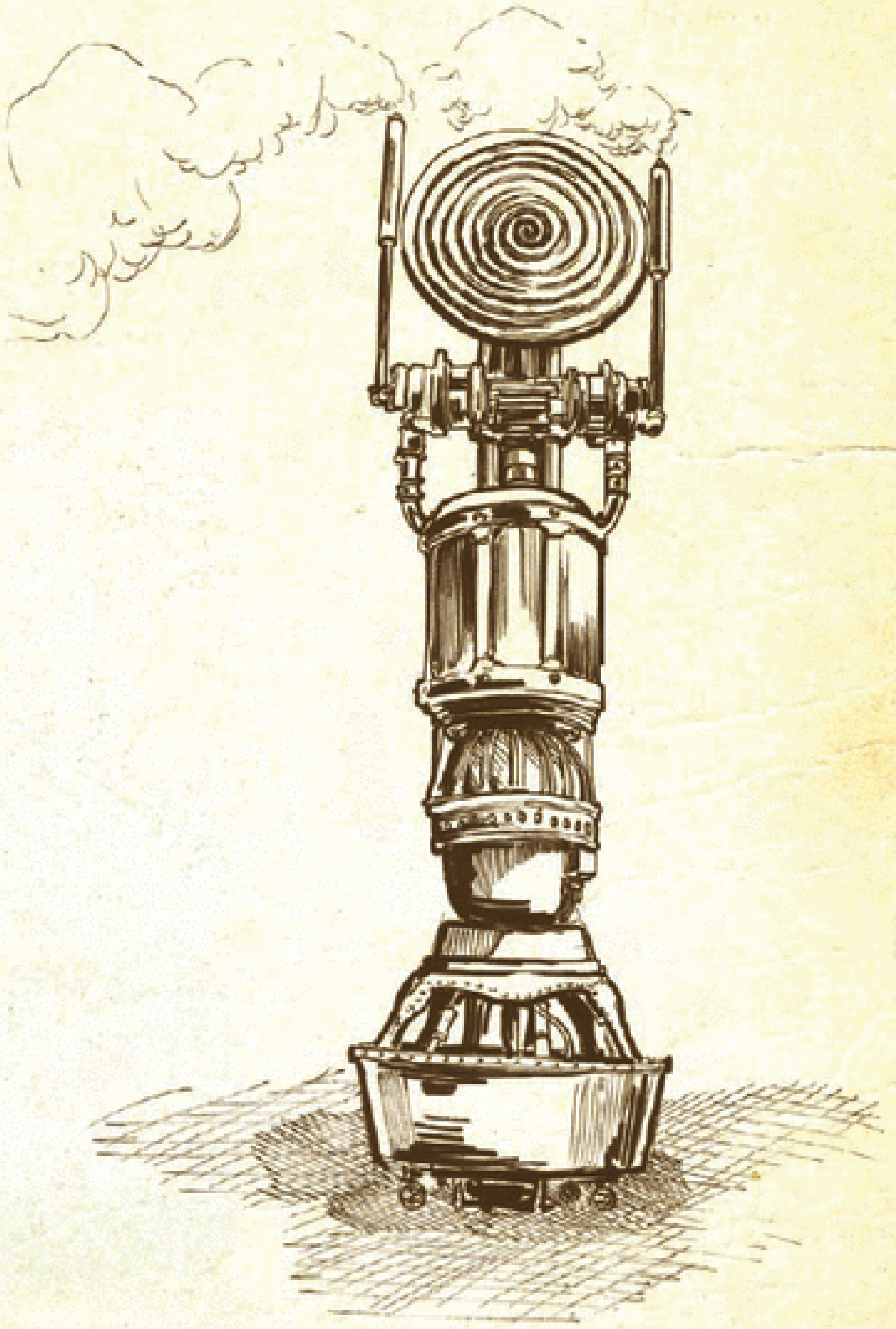
Magical Electric Amplification Device!

TRIODES



There are makers, and then there's Claude Paillard, a French ham radio enthusiast who makes his own vacuum tubes — from scratch! Watching his video of the process is like watching a great stage magician at work. But instead of pulling a rabbit out of a hat or reconstituting a sawn-in-half lovely assistant, with a graceful flourish of work-worn hands Paillard *voilà*s a working triode. And as impressive as his triodes are, the fact that he builds many of the machines and jigs that he uses is equally awe-inspiring.

.... **paillard.claude.free.fr**

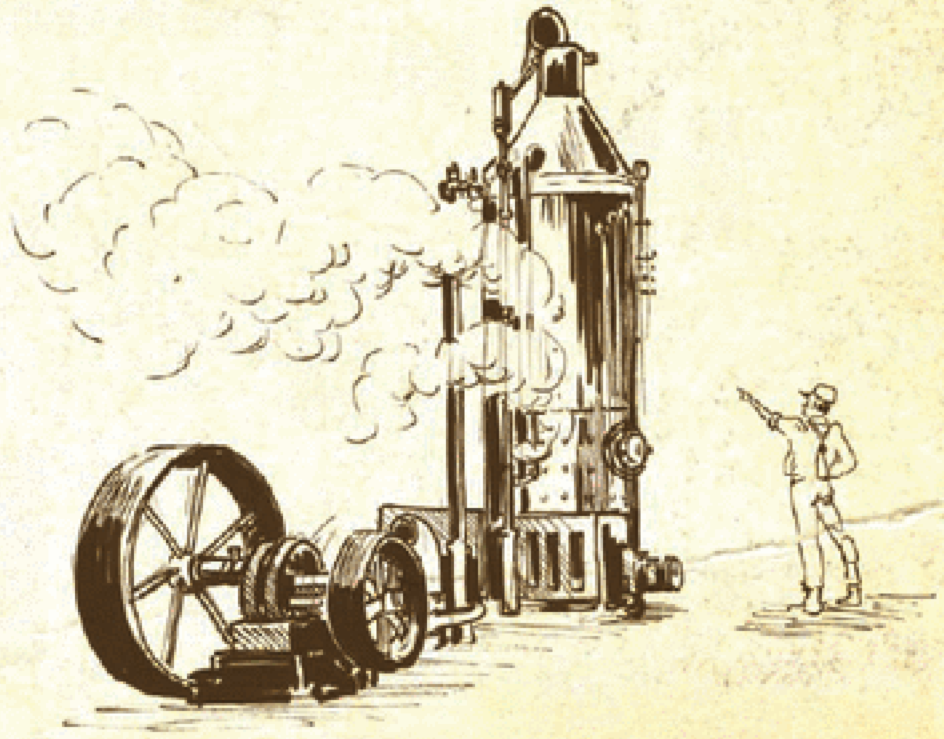


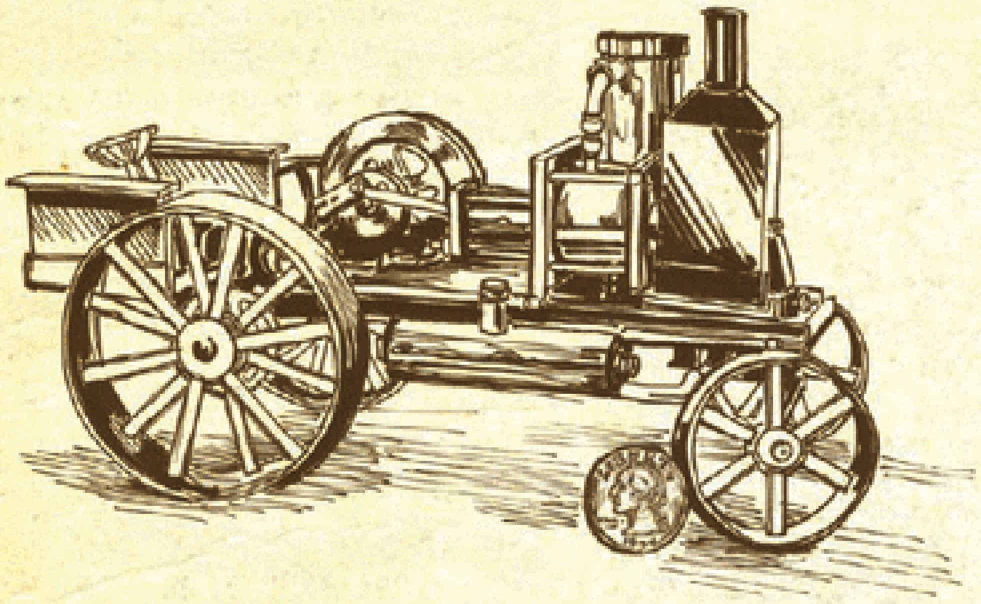
Don't Get Angry, Get Steamed

YANKEE STEAM-UP

Every year, the New England Wireless and Steam Museum in East Greenwich, R.I., hosts the Yankee Steam-Up, a daylong fall gathering where model makers, machinists, engineers, and historians interested in steam power get together and show off their latest projects. These are industrious makers who were hacking steam long before it became fashionable and who will likely be pressurizing their boilers long after the poseurs have hung up their brass goggles.

.... **newsm.org**





Engineering Marvels on a Dime

☞ CRAFTSMANSHIP MUSEUM

The Craftsmanship Museum in Vista, Calif., offers an impressive collection of the best model engineering in the world. Hundreds of precision-built miniature steam, gas, and Stirling engines; miniature gunsmithing examples; model ships, cars, and planes; handmade scientific instruments; even unusual pieces such as hand-knapped microscopic arrowheads are on display. Much of the collection is also viewable online in their "virtual museum." It's hard to visit, either in person or via the aetherweb, and not come away with the sense that you can do anything if you're dedicated enough. .... **craftsmanshipmuseum.com**

Time-Traveling How-Tos

☞ LINDSAY'S TECHNICAL BOOKS

If there's one catalog that'll allow you to travel back to the time of steam engines and blacksmiths, mountainside moonshiners and pedal-powered wood shops, it's Lindsay's Technical Books. They carry hundreds of how-to books for all sorts of largely forgotten, obscure, fringe, or replaced technologies. A gold mine for retro-technicians. .... **lindsaybks.com**

RTFM! (Read the Ferrous Metal!)

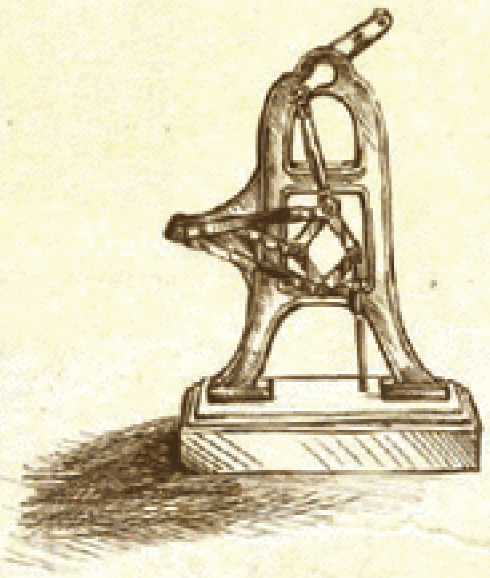
BY DALE DOUGHERTY

☞ SORGHUM PRESS

In planting an experimental "energy garden" in northern California, Julian Darley and wife Celine Rich thought they'd try growing sorghum as potential biofuel. Sorghum is normally grown in the South as a source of sugar. Growing the sorghum was easy; finding a working sorghum press was harder. The press they found is more than 100 years old. They weren't sure how it worked, but fortunately, it came with instructions — forged into it, describing how to use and how to maintain it. One side reads: "Always keep bottom boxes filled with oil." Below that is a terse operating manual: "Feed cane large end foremost."

The Wonders of Mechanical Linkage

BY CHARLES PLATT



In the early days of the Industrial Revolution, lack of sophisticated lubricants (among other factors) made it impossible to create a lubricated guide to control the linear motion of a rod in and out of the cylinder of a steam engine. A lot of head-scratching occurred as people tried to figure out how to build a linkage that could control linear motion. James Watt could only find an approximate answer. Solving this problem ultimately took 100 years.

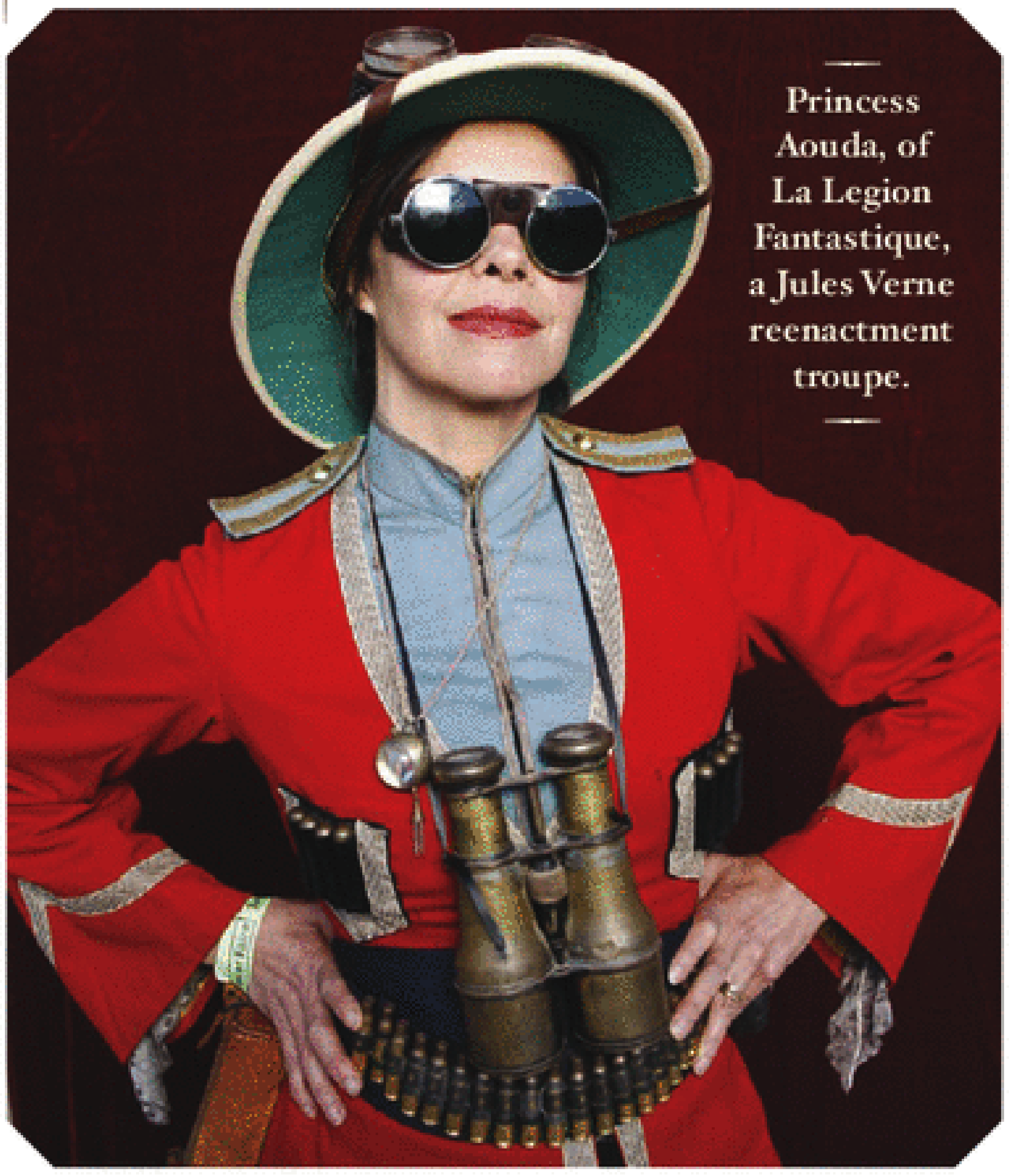
The solution is known as Peaucellier's Inversor. It's said that when Lord Kelvin witnessed a model of the device, he exclaimed that it was the most beautiful thing he'd ever seen. The geometry is difficult to understand. A proof can be found at **tinyurl.com/56w6gm**.

Linkages that control motion in clever ways are rare these days, but still turn up in odd places such as the trunk lid of your car. The Brock Institute for Advanced Studies has a collection of linkages in very nice Java animations at **brockeng.com/mechanism**.

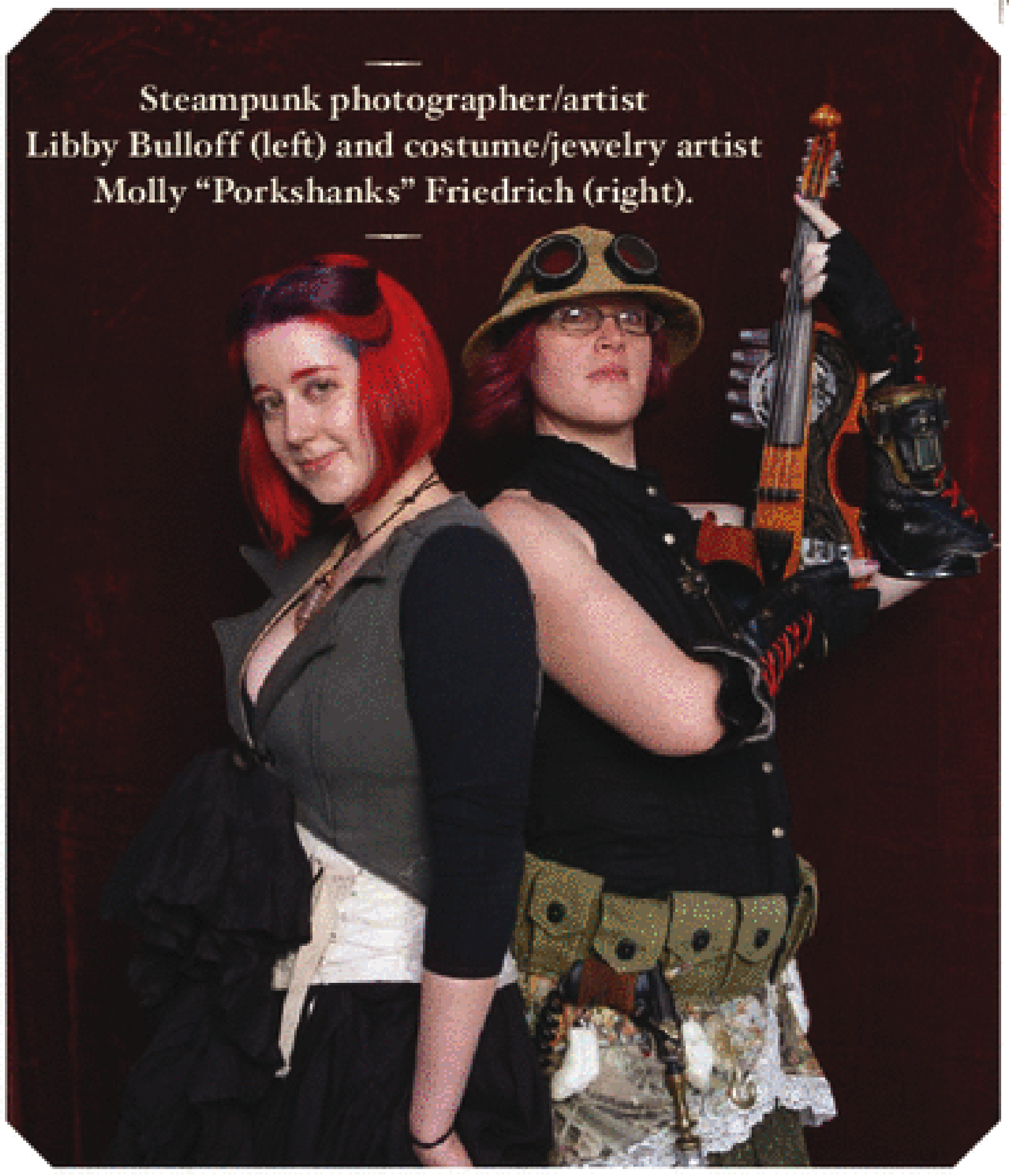
☞ **THANKS TO:** Saul Griffith, Mister Jalopy, Marc de Vinck, Paul Spinrad, Charles Platt, Patti Schiendelman, Keith Hammond, John Edgar Park, Bill Gurstelle & Brian Jepson

Steampunk Family Album

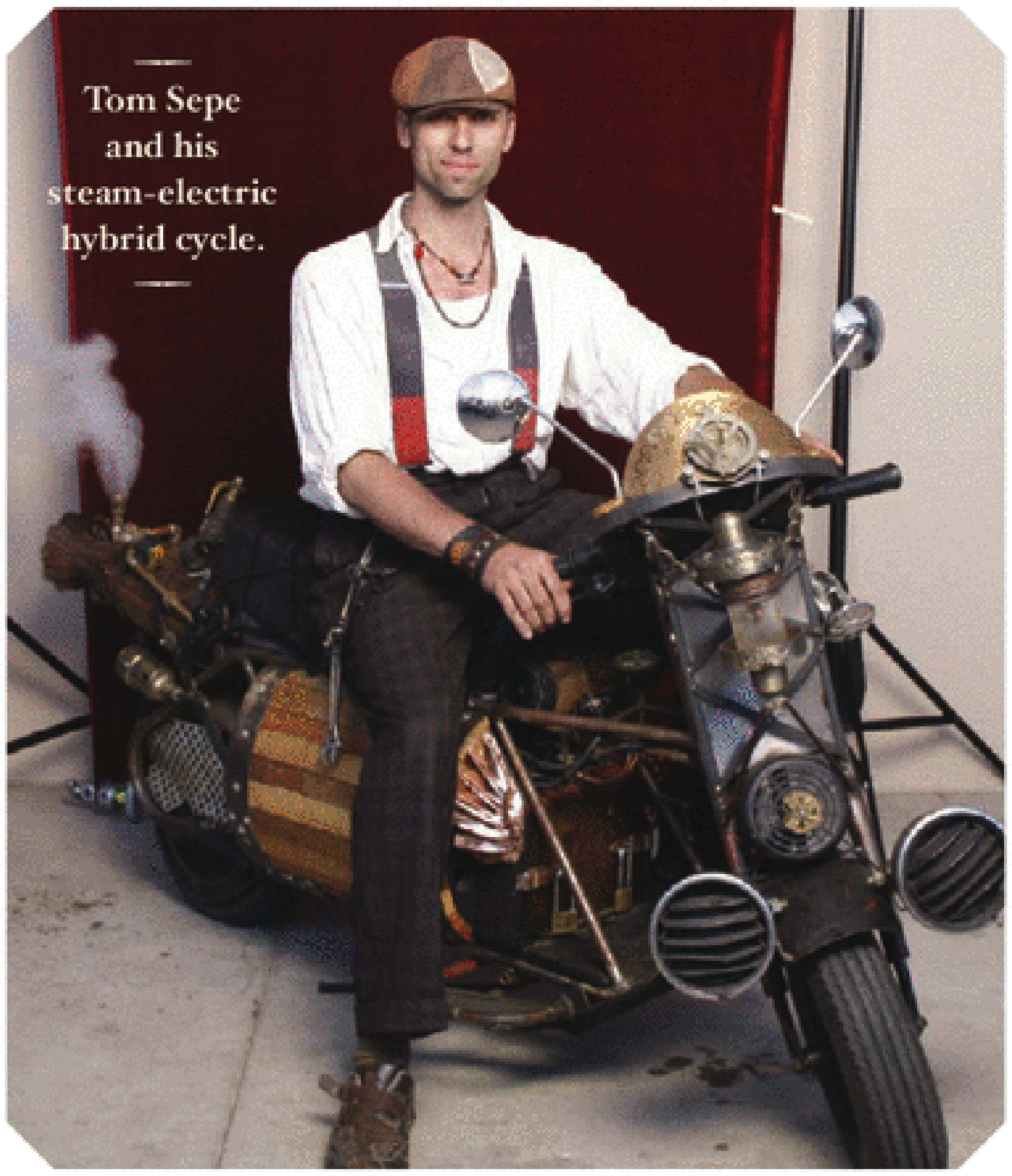
At last year's Maker Faire Bay Area, in the literal shadows of the Neverwas Haul (the Victorian house on wheels), and amongst the tinkering of the Contraptors' Lounge, the eerie whining of Electric Western's tube-driven theremin, and the lightning-fast pen and ink portraiture of Suzanne Forbes (also featured in this issue), photographer **Elena Dorfman** set up an outdoor studio. There, she captured some of the more colorful, creative expressions of alt.Victorian finery as it paraded through the crowd. *—Gareth Branwyn*



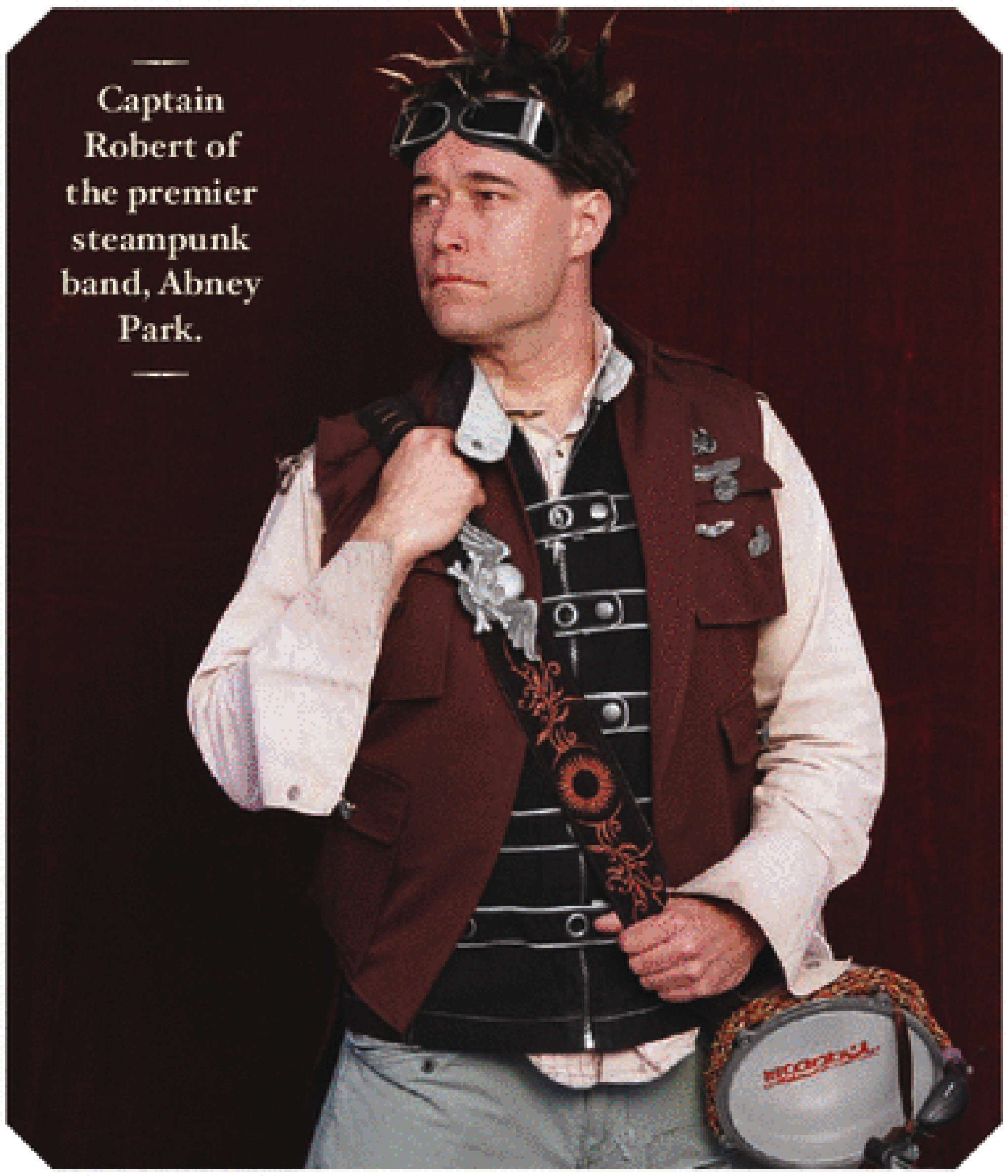
Princess Aouda, of La Legion Fantastique, a Jules Verne reenactment troupe.



Steampunk photographer/artist Libby Bulloff (left) and costume/jewelry artist Molly "Porkshanks" Friedrich (right).



Tom Sepe and his steam-electric hybrid cycle.



Captain Robert of the premier steampunk band, Abney Park.

Kitty Kaleidoscope

Make magnificent mandalas from kittehs and other kritters. By Erico Narita

A typical kaleidoscope contains 2 mirrors angled at 60°, which reflect a pattern to create a symmetrical effect that we can emulate in software such as Photoshop. Here's how I did it.

Choose a photograph that has a wide range of shading from light to dark, and some features that will be recognizable after they've been chopped, rotated, and reflected (eyes always work well). For my first effort, I made an LOL-cat. Here are the steps in Photoshop 6 or later.

1. CHOOSE THE POLYGON TOOL

Choose the Polygon tool, which looks like a hexagon and is hidden in the toolbar. You may have to read Help to find it. After you select it, use Window ⇒ Options to show the tool Options bar, and click the button "Create new work path" or just "Paths" (the wording varies in different Photoshop versions). Also in the tool options, specify 3 sides.

2. FIND AN INTERESTING PART

Drag to create an equilateral triangle over your photograph, then go to Edit ⇒ Transform Path ⇒ Rotate, or Edit ⇒ Transform Path ⇒ Scale (while scaling, hold down Shift so that your triangle remains symmetrical), to modify the size and position of your triangle, until it contains an interesting area of your photograph. While scaling or rotating your triangle, you can also drag it around. When you have what you want, press Enter to confirm.

3. COPY PATH TO A NEW LAYER

If your Paths palette is not open, open it from Window ⇒ Show Paths. Photoshop will have put

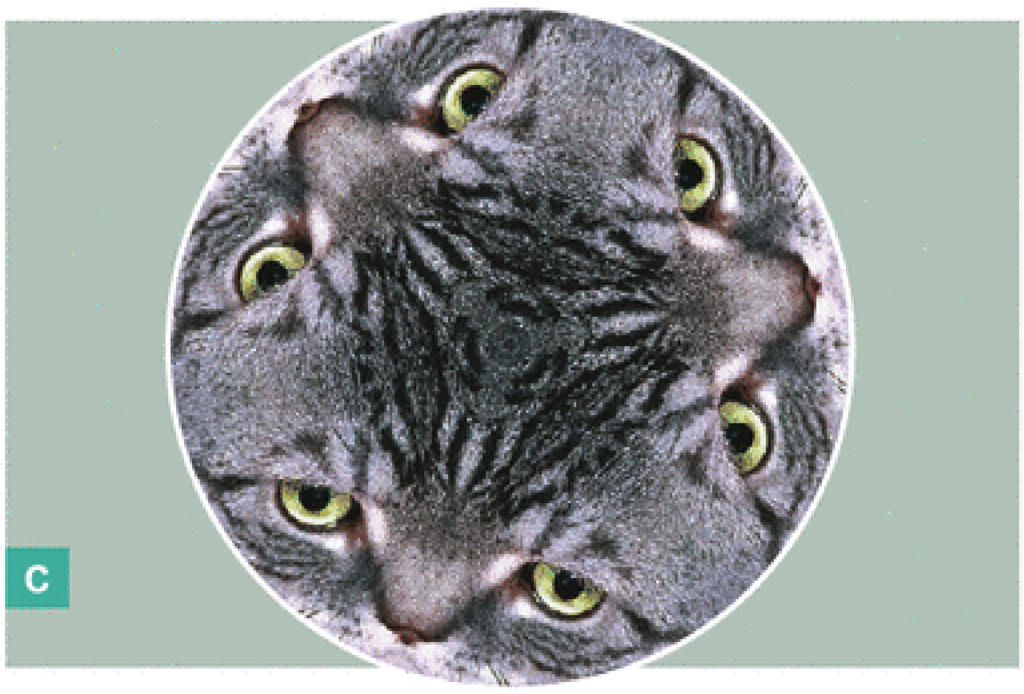


Fig. A: Looking for a cute subject? Start with a cat. **Fig. B:** An eye, a nose, and a striped fur pattern guarantee that this image will work kaleidoscopically. **Fig. C:** This is how kitty would look through a kaleidoscope. **Fig. D:** By duplicating more triangles, flipping and turning them, you get a pattern that could work as upholstery for kitty's favorite couch. He'll blend right in.

Photography by Erico Narita and Charles Platt

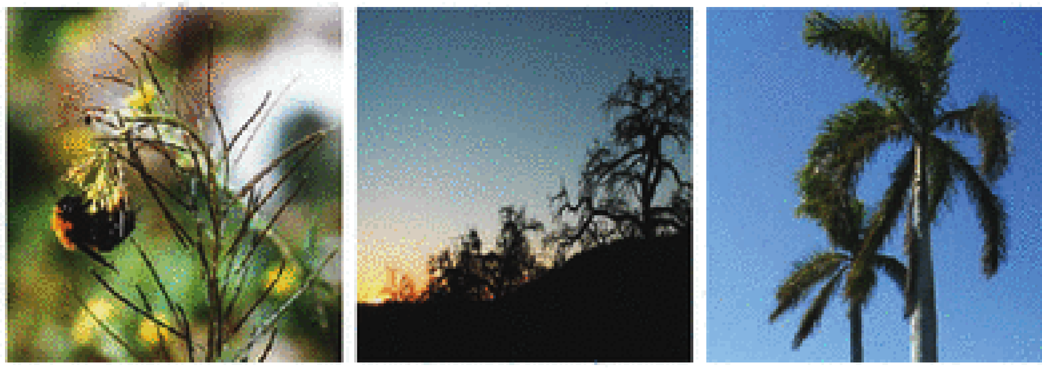


Fig. E: A bee on a flower isn't very interesting until you make it kaleidoscopic. **Fig. F:** A simple sunset begins to look like a lake when reflected 45°.
Fig. G: Two palm trees change completely when sliced and repeated 20 times.

your triangle path in the palette. Ctrl-click (Windows) or Command-click (Mac) the name of the path to turn it into a selection. Copy, then paste, to duplicate the selected area in a new layer.

In the Layers palette, click the eyeball beside the Background layer to hide it. In the toolbar, select the Rectangular Marquee tool.

4. MAKE A COPY OF THE PART

In your new layer, move the mouse pointer to the triangle, hold down Ctrl and Alt keys (Command and Option on the Mac), and drag the triangle to make a copy of it, which will pop up in another new layer.

5. MAKE A MIRROR IMAGE

Use Edit ⇒ Transform ⇒ Flip Horizontal to make a mirror image. Now use Edit ⇒ Transform ⇒ Rotate to turn and move the second triangle so that it goes edge-to-edge with the first. Press Enter when you have it exactly right, then Ctrl-E (Command-E on a Mac) to merge the 2 layers.

6. MAKE A HEXAGON

Drag off a copy of the diamond shape that you've created, select Edit ⇒ Transform ⇒ Rotate, and type a value of 120 degrees in the Tool Options palette. Drag the selection into place, press Enter, then repeat to make one more rotated diamond shape to complete a hexagon.

7. CROP INTO A CIRCLE

Go to Layer ⇒ Flatten Image (discard the hidden background layer containing your original photograph). Select the Elliptical Marquee tool, hold down Shift, and make a circular selection that extends to the edges of your image. Go to Select ⇒ Inverse and then delete, to remove pixels outside of the circle. You now have your kaleidoscopic image — or in my case, a fine LOL-cat! (I also repeated the triangle many more times in another document to make the design shown in Figure D.)

Figures C, E, and F were repeated 6, 12, and 8 times. Can you use other numbers of repetitions? Of course! Divide the number of repetitions that you want into 360°. Then make a selection with the Rectangular Marquee tool, go to Edit ⇒ Transform Path ⇒ Skew, and in the tool Options bar, enter the number of degrees for the horizontal skew angle. Convert it to a selection as in Step 3 and use the Rectangular Marquee tool to chop the left or right part, to leave you with a triangle that you can reflect and rotate as before. I used palm trees, reflected them, then rotated 10 copies of the pair.

Repeated angular patterns have been used in mandalas to form a focus for meditation. There's something about this kind of pattern that fascinates the eye. Applying this process to everyday photographs may not help you reach an altered state of consciousness, but it can be fun.

Erico Narita is a graphic designer in New York City.

Make Scalable Art

Use simple commands to build organic patterns with Context Free software.
By John Edgar Park

Context Free (CF) is a free program for creating images of incredible beauty and complexity. Instead of a complicated user interface cluttered with tools, it uses a very simple set of commands called the Context Free Design Grammar. Here's how you can dive in and use it to create an organic, recursive tree graphic suitable for printing on canvas, silk-screening on a T-shirt, or even laser etching onto your iPhone (that's what I plan to do). Even if you've never programmed a line of code before, don't panic! Anyone who can type can write instructions to create wonderful art like you see in these images.

First download the appropriate version of CF for your operating system from contextfreeart.org. Install the software and then launch it.

NOTE: Windows and OS X versions have a graphical user interface; the Linux version is command-line only.

1. CREATE A NEW DOCUMENT

Select File ⇒ New from the menu. You don't need to specify an image size, because the designs you create with CF can be rendered at any resolution you need.

2. PLAN YOUR DESIGN

There are only 3 possible building blocks of a CF program: square, circle, and rectangle. These are usually stamped down and transformed in a repetition to create an image. For example, stamp down a circle, then scale and rotate a second circle; repeat until the stamps are too small to see and you can create a perfect, smooth spiral. Introduce some randomness to the angles and scales of your recursive circle and you can create fantastic tendrils. We'll use this principle to make our design.

3. DESCRIBE THE MAIN SHAPE

There are a few rules in CF. First, there is always a main shape described at the beginning of a file. Click in the text entry window on the left-hand side of the interface, and type the following, pressing Enter at the end of each line.

```
startshape TENDRILS
```

NOTE: While this may look like other programming languages, such as C, it's not quite the same. Type the lines exactly as they're listed here to see how they work.

4. DEFINE THE TENDRILS RULE

The next rule is that all shapes must be defined. Let's define the TENDRILS rule. We'll start simple, and add to it as we go. New lines of code are highlighted in blue text.

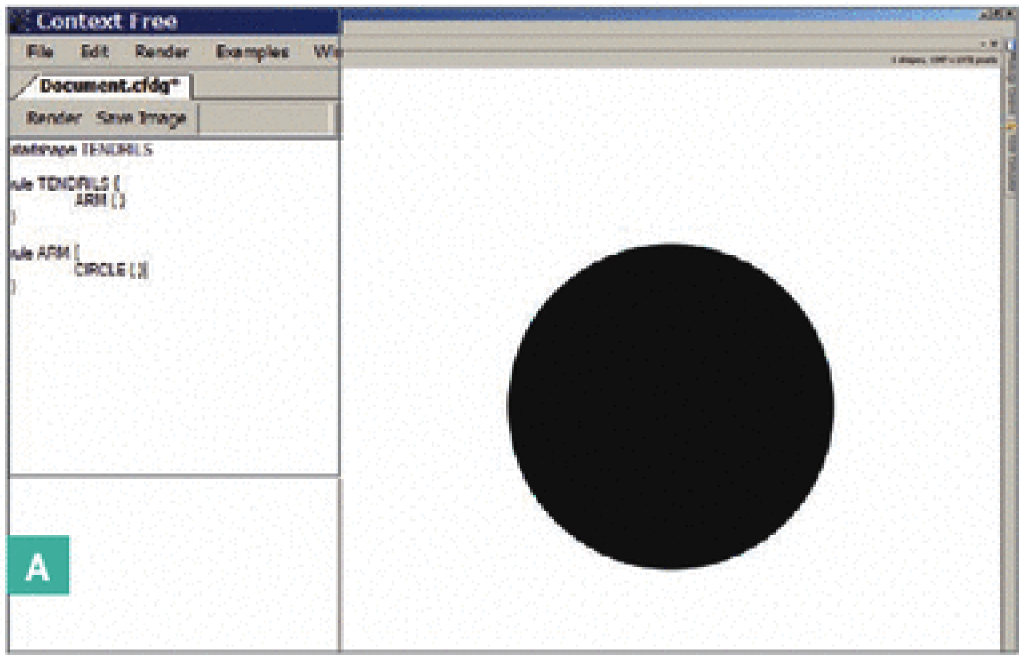
```
startshape TENDRILS
rule TENDRILS {
ARM { }
}
```

This tells CF that when it tries to draw a TENDRILS rule it will do so by drawing an ARM shape. What's an ARM shape? Well, we have to go define that as a new rule.

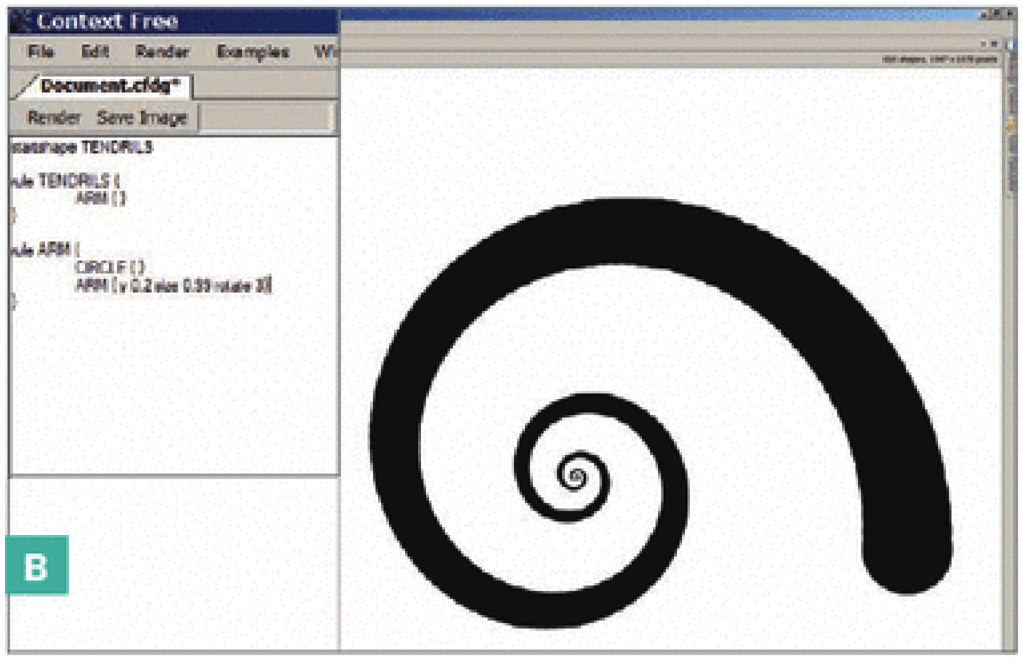
5. DEFINE THE ARM RULE

The ARM rule will be made from a recursion of the circle shape. First type:

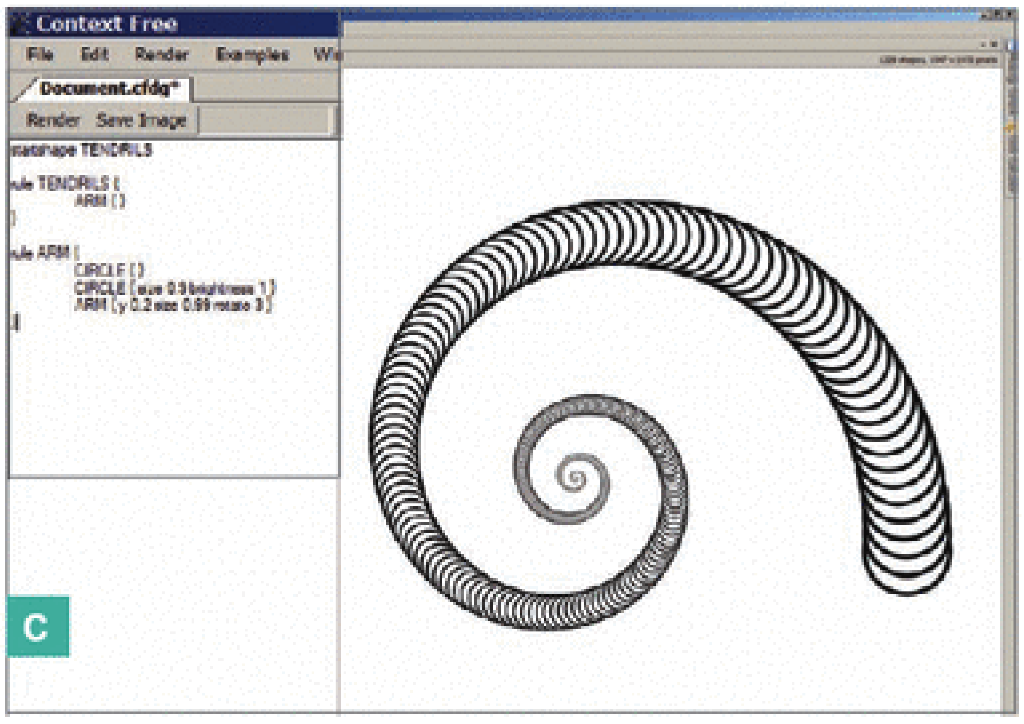
Images by John Edgar Park



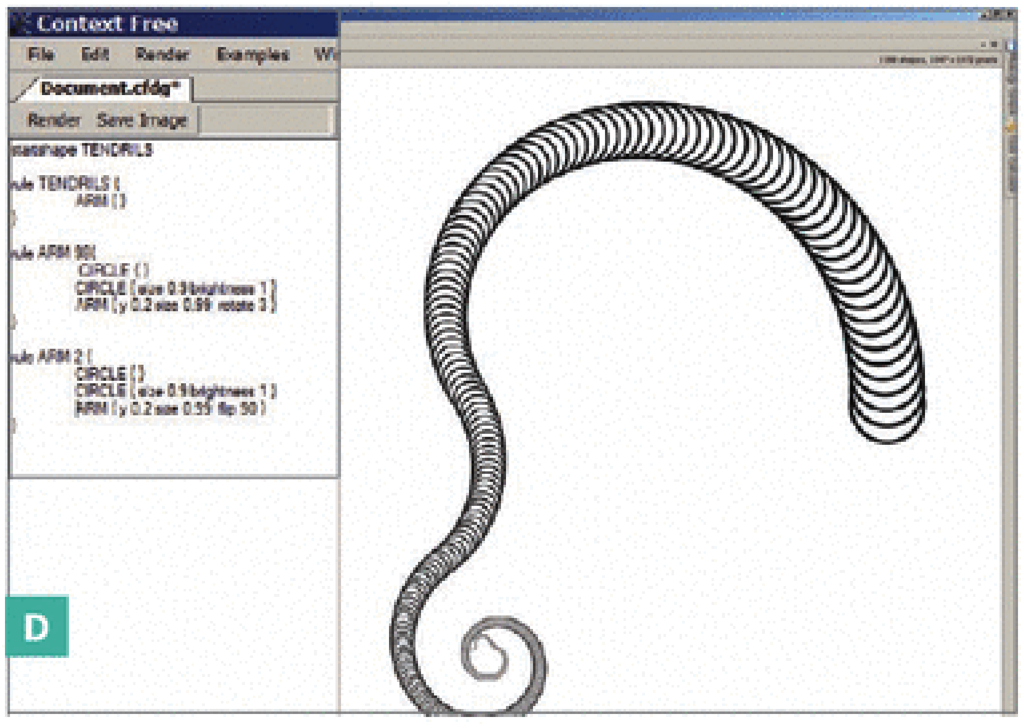
A



B



C



D

```
startshape TENDRILS
rule TENDRILS {
ARM { }
}
rule ARM {
CIRCLE { }
}
```

You can test this out now by clicking the Render button at the top of the CF interface. This draws a circle (Figure A). Not too exciting, but it's a start.

Let's now modify the **ARM** rule to add a recursion. We'll do this by having the **ARM** rule reference itself. This causes a loop, which would go on infinitely, but for the fact that we'll have it scale the circle a little smaller on each iteration of the loop. CF will end the loop as soon as a shape becomes too small to draw. Here's the modified rule:

```
startshape TENDRILS
rule TENDRILS {
ARM { }
}
rule ARM {
CIRCLE { }
ARM { y 0.2 size 0.99 rotate 3 }
}
```

Render this and you'll get a nice arm spiral (Figure B). The adjustment in the **ARM** shape call moves it up on the y-axis by 0.2 "units," sizes it down to 99% of its original size, and rotates it 3°.

6. MAKE OUTLINED CIRCLES

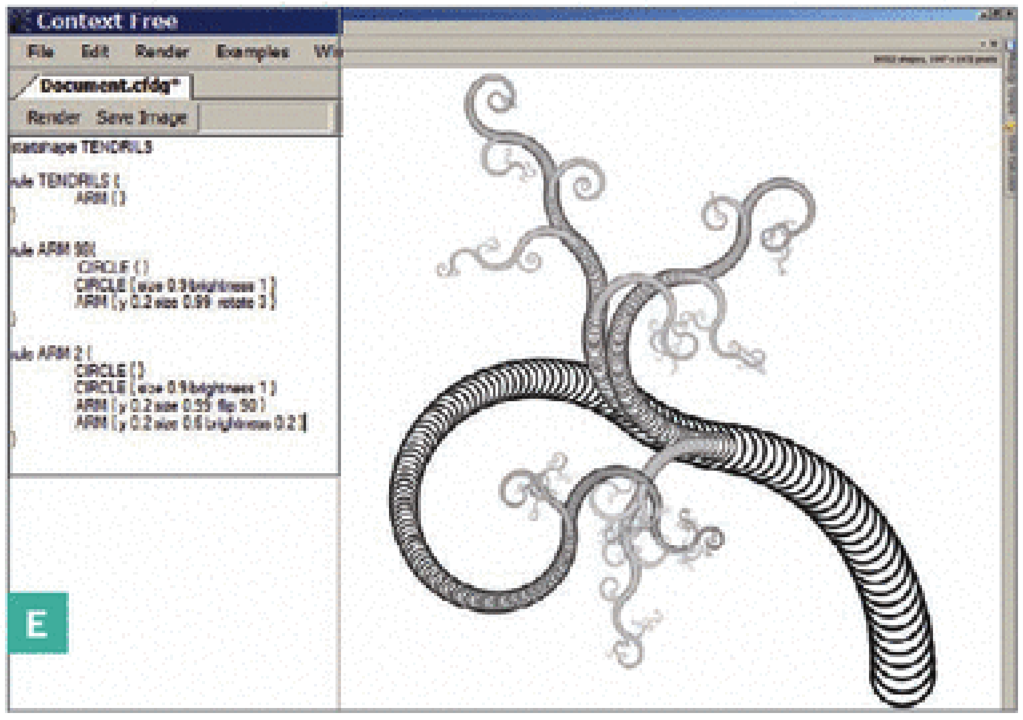
Instead of solid circles, I want outlined circles. We'll add a line to the **ARM** rule that makes a second, slightly smaller white circle. This is done through adjustments to the circle shape: **size 0.9** scales the size down and **brightness 1** makes it white.

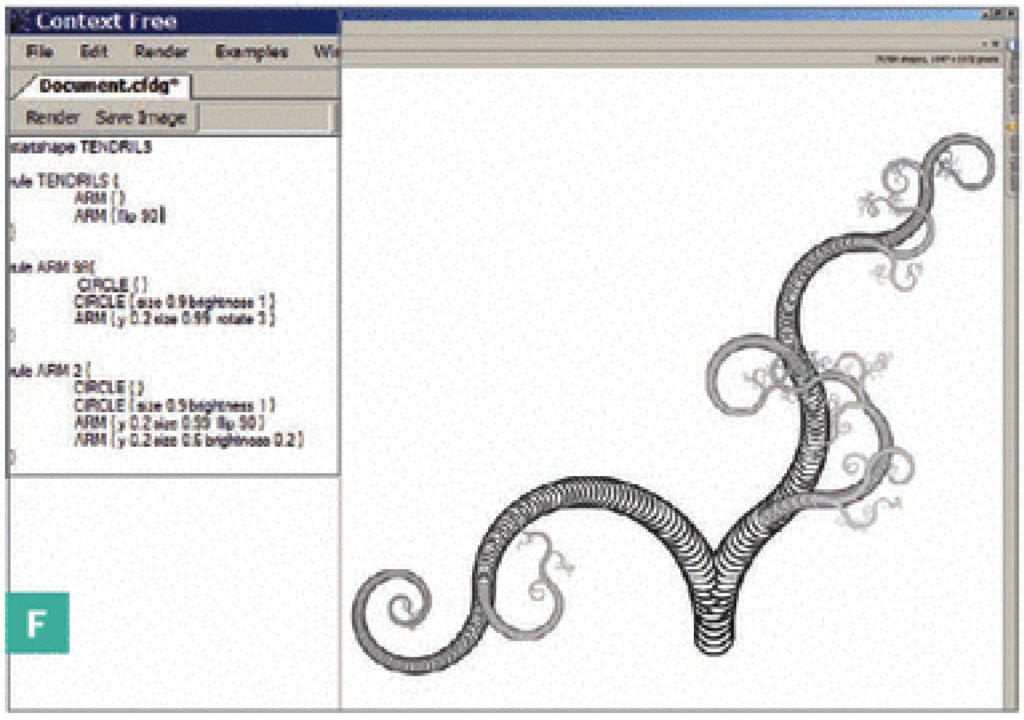
CF draws shapes in the order that they're encountered in a rule, so we'll now have the black circle, then a smaller white circle on top of it (Figure C).

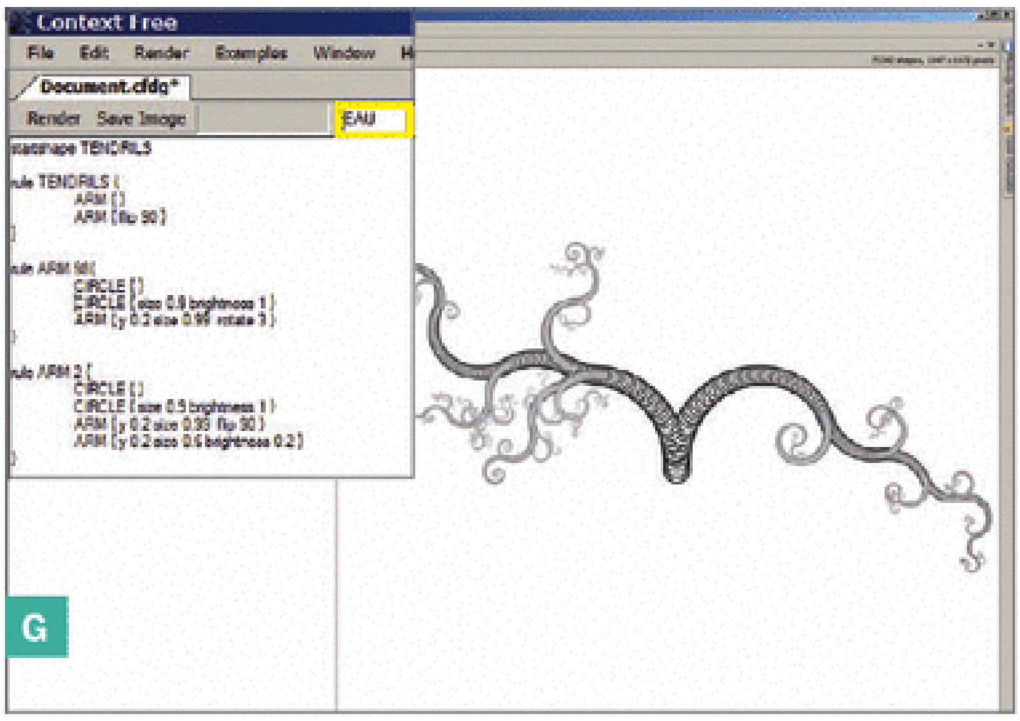
```
startshape TENDRILS
rule TENDRILS {
ARM { }
}
rule ARM {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 rotate 3 }
}
```

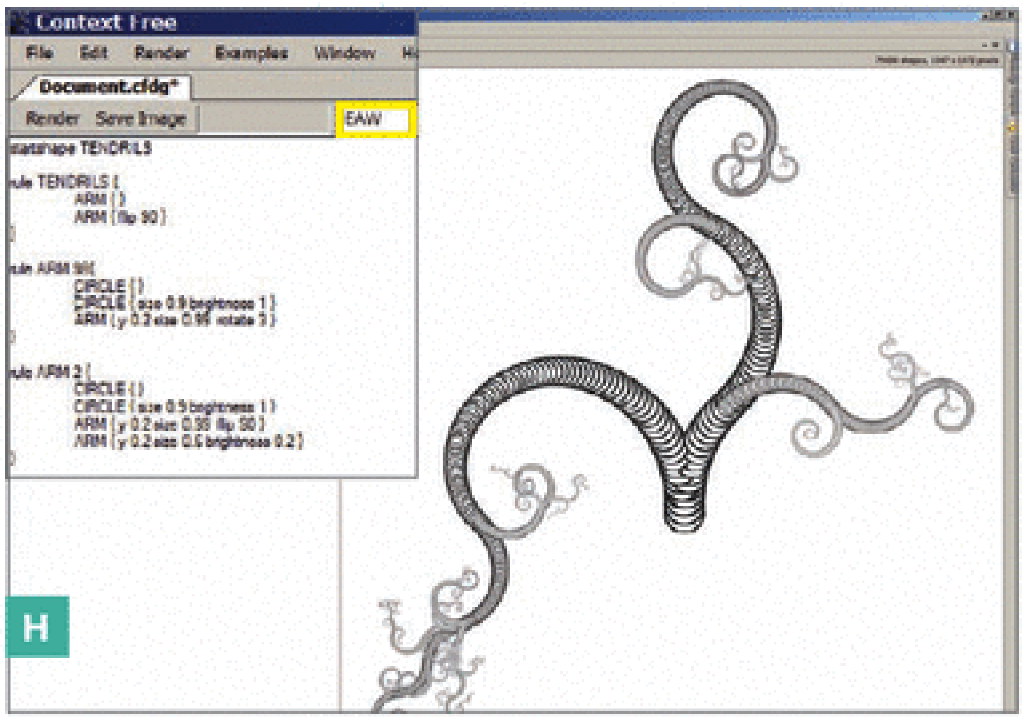
7. ADD RANDOMNESS

Randomness is at the heart of any organic design. This is the part that's difficult to create in a drawing program like Photoshop, but simple in CF. We can









define a rule more than once, with different adjustments to the rule, and CF will randomly choose which version of the rule to draw each time it encounters it.

We'll add a second definition of the ARM rule that is the same as the first, but has a 90° flip in it. We'll give this a very low probability of being chosen by adding a small "weight" value after the rule name: 98% of the time the large arm will be drawn, and 2% of the time it will branch to the smaller arm:

```
startshape TENDRILS
rule TENDRILS {
ARM { }
}
rule ARM 98 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 rotate 3 }
}
rule ARM 2 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 flip 90 }
}
```

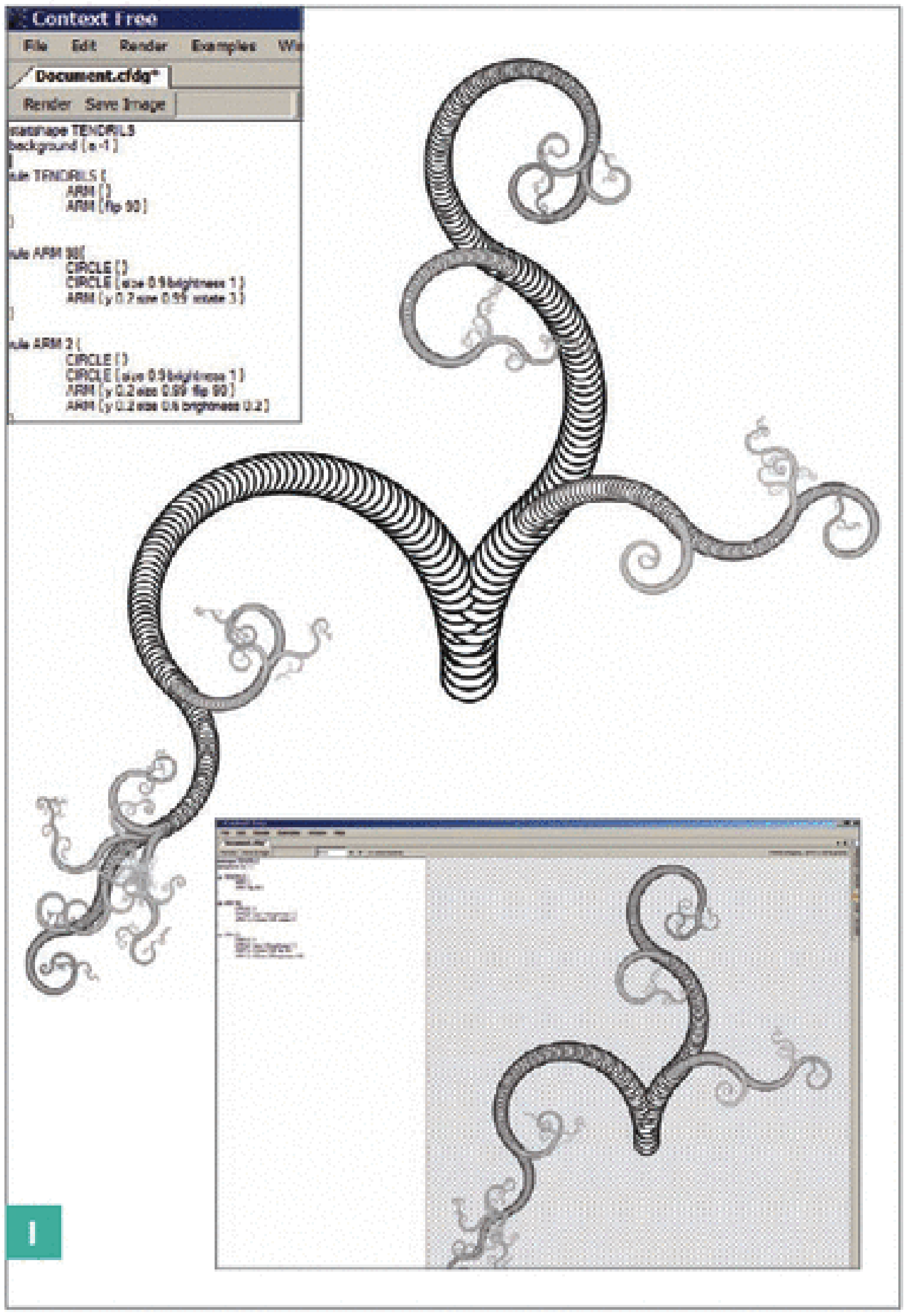
Render this and you'll see that the ARM is no longer a perfect spiral, but is an organic vine shape (Figure D, previous page). Each time you render it, the shape will vary.

8. DEFINE FADING BRANCHES

In order to make fading branches fork off the main arm, we'll modify this low-probability version of the ARM rule to create a second recursion that's sized down to 0.6, light gray, and nearly half of the current circle size:

```
startshape TENDRILS
rule TENDRILS {
ARM { }
}
rule ARM 98 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 rotate 3 }
}
rule ARM 2 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 flip 90 }
ARM { y 0.2 size 0.6 brightness 0.2 }
}
```

Render this and you'll see a wonderful, complex shape emerge (Figure E).



the variation code that appears in the top of the window (usually 3 letters, such as *EAW*) and using that to render the script (highlighted in yellow in Figures G and H).

If you want to get perfect alpha-channel transparency around the image so you can layer it easily in Photoshop or other compositing programs, just add this line to the top after the initial startshape line (Figure I):

```
startshape TENDRILS
background { a -1 }

rule TENDRILS {
ARM { }
ARM { flip 90 }
}

rule ARM 98 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 rotate 3 }
}

rule ARM 2 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 flip 90 }
ARM { y 0.2 size 0.6 brightness 0.2 }
}
```

9. ADD TRUNKS TO THE SHAPE

To create two main trunks of the shape, modify the TENDRILS rule to add a second, flipped ARM (Figure F):

```
startshape TENDRILS
rule TENDRILS {
ARM { }
ARM { flip 90 }
}
rule ARM 98 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 rotate 3 }
}
rule ARM 2 {
CIRCLE { }
CIRCLE { size 0.9 brightness 1 }
ARM { y 0.2 size 0.99 flip 90 }
ARM { y 0.2 size 0.6 brightness 0.2 }
}
```

10. RENDER A HIGH-RES COPY

For a high-resolution version of your image, select Render ⇒ Render to Size, choose your dimensions, then select Render ⇒ Save Image. You can reproduce an exact variation by making note of

11. GOING FURTHER

You can even output your work as an animation, by choosing Render ⇒ Save Movie and then adjusting the output settings. It's quite trance-inducing to watch your shape build itself over time.

This is just a tiny fraction of what you can do with this powerful design tool. Other techniques include tiling, color, complex transformation ordering, shearing, expressions, and path operations. Check out the gallery and forums on the Context Free website to see fantastic examples and to learn more.

Check out some CF art by other users at contextfreeart.org/gallery.

John Edgar Park (jp@jpixl.net) is a character mechanic at Walt Disney Animation Studios and the host of the Maker Workshop on *Make:* television.

Beautiful Brushes

Simplify applying images with the Paintbrush tool.
By Charles Platt




Brushes are a lesser-used feature of Photoshop that designer Silvia Bukovac Gaševi has exploited to extreme effect. The concept is simple: Create an image, define it as a brush, and apply it with the Paintbrush tool.

As an example, she suggests, "Let's say I wish to add a snowing effect to a graphic. Instead of placing snowflakes one by one to the image, I just select a snowflake brush."

Gaševi's website at graphics-illustrations.com contains a huge variety of brush patterns, ranging from alphabets to leaves to lipstick impressions. Some designs are for sale, while others are free.

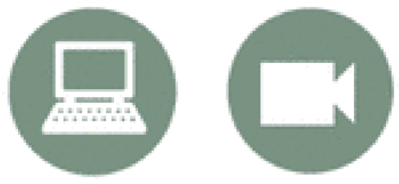
The site also offers tutorials, beginning with basics and progressing to esoteric topics such as "How to create grungy vector brushes."

Gaševi creates many of her brushes in Adobe Illustrator or Corel Draw before importing them to Photoshop, but a few have a more organic genesis. "My Coffee Stains brushes," she says, "are real stains that are scanned and imported directly into Photoshop."

There's only one snag if you want to brush up on your brushes: you'll need Photoshop 7 or later to make full use of this feature.

Images by Silvia Bukovac Gaševi

New Video Options



An increasing range of possibilities for hassle-free video. By Charles Platt

LEFT TO RIGHT: The Digital Concepts 3.1MP Digital Video Camcorder won't dazzle you with quality, but at $40, it's kind to your wallet and works for YouTube. At the other extreme, the semipro Canon Optura Xi lets you record onto MiniDV tape (optimum quality) and flash memory cards, but costs almost $2,000. The Sanyo Xacti range looks like a good-quality compromise.

A year ago I recommended Sanyo Xacti solid-state camcorders for creating video clips that can be uploaded simply by plugging in a USB cable. Sanyo's decision to use flash memory for storage, instead of tape or discs, eliminated unreliable moving parts and enabled a palm-sized camera. This was relatively unusual at the time. Good news: many similar competitors are now available.

Go to the Camcorder section of Amazon and search for "MPEG-4" (the compression format commonly used with flash memory) and you'll see what I mean.

Of course, more options create more shopping dilemmas. First you have to decide whether you want the traditional 4:3 picture shape, or a wider HD picture. HD does entail some compromises, because it requires more pixel data. Personally I still prefer the quality of a 4:3 picture on current consumer equipment.

You also need to decide whether your main purpose is to save videos onto a hard drive to watch on a monitor, or burn DVDs to watch on TV. Computer monitors have square pixels and will display non-interlaced pictures. A format of 640×480 pixels looks good. Traditional TV pictures (and many HD formats) are interlaced, and a typical 4:3 digital video picture uses 720×480 rectangular pixels.

Conversion between formats is automatic in most software, but you lose quality as resampling occurs. Several of the Sanyo Xacti models are clearly intended for use with computers, since their pictures have square pixels and are non-interlaced. If you want to email video clips to your friends or upload them to websites, this is the way to go.

Lastly I suggest you look for a camcorder that has the H.264 version of MPEG-4 compression, since this produces fewer visible artifacts than earlier schemes.

For viewing your videos on a computer, try VideoLAN's VLC Media Player version 0.9. This latest edition is a free download, available for Mac or Windows, and has already won a Community Choice Award from SourceForge. I consider it far superior to Windows Media Player or the Mac equivalent. It has a particularly elegant screen-capture feature, and a very good set of help files. Check it out at videolan.org.

I'm still looking for really versatile free video editing applications, but the ones bundled with OS X or Windows are adequate for simple projects. Add it all up, and there has been significant progress in the last year if you want to make your own video and copy it, upload it, and share it as simply and cheaply as possible.

Charles Platt is the section editor of Upload.

1+2+3 Wind-Triggered Lantern

An LED, a feather, and a spring. By Morten Skogly

Create a little magic in your yard with this flickering garden lantern triggered by the wind, made with spare parts you probably have lying around your house.

YOU WILL NEED

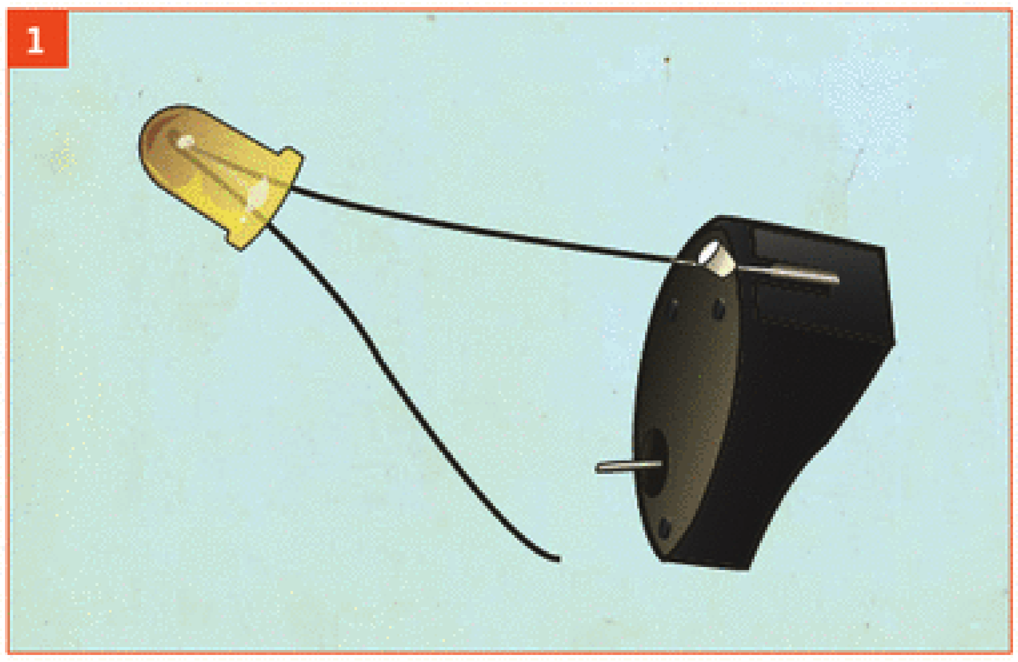
- LED
- 3V button battery
- Something springy made of metal
- Feather
- Thread
- Soldering iron and solder, or tape
- Carpet knife
- Strong wire
- Battery holder (optional) recommended
- Glass jar with lid (optional) for weather protection

1. Attach the LED to the battery.

Solder one of the LED's leads to the battery holder (Figure 1). I got the battery holder for the flat 3V button cell battery from an old PC that I've been scavenging parts from. (It's the battery that powers the internal clock, and I guess every PC has one.) You don't need a battery holder at all — you could just tape one of the LED's feet to the battery — but a battery holder makes things easier.

NOTE: Remember to test the LED first, so you know you're attaching the correct lead to the correct side of the battery.

1

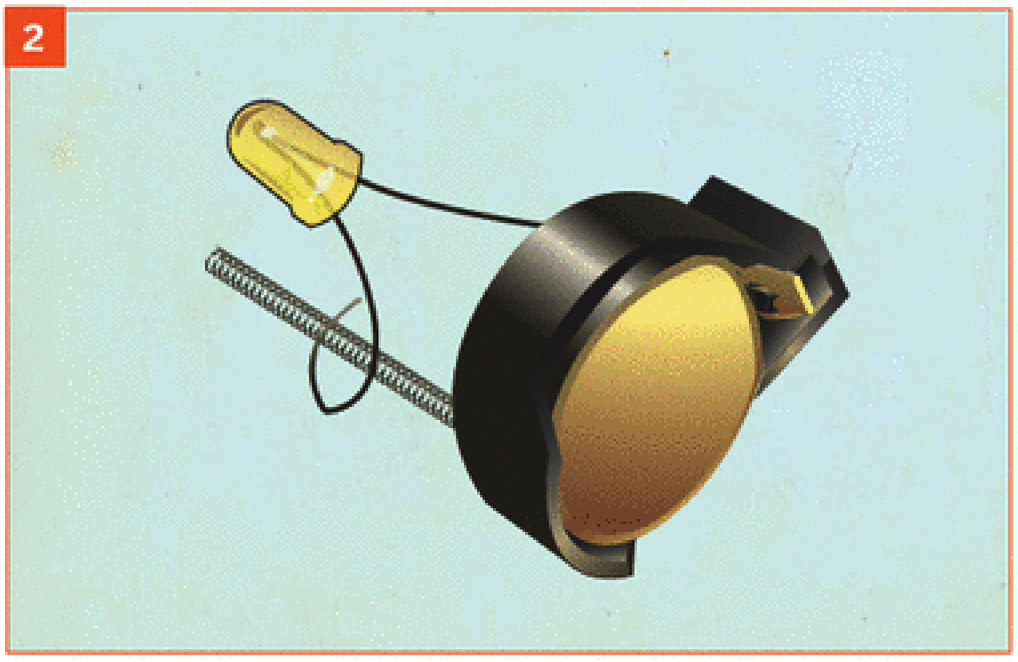


2. Make the flickering mechanism.

Solder a flexible piece of metal to the other side of the battery holder. I happened to have a long, thin spring from the CD-ROM drive of an IBM ThinkPad I took apart a while back; it works great. Another option could be a copper thread or wire, as thin as possible, or a piece of guitar string. Then bend the unsoldered lead of the LED so it curves around the spring without touching it (Figure 2).

Attach a feather to the spring with a piece of thread. When the feather moves in the wind, it pulls on the spring, which touches the foot of the LED and closes the circuit — which equals blinking!

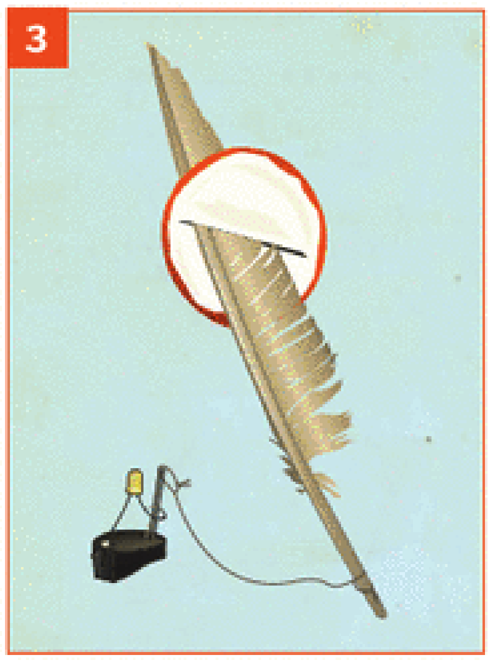
2



3. Hang it in the garden.

For weatherproofing, cut a slit in the lid of a jar and put the feather through it (Figure 3). Fiddle with it until the mechanism moves freely. Use 1yd or so of strong wire to wrap around the jar, to make a "harness" and a handle. Then go out and hang it in the garden (or run around with it, giggling, like I did).

3



Possible improvements: Add a solar cell and battery. Create a prettier casing, perhaps using beeswax? Or maybe even add sound!

Illustrations by Alison Kendall; photograph by Morten Skogly

Morten Skogly is a cheerful man, even in the dark. He makes things to impress his wife and kids. See more of his DIY stuff at pappmaskin.no.

Make: Projects

Look to both the past and future with these fresh interpretations of very different technologies. First, watch sparks fly as you re-create the historic Wimshurst machine with steampunk flair. Or take to the skies with a model glider inspired by classic versions from years past. Lost your bearings? Find the beat with a tangible rhythm sequencer that's bound to open up all kinds of musical possibilities.

Photograph by Elena Dorfman

THE WIMSHURST INFLUENCE MACHINE

By Jake von Slatt

SPARKS IN YOUR PARLOR

When assembling a proper laboratory, the gentleman or lady experimenter should be sure to include a Wimshurst electrostatic generating machine. This device will serve tirelessly in investigations into the field of natural philosophy, and provide interesting parlor games such as the "electric kiss." Herein we will demonstrate the construction of such a spectacular device, with materials easily acquired from your local home center and hardware store.

Electrostatic machines create high-voltage charges without the familiar coils of copper wire, permanent magnets, and commutators found in conventional generators. They're made of brass, glass, and wood, and they look more mechanical than electrical.

The coolest thing about them is that you can feel them working. As you begin to crank a Wimshurst machine, you can hear it crackle and hiss with energy, you can smell the sharp tang of ozone, and you can feel the hair on your arms stand up as the Leyden jars begin to charge.

Photography by Jake von Slatt

Set up: p.97 **Make it: p.98** **Use it: p.107**

Jake von Slatt is a lifelong tinkerer and maker currently residing outside Boston. He works as a Linux sysadmin for a small aerospace research firm, but his true passion is the construction of anachronistic contraptions in his Steampunk Workshop (steampunkworkshop.com).

ELECTRONS UNDER THE INFLUENCE

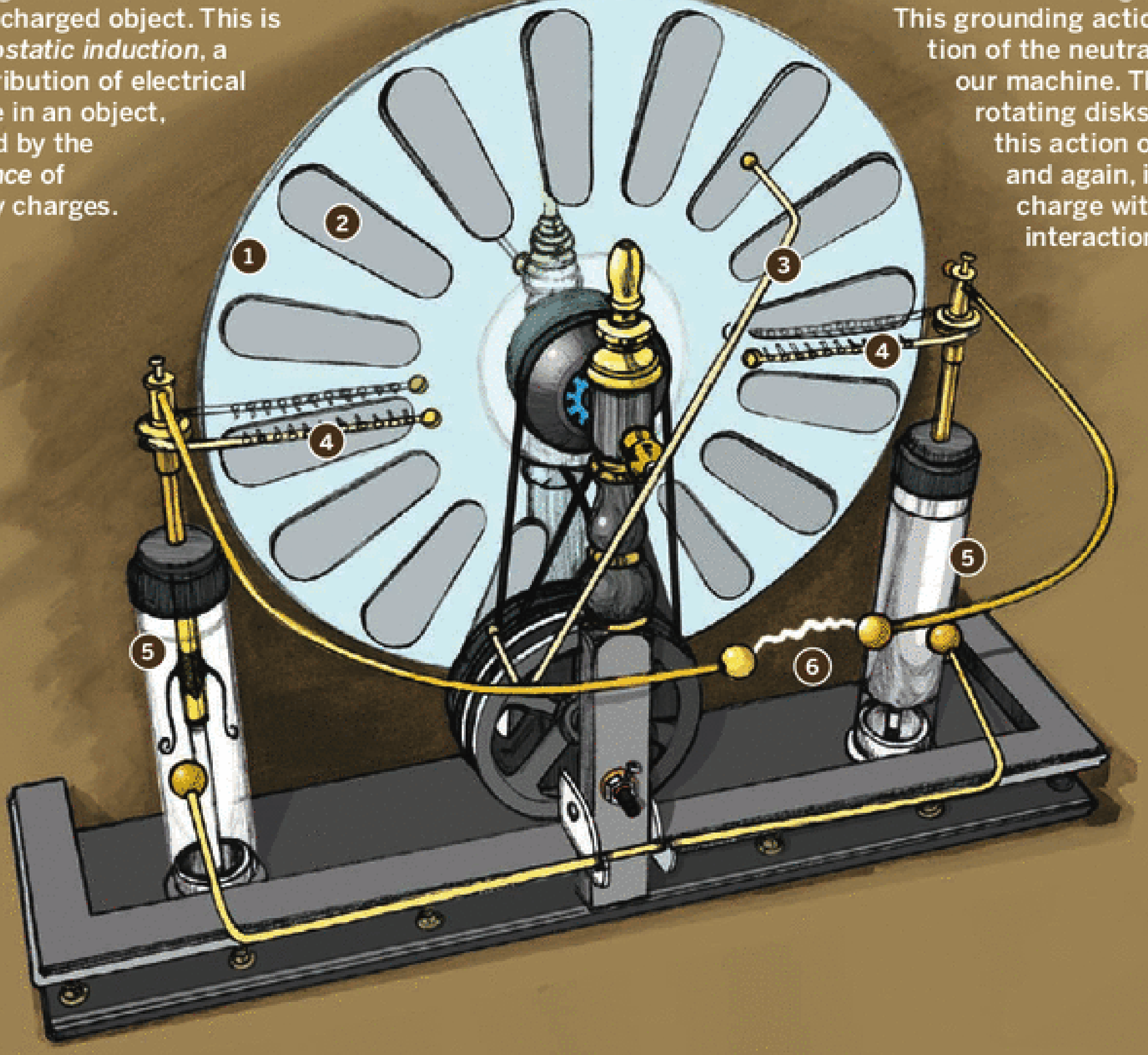
HOW A WIMSHURST MACHINE WORKS

In dry weather, getting up from a seat and touching a doorknob can give you a shock, because the act of separating your posterior from the chair causes a charge imbalance. The Wimshurst influence machine is essentially an idealized cycle of posteriors and chairs, endlessly sitting and standing.

How does it work? The basic operating principle is this: when you bring an electrically charged object close to an uncharged object, a charge imbalance is induced in the uncharged object. This is *electrostatic induction*, a redistribution of electrical charge in an object, caused by the *influence* of nearby charges.

In our Wimshurst machine, each metal sector has 2 sides, and there can be a charge imbalance between them. When you bring a positively charged sector near an uncharged sector, it pulls negative charges to the near side and pushes positive charges to the far side of the uncharged sector.

If you then ground the far side of the uncharged sector prior to removing it from the influence of the charged sector, you're left with a sector that now carries a negative charge. This grounding action is the function of the neutralizing bars on our machine. The counter-rotating disks ensure that this action occurs again and again, increasing the charge with each sector interaction.



The counter-rotating disks (1) continually pass their metal strips (or sectors) (2) near one another, and then separate them, increasing the sectors' electrical potential or charge.

A pair of neutralizing bars with conductive brushes (3) contact each sector while it's still under electrostatic influence, grounding its positive side and leaving it with a negative charge, or vice versa.

A pair of charge-collecting combs (4) strip off the charges — negative on one side and positive on the other — and deliver them to the Leyden jars (5) where they are stored. (Learn more about Leyden jars on page 103.)

When sufficient voltage builds up, a spark jumps the gap between 2 electrodes (6) — *CRACK!*

Illustration by Damien Scogin

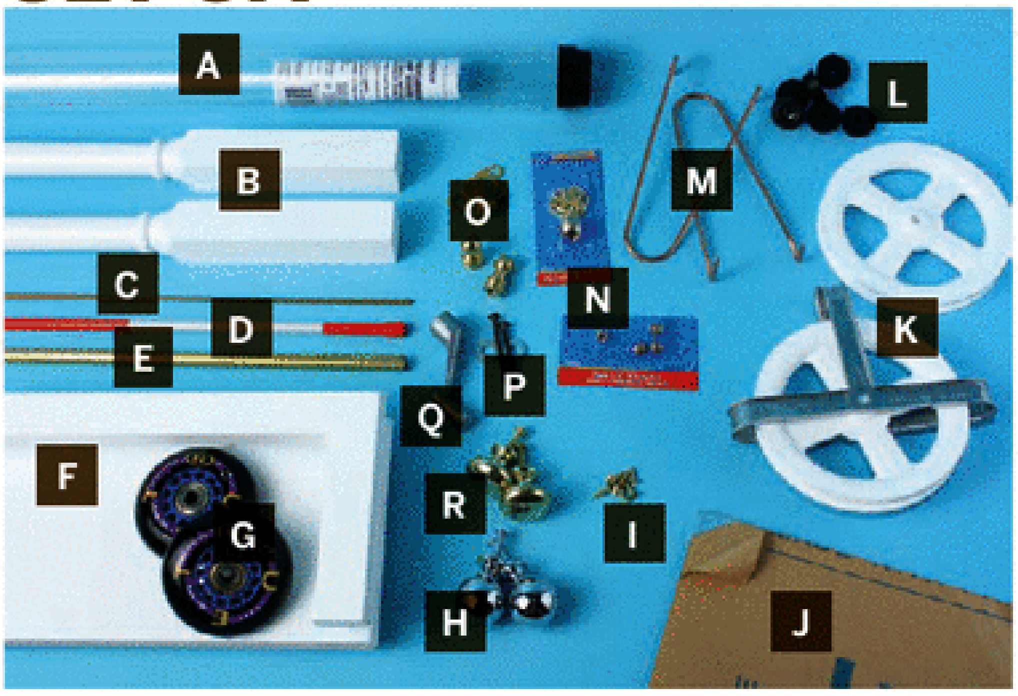
A BRIEF HISTORY OF ELECTROSTATIC GENERATORS

The earliest electrostatic generators, from the 17th century, rubbed amber, sulfur, or glass against a cloth or brush to induce a charge. Around 1865, the German physicists Wilhelm Holtz and August Toepler independently developed "influence" machines that created a charge by induction, without direct friction between electron-donor and acceptor materials.

In 1880, James Wimshurst, an English engineer and inventor, refined the design of the influence machine by using two counter-rotating disks rather than one. He never applied for patents, but he so improved the function of these machines that they became known by his name.

Wimshurst machines soon found practical application in exciting the X-ray tubes used in early medical imaging.

SET UP.



MATERIALS

The one item I couldn't find in a home and hardware store was the pair of O-rings. The total cost of materials was about $100, but most are common items, so a little scrounging and perhaps some dumpster diving should net you significant savings.

[A] Fluorescent lamp protector sleeve for the Leyden jars

[B] Staircase balusters (2) for supports for the rotating disks

[C] 1/8" bronze brazing rod from a hardware store or welding supply shop

[D] Fiberglass driveway marker rod, 5/16" diameter

[E] 3/8" OD thin wall brass tubing, 3' section

[F] Knick-knack shelf kit, approximately 24"×6" for the base. You can use any 3/4" board, but this shelf has a nice rail that adds to the overall look.

[G] Inline skate replacement wheels (2)

[H] Large brass lamp chain pull balls (2) for the Leyden jar shunts

[I] #4 or #6×1/2" flathead (countersunk) wood screws (4) to mount disks to skate wheels

[J] 3/16" acrylic glazing aka plexiglass, or polycarbonate aka Lexan enough to cut two 14" circles. Polycarbonate is easier to work with but costs twice as much.

[K] Clothesline pulleys must be plastic

[L] Rubber feet (6)

[M] 1" copper pipe hangers (2) Found in the plumbing section, they're copper-plated steel.

[N] Lamp parts Pictured here are various pull chains, brass finials, and ball nuts.

[O] Small brass ball cap nuts (2) for the electrodes. Found in the electrical section, they're commonly used to secure the top of brass outdoor lighting fixtures.

[P] 2" drywall screws (2) with large washers

[Q] Casement window crank

[R] 3/8" threaded lamp finials (2) for the charge collectors

[NOT SHOWN]

Brass lamp finials (2) for the brush supports. These have a 3/8" threaded hole in one end and a small hole in the other. I think they're made for ceiling fixtures that have a center pull string.

#8-32 screws (2)

Flat rubber washers (2)

3/8" OD thin wall brass tubing, 6" lengths (2)

3/8" threaded collars (2)

3/8" lamp nipples, 1" long (2)

Lamp washer nuts, threaded (2)

3/8" brass washers (2)

Brass lamp finials with 1/2" ball end (2) for the electrodes

3/4" square dowel, 12" length or equivalent scrap. Pine works, but hardwood is preferable.

Sixpenny nails (2)

Plastic milk jug

Pushpins

5/16" bolt with large (fender) washers

Scrap of foamboard, about 15" square

Aluminum tape with peel-off paper backing found with the duct tape and HVAC supplies

Alligator clips (4) and copper braid or solder wick for the neutralizing brushes. Try RadioShack.

3'–4' of bare copper wire

Plastic closet pole mounting sockets (2)

5/16" setscrew collars with setscrews (4) for the axles/shafts

#6-32 setscrews (2) for the neutralizing brush supports

Rubber O-ring belts (2) McMaster-Carr part #94115K259 (mcmaster.com), $15 for 8

14 AWG solid copper wire, about 12" length

Small brass wood screws (2)

TOOLS

Power drill and bits: 1/8", 5/16", countersink, and multi-step bit

Hacksaw with fine tooth blade, coping saw, and miter box

Hobby knife, scissors

Metal files: Fine metalworking, round (rat-tail), and flat crosscut intermediate (bastard)

400-grit sandpaper, #00 steel wool

#6-32 screw tap and handle

Small soldering torch and/or large soldering iron I use a Lenk LSP-180 torch. It's a marvelous tool.

Miscellaneous screwdrivers and small pliers

Tape measure, ruler

Epoxy, cellophane tape, rosin-core solder

Drawing compass

Small carpenter's square

MAKE IT.

BUILD YOUR ASTOUNDING WIMSHURST GENERATOR

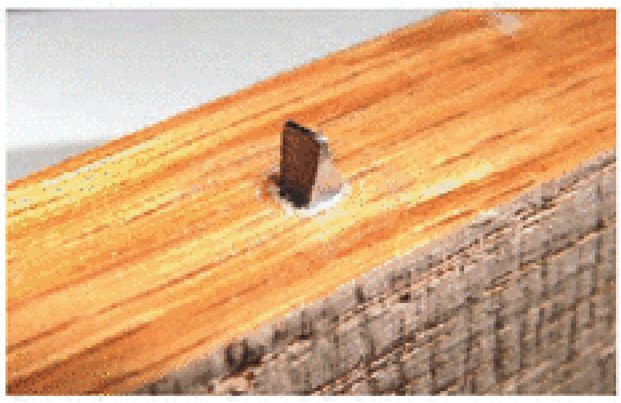
START **Time: 2 Weekends Complexity: Moderate**

This is a moderately difficult project. No single operation is particularly difficult, but a variety of techniques are involved. You'll likely find the soldering to be the most challenging, but don't fear, it's easier than it looks. Practice on some scraps before each operation, and you should be fine. A dimension diagram of the main parts is online at makezine.com/17/wimshurst.

1. MAKE A CIRCLE-CUTTING TOOL

To cut the two 14" acrylic circles, we first need to make a tool.

1a. Cut a 12" length of ¾" square wood dowel. Drill a pilot hole near 1 end and press or drive a sixpenny nail through the stick so the point sticks out about ¼". Drill a second hole exactly 7" from the first and insert another sixpenny nail.



1b. Use a fine metalworking file to shape the second nail as shown. You want to make a chisel point with a slight undercut on the leading face.

2. CUT 2 ACRYLIC DISKS

2a. Lay out your circles with a compass to be sure they'll both fit on your acrylic (or polycarbonate) sheet. Drill a ⅛" hole in the center of your circle. Be gentle when drilling acrylic, as it cracks easily. Polycarbonate is much tougher.

2b. Working on a carpeted floor, insert the unmodified nail into the center hole and begin scoring your circle with the cutting nail. Cut around the circumference, about ¼ of the way around with each stroke. If the cutter sticks, lift it out and move to a different spot. When you've cut about halfway through, flip the sheet over and cut from the other side. Repeat as necessary. When the circle pops free, clean up the edge with some 400-grit sandpaper, and set aside.

3. CUT BELT GROOVES INTO THE SKATE WHEELS

3a. Gently clamp or strap your drill to a workbench as pictured. Assemble a mandrel from a 5/16" bolt and some large (fender) washers, to grip the skate wheel. When assembled, the entire wheel must spin, not just the bearings.

3b. Chuck the assembly into the drill. The wheel should turn toward you and the speed should be fairly fast. With a crosscut bastard file, make a 1/4"-wide flat on the wheel. Then switch to a rat-tail file to cut the groove. Apply light and even pressure to the file.

4. ATTACH THE SKATE WHEELS TO THE DISKS

4a. Use a step drill bit to widen the hole in the acrylic disk to 5/16". Be gentle, and go slowly, because acrylic is easily cracked.

4b. Remove the washers from the wheel and use the 5/16" bolt to center the wheel against the disk. Drill four 1/8" holes through the disk but not into the wheel. Then switch to a 3/32" bit and drill partway into the wheel in 4 places. Finish the holes with a countersink.

4c. Remove the 5/16" bolt and drill the center hole out to 1/2" or 5/8" using a step bit. You want the edges of the hole completely clear of the rotating parts of the wheel bearing. Install 4 small countersunk screws. Tighten these so they just touch the disk. The disk must remain as flat as possible.

5. CUT THE SECTORS

Decide how many sectors you're willing to cut. I'm rather lazy and opted for fewer, 16 per disk. If you make 24 or 32, you'll have to make them smaller but you'll be rewarded with longer sparks.

Following the diagram at makezine.com/17/wimshurst, make a template from a plastic milk jug, then trace each sector onto aluminum tape. It's a good idea to make some extra sectors to practice with. Cut them individually; don't be tempted to stack multiple layers or your cuts will end up ragged and bleed charge away into the air.

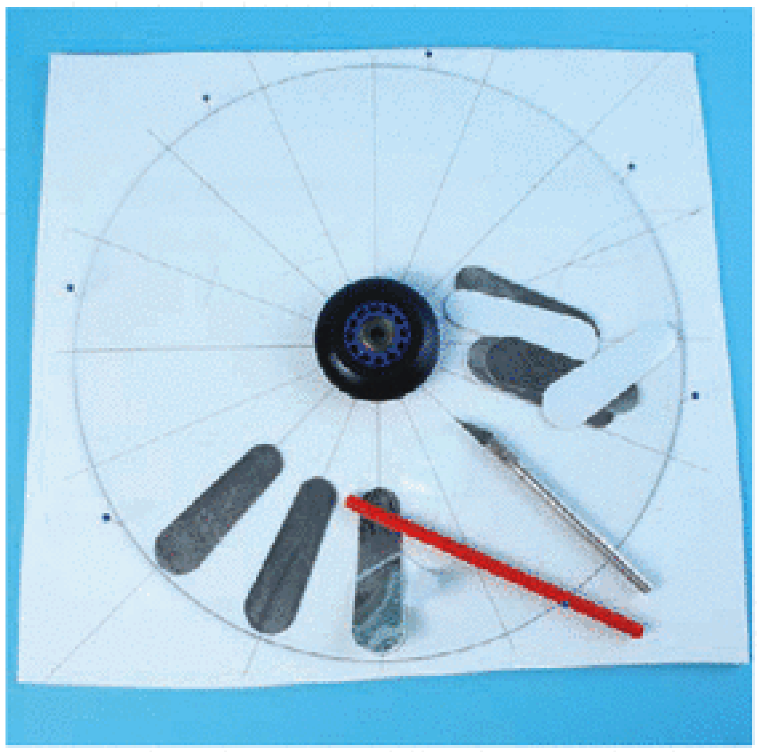
TIP: I found it easiest to use an X-Acto knife and straightedge to cut the long sides, and then switch to scissors for the curved ends.

6. ATTACH THE SECTORS

6a. Draw a 14" circle on foamboard, and draw radial lines to correspond with your number of sectors. Place your sector template centered at 6 o'clock and trace it. The large end should face out and be about ¼" from the edge of the circle.

6b. Center the acrylic disk on the foamboard and insert pushpins around the circumference so it turns in place.

6c. After practicing with some spare sectors, carefully peel and stick the first one in place. A length of fiberglass rod makes an excellent burnishing tool. Turn the disk 1 line to the left and repeat. Always index the line to the first sector you stuck down; this will help make the spacing as even as possible.



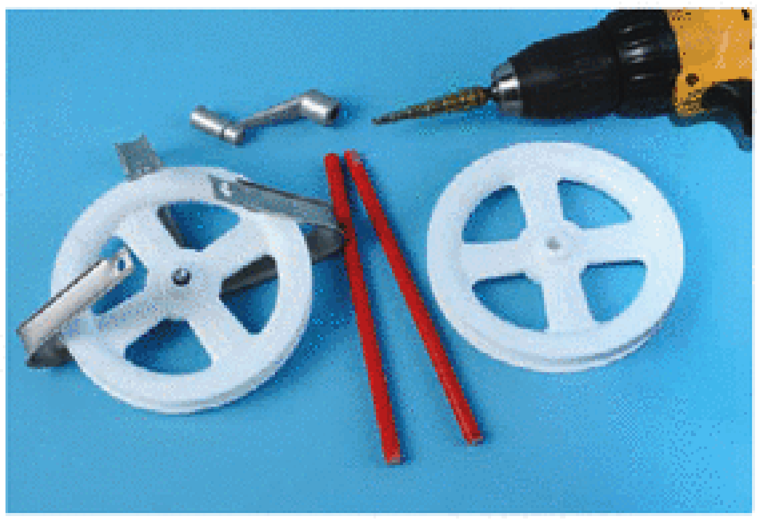
7. PREPARE THE DRIVE PULLEYS AND CRANK

7a. Remove the pulleys from their cages by drilling out the rivets, then use the step bit to enlarge the holes to 5⁄16". Drill from one side, then the other, to enlarge the full depth of the hole in the pulley.

7b. Cut two 7" lengths from the fiberglass rod, and slightly bevel the ends with a file to prevent chip-out. These are the disk axle and drive shaft. Be careful of the glass fibers — they can be irritating!

7c. Drill the splines out of the window crank's bore with a regular 5⁄16" drill bit. Clamp the crank in a vise and drill slowly, making sure the bit is in line with the axis.

NOTE: It's important to use the step bit here because it is self-centering.

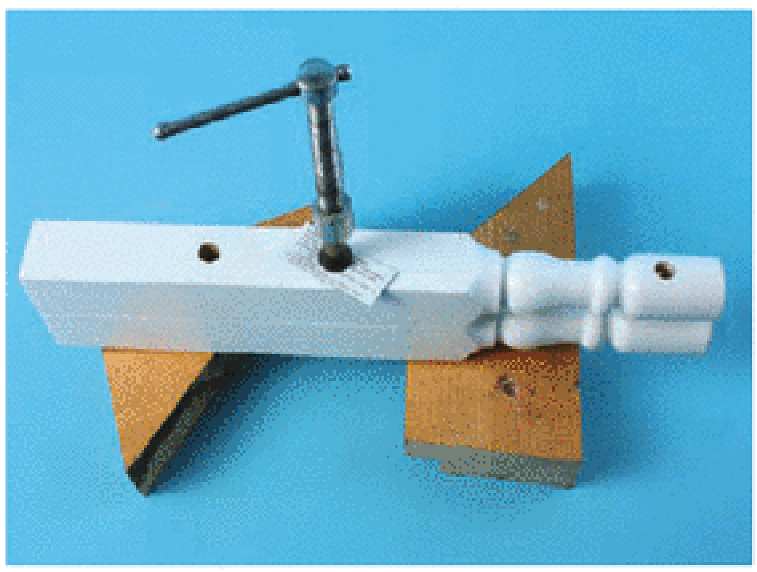


8. CUT AND DRILL THE DISK SUPPORTS

8a. Cut a 12" length off each staircase baluster. Choose the end that you think looks best.

8b. Clamp the 2 supports together as shown and drill 5⁄16" holes at 3¼" and again at 11" inches from the bottom (square end).

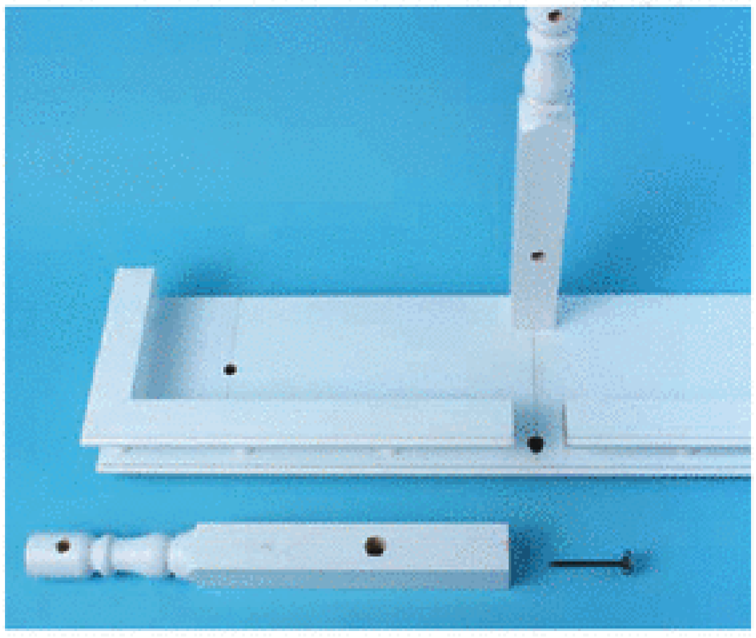
8c. The lower hole needs to be reamed out so that the fiberglass axle turns freely in it. Use a slightly larger drill or rat-tail file. You can also drill it larger and insert plastic bushings or skate bearings for smoother operation.



9. BUILD THE BASE

9a. Draw a line lengthwise on the knick-knack shelf, parallel to the back, 2½" in. Then draw a centerline perpendicular to the first.

9b. Cut a 1¼" gap in the rail on the centerline, as pictured.



9c. Drill two ⅜" holes in the base on the centerline, ⅝" from the front and back edges. Use 2" drywall screws and large washers to attach the disk supports to the base. The oversized holes and washers will allow you to adjust and align the position of the rotating disks precisely.

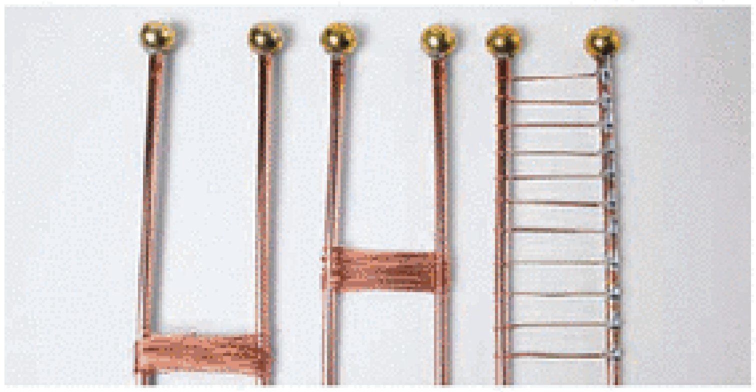
9d. Drill two 5⁄16" holes on the lengthwise line, 7⅝" from the centerline on each side. These need to be perfectly vertical, so use a small carpenter's square to line up the drill.

10. MAKE THE CHARGE COLLECTOR COMBS

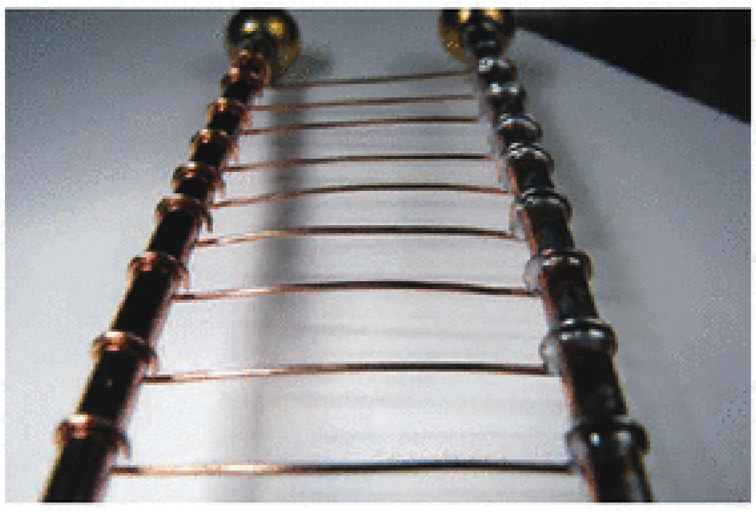
10a. Cut each pipe hanger to 5" with a hacksaw, removing the nail ends. Save the scraps. Place the small brass ball nuts on the ends, heat them with a small torch, and apply just enough solder to fill the joint.

NOTE: The pipe hanger is copper-plated steel; be careful not to overheat it or the solder may not adhere.

10b. You need to make 8 to 12 pointy prongs down each side of the collector combs. Wrap copper wire around each pipe hanger (I made 11 turns), then cut away the center portion on 1 side only and bend the cut ends around the pipe hangers. Spread these wires out evenly along the portion of the charge collector that will face the sector.



10c. Solder the prong wires. Crimp the ends tightly around the pipe hanger and use a large soldering iron to solder each joint. Apply sufficient solder so that it flows down to fill the gap at the end of each length of wire. We want to avoid any points other than the prongs themselves.

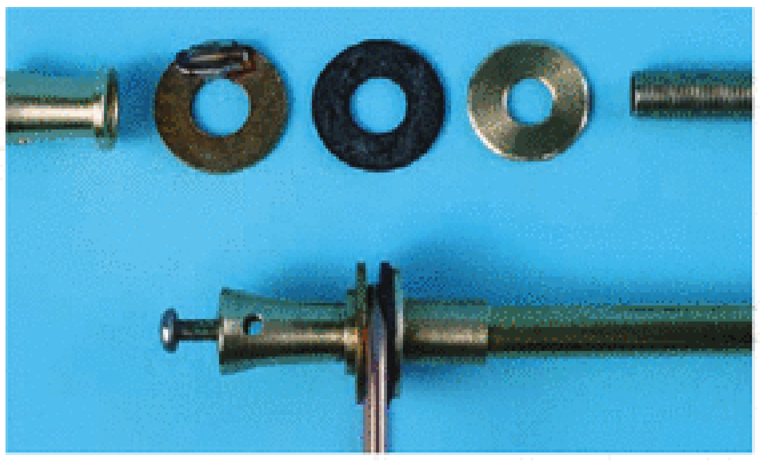


Once you've soldered all the joints, cut down the center of the wires, but don't trim the prongs to length until it's time to install the combs.

11. PREPARE THE CHARGE COLLECTOR MOUNTS

11a. Using the step bit, bore out half of the threaded collar. Screw the nipple halfway into the collar. Insert the brass tubing into the other end and solder it in place.

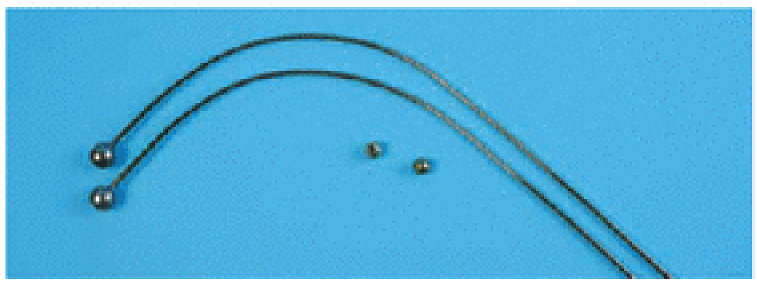
11b. Drill a hole straight down into the top of the ⅜" threaded finial and thread it with a #6-32 tap. Use the drill size written on the tap. Then drill a ⅛" hole through the body of the finial as shown; this is for the discharge electrode.



11c. Cut a ½" length from the scraps you trimmed off the pipe hanger, and solder it to the brass washer. This will allow the assembly to clamp and hold the charge collector perpendicular to the support. Test-assemble the mount, and then disassemble and set it aside. Make another the same way.

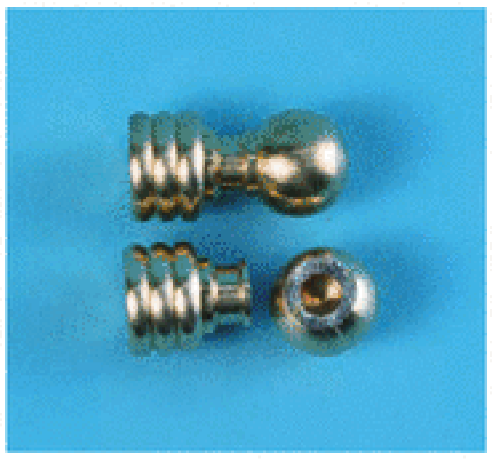
12. MAKE THE DISCHARGE ELECTRODES

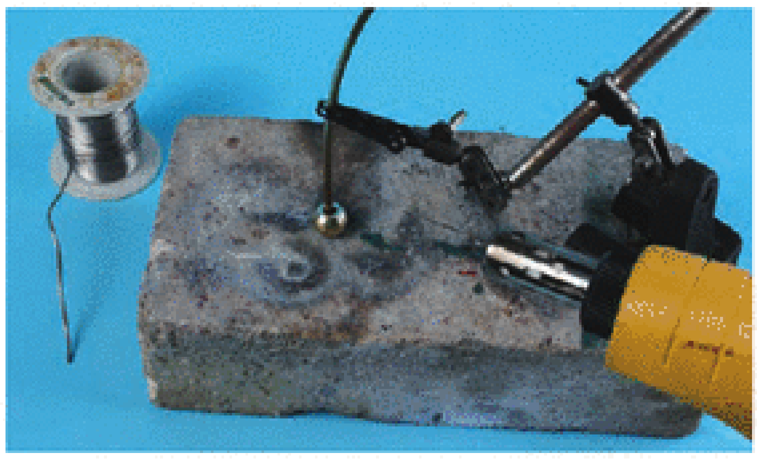
12a. Cut two 15" lengths of brazing rod and bend them as shown. I bent mine by hand but you could bend a 30" length around a 5gal pail and then cut it in the center for a neater appearance.



12b. With a hacksaw, cut ½" balls off 2 brass lamp finials. Solder 1 ball to each electrode; fill the hole with solder so it makes a smooth transition to the rod.

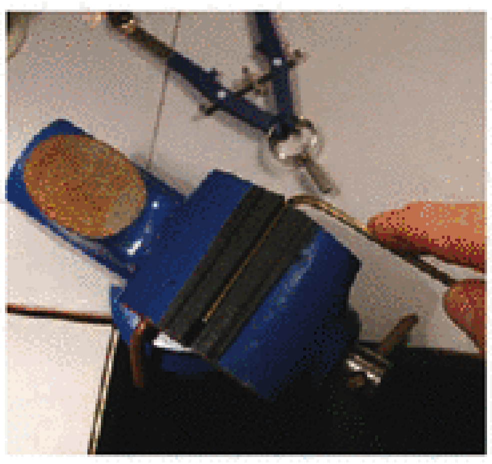
NOTE: Do not solder the small ball nuts in place! You'll use them after you attach the electrodes to the charge collector mount.

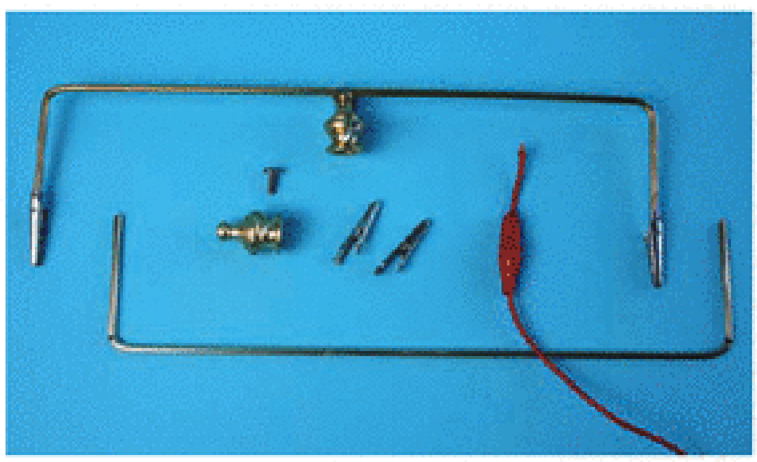




13. FABRICATE 2 NEUTRALIZING BRUSH SUPPORTS

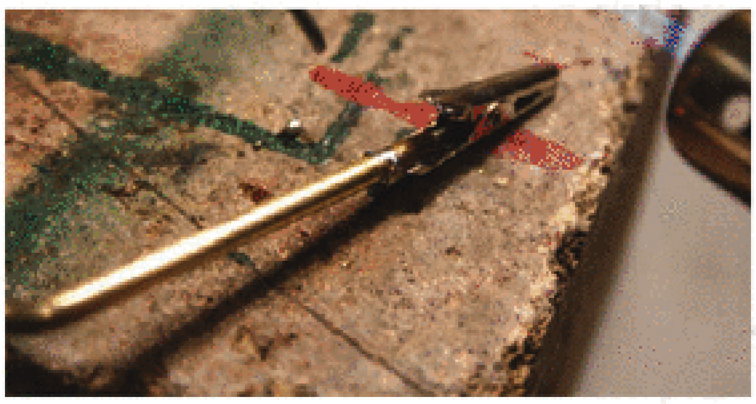
13a. Cut two 14" lengths of brazing rod and make two 90° bends in each as shown, 2" from either end. These are the brush supports.





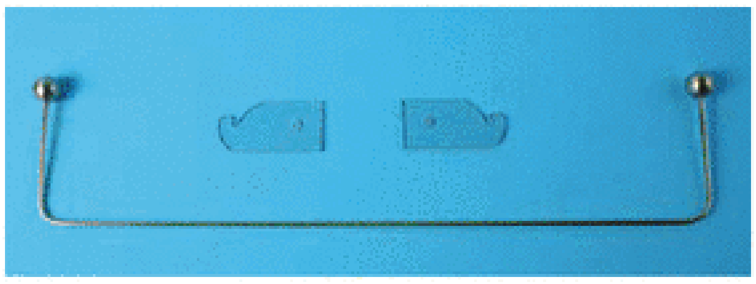
13b. Solder the brush supports to the brush bosses (hubs). First drill a sideways hole for a setscrew in the base of the finial, and tap it with the #6-32 tap. File a groove in the top of the finial, then center the brush support bar on the finial, prop it parallel to the workbench top, and solder it in place.

13c. Crimp the alligator clips onto the ends of the brush support bars, and solder.

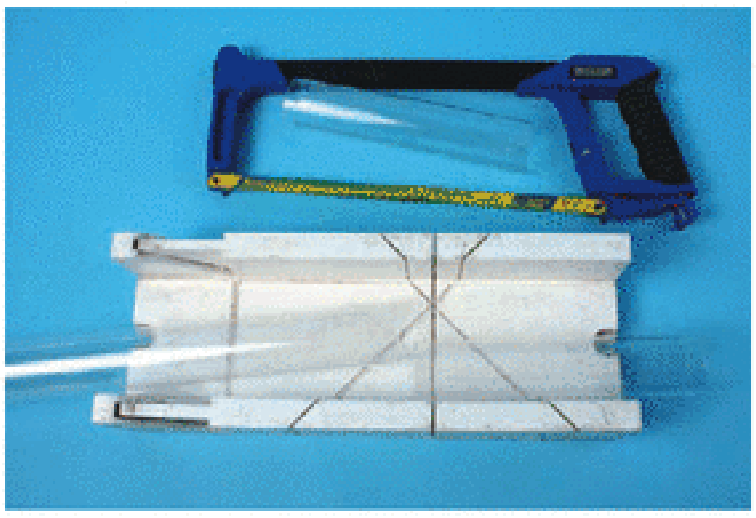


14. FABRICATE THE LEYDEN JARS AND SHUNT

14a. Make the Leyden jar shunt. Cut a 22" length of brazing rod and make a 90° bend 3½" in from each end. Solder 2 large brass lamp chain pull balls to the ends. (Smaller finial balls or cabinet knobs would work, too. If you use knobs, be sure to remove any lacquer finish.)



14b. Cut the Leyden jar bodies. Using the miter box and fine tooth hacksaw, cut two 7½" lengths from the fluorescent lamp protector sleeve.



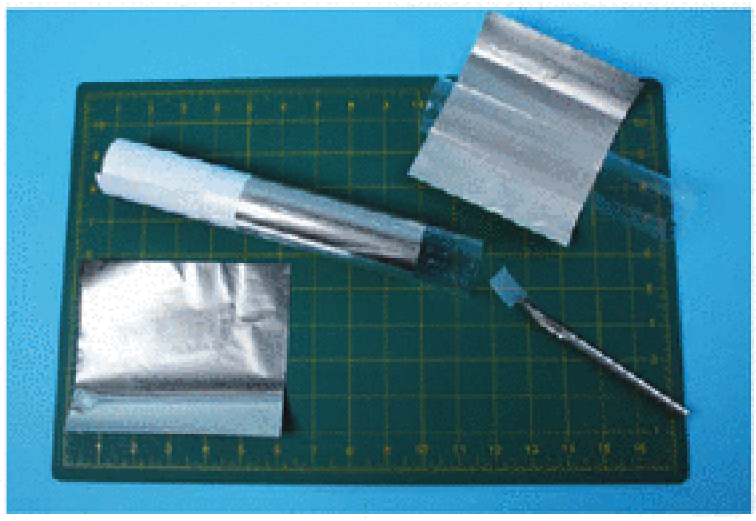
Leyden Jars

The Leyden jar is the granddaddy of the modern capacitor. It consists of inner and outer layers of metal foil separated by a dielectric, or insulator. The amount of charge the jar can hold is determined by the area of these 2 plates, their distance from each other, and the insulating capability of the material between. Original Leyden jars were made with silver or lead foil and glass. However, plastic is a far superior insulator due to glass' propensity to absorb water molecules, thus reducing its dielectric properties.

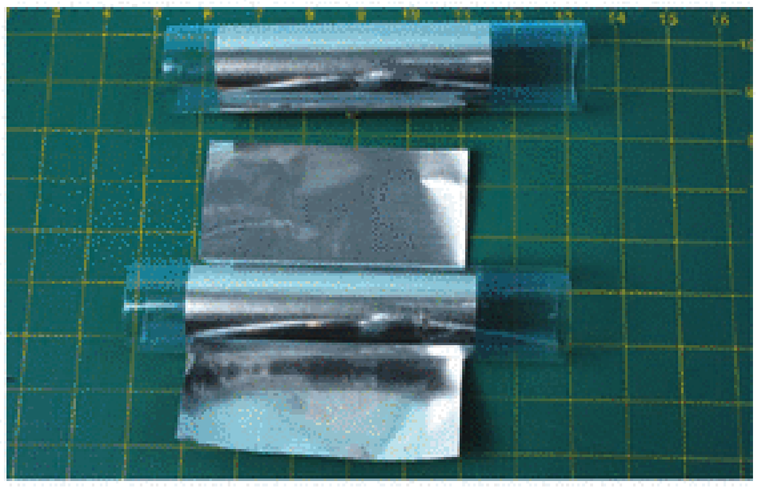
Our Leyden jars are large enough to give you a jolt, but not so large as to harm a healthy person. Leyden jars capable of administering a lethal shock are quite easily built — so be sure you fully understand their properties if you decide to construct larger jars than those here.

The first generally acknowledged accidental death by electrocution occurred in St. Petersburg, Russia, in 1783 when a professor brought his head a bit too close to a charged bank of Leyden jars.

14c. Affix the inner and outer plates. Cut four 5"×6" sheets of heavy-duty aluminum foil. Form 2 sheets by wrapping them around the tubes along their 6" axis, so each foil cylinder is 5" high. Insert 1 cylinder into each tube so that it's 1" from 1 end, then use a couple of rolled-up sheets of paper to hold the foil firmly against the inside of the tube while you tape it in place, the tighter the better.



Wrap 1 piece of foil around the outside of each tube, and tape it in place. Again, the tighter the better, but don't wrinkle the foil.



14d. Snap the tube end caps onto the opening that is 1" from the foil. Make the Leyden jar bases from a pair of plastic closet pole mounts; I had to trim off some reinforcing ribs with an X-Acto knife to make them slide into the tubes. Drill out the center hole to 5⁄16".

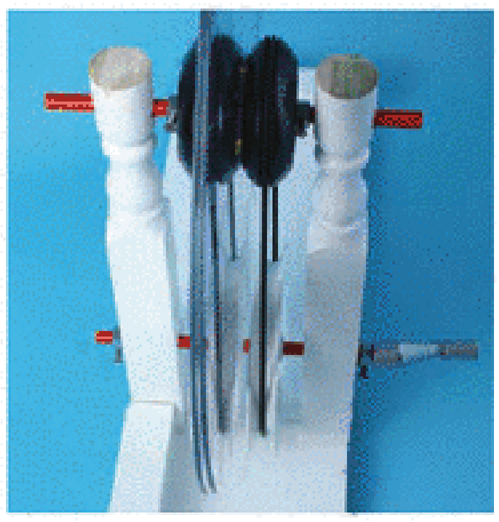
15. MOUNT THE DISKS AND DRIVE LINE

15a. Slide the disk axle through the top holes in the supports, adding a 5⁄16" setscrew collar, an O-ring belt, the 2 disks, the other belt, and another collar, as shown.

15b. Attach the casement window crank to the drive shaft. Insert the bushings in the supports if you're using them, slide the shaft through the pulleys, and put a setscrew collar on either end. The pulleys should be tight; you'll have to twist the shaft back and forth to get it through.

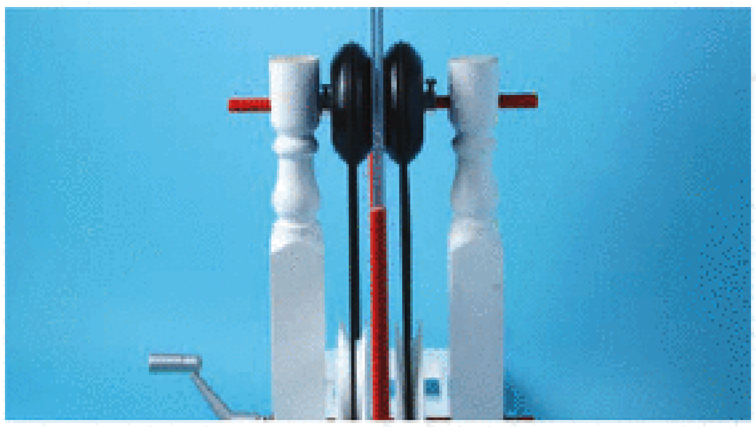
15c. Stretch the belts around the pulleys; don't forget to twist one, so that the disks rotate in opposite directions. (In this photo, the belt with the twist is hidden behind the disk. What you are seeing is a reflection of the untwisted belt.)

NOTE: You might need a spacer between the disks. My machine became difficult to turn once it was fully charged, due to the electrostatic attraction of the disks. I cut a 2½" washer from a plastic milk jug and placed it on the shaft between the disks to remedy this problem.



16. ALIGN THE DISK AND COLLECTOR SUPPORTS

Cut two 11" lengths of fiberglass rod and press them into the holes in the base. Loosen the screws that hold the 2 disk supports and adjust them so the disks are perfectly in line with these charge-collector supports. Retighten the supports.

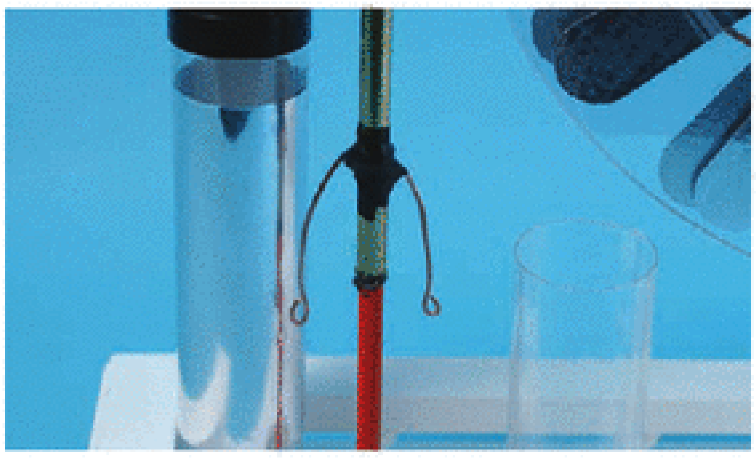


17. INSTALL LEYDEN JARS AND CHARGE COLLECTORS

17a. Slide the Leyden jar bases, then the charge collector assemblies, over the fiberglass charge collector supports.

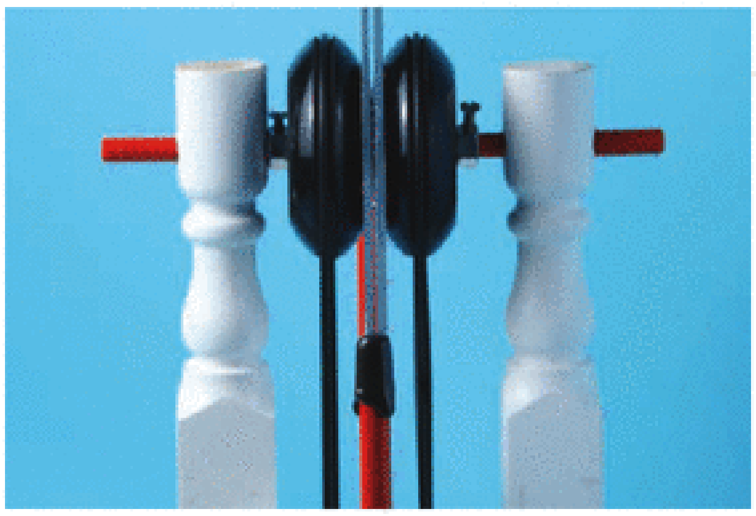
17b. Use about 6" of 14 AWG solid copper wire to form each inner plate contact. Wrap it once around the brass tube and form 2 loops in the ends.

Using a scrap of the plastic tube as a guide, adjust the inner plate contacts so they apply even, gentle pressure. You want good contact with the foil but you don't want to rip it when you install the Leyden jars.

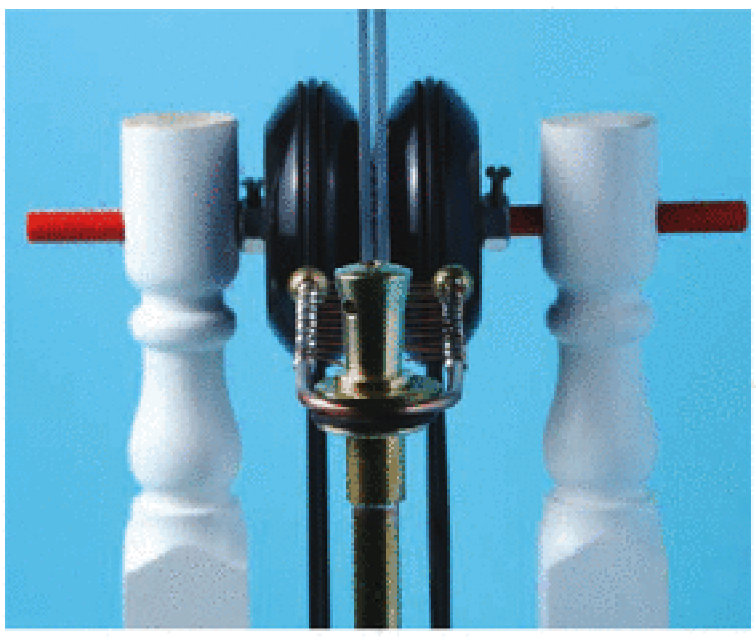


17c. Apply epoxy to the end of the fiberglass support rod, slide the brass charge collector assembly down onto it, and set it aside while the epoxy cures.

17d. Slide the Leyden jars onto their bases, being careful not to tear the foil as you make contact.



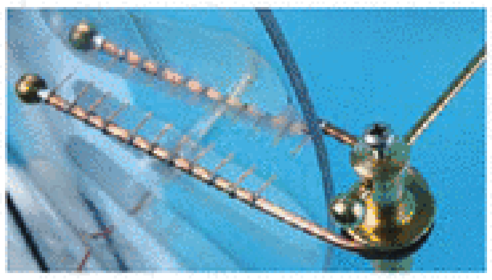
17e. Line up the charge collector combs, test-spin the disks to see if there's any wobble, then trim the prongs to come as close as possible to the disks without touching. Tighten the charge collector assemblies to hold the combs in place.

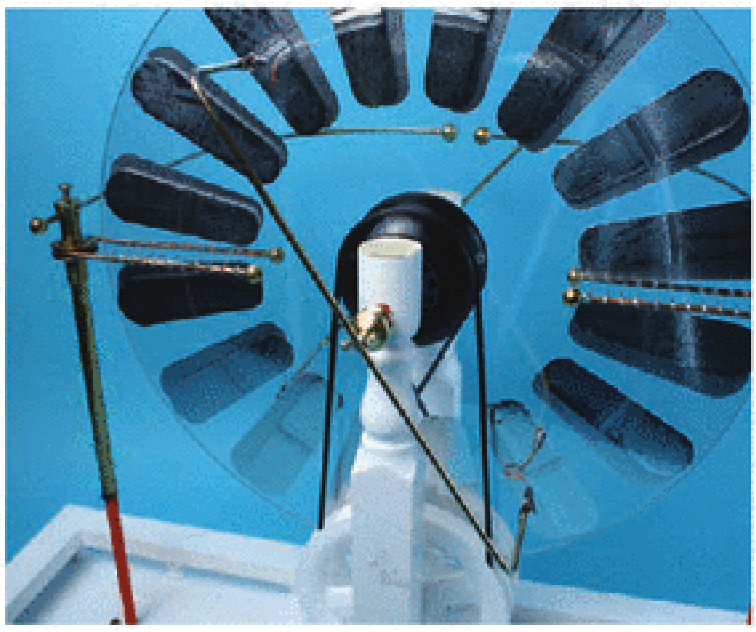


18. INSTALL DISCHARGE ELECTRODES AND NEUTRALIZING BRUSHES

18a. Insert the discharge electrode into the finial on the charge collector and tighten the screw to hold it in place. (The finial should be tight enough to hold the collector comb but still allow the electrode to move. If it's too tight, or not tight enough, the support rod can be twisted in the base to accommodate.)

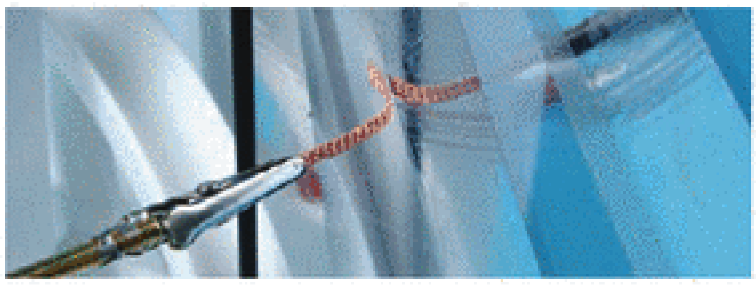
18b. Wrap a bit of tape around the bare end of the electrode and screw on one of the small ball nuts; this will prevent charge from bleeding off the sharp end. Repeat with the second electrode.





18c. Slide the neutralizing bars onto the upper shaft and align them roughly 45° from the collector combs. A sector should pass through a charge collector, encounter a neutralizing bar after about ⅙ of a rotation, and then encounter the other charge collector after a further ⅓ of a rotation. Tighten the setscrew to secure.

18d. Add the neutralizing brushes. Clip 1½" lengths of solder wick or copper braid to the ends of the neutralizing rods so they make good contact with the disk.

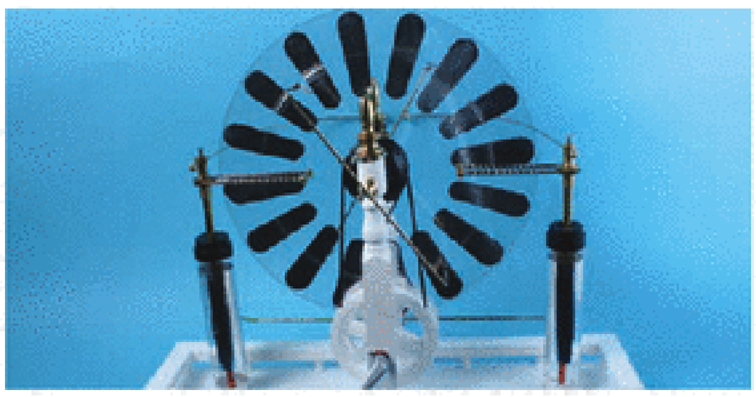


19. MOUNT THE LEYDEN JAR SHUNT AND ADD FINISHING TOUCHES

19a. Cut the 2 acrylic brackets as shown in the parts diagram, then use small brass wood screws to attach them to the front disk support, leaving them a little loose at first. Place the Leyden jar shunt in the brackets and line them up so the balls on the shunt lean comfortably against the Leyden jars. Tighten the brackets.

19b. Attach the 6 rubber feet to the base.

19c. The tops of the 2 disk supports looked a little bare to me, so I raided my junk box for more lamp parts and came up with these decorative finials. The wealth of finial and cabinet knobs at the typical home center means that there are infinite opportunities for creativity here! That's it. Your Wimshurst machine is done!



CAUTION: HIGH VOLTAGE! This machine, or more specifically the Leyden jars that are a part of it, are capable of delivering shocks in excess of 50,000 volts. While the current is quite low and therefore unlikely to harm a healthy person, a serious jolt might knock you off your feet — and who knows what your head will hit on the way down. Please be careful and treat all sources of high voltage electricity with the utmost respect.

FINISH X

NOW GO USE IT »

LET THE SPARKS FLY

OPERATION

There are 3 variables you can play with: size of the spark gap, angle of the neutralizing bars, and switching of the Leyden jars in and out of circuit.

Start with the spark gap set to about 1", the neutralizers at 45° to the collector combs (90° to each other), and the Leyden jars disconnected. Turn the crank smoothly at a moderate speed. The electrodes should produce a thin blue spark. Look closely and you'll notice that one end is brighter; this is your positive electrode.

Stop cranking and engage the Leyden jars. These can hold a charge for days. From this point on, consider the machine "hot" until you short the electrodes by simultaneously touching both with the tip of a screwdriver. Also be warned that Leyden jars can acquire charge just sitting there, so you need to discharge them this way each and every time before you touch the electrodes.

Turn the crank again. After several revolutions you'll hear the neutralizing brushes crackle, you'll smell the fresh scent of ozone, and — *CRACK!* — a strong blue spark will jump the gap.

ADJUSTMENTS

Short the electrodes and reposition them a little farther apart. Crank some more and you'll see a bigger spark. Repeat this procedure until you see multiple small sparks jump from one of the collectors, across several sectors, to a neutralizing brush. You've reached your maximum spark length.

After you find the maximum gap, you can adjust the neutralizing bars. Narrowing their angle from 90° to about 60° will increase the maximum voltage at the expense of a small decrease in current.

MAINTENANCE

Your machine should require little maintenance, but may require periodic replacement of the belts and cleaning of the disks. Use only water to clean them, or rubbing alcohol if you suspect there is oil on them.

THE ELECTRIC KISS (AND OTHER ENTERTAINMENTS)

Wimshurst machines had a place in Victorian entertainment. After a fine meal, guests might adjourn to the parlor for games, discussion, and scientific demonstrations. One can imagine the visceral impact of the Wimshurst machine, with its spinning glass disks, electrical discharges, and the loud report of 6" sparks.

For the adventurous, in the right company, there was a demonstration known as the electric kiss. Two volunteers would stand on insulating surfaces. Each would touch one of the 2 charge collectors and then they'd slowly, without any other part of their bodies touching, bring their lips together for the inevitable "tingle" of electricity.

CAUTION: Demonstrate the electric kiss only with the Leyden jars taken out of the circuit, to avoid a painful jolt.

To demonstrate the Wimshurst machine with Franklin's Bells, see makezine.com/17/wimshurst.

For further reading, I suggest:

Ford, R.A., *Homemade Lightning: Creative Experiments in Electricity*, 2001

Francis, G.W., *Electrostatic Experiments: An Encyclopedia of Early Electrostatic Experiments, Demonstrations, Devices, and Apparatus*, 2005

See the Wimshurst machine in action at makezine.com/17/wimshurst and on *Make:* television, Episode 103, at makezine.tv/episodes.

MEDICINE MAN GLIDER

By Ryan Grosswiler

BALSA FLIES BETTER

Build a majestic, 5-foot-wingspan model airplane inspired by stick-and-tissue designs of the 1930s, then fly it free or radio-controlled and watch it outclass all the toy-store plastic.

The summer before ninth grade, in 1985, I was stuck at home while my usual friends were away. I started talking with Eddie, the World War II vet who lived across the street, and during those 3 months he taught me the fundamentals of model airplane building. His lifelong hobby, which he had learned during the Great Depression, became my own, and it inspired my career as a flight instructor and developer of UAVs for the U.S. Air Force.

I designed the Medicine Man to reintroduce this largely lost art, drawing on my own experience and discussions with fellow modelers. I made it a glider because gliders are the purest form of flying machine, they're cheaper to build, and they develop piloting skills without the distraction of engine management. It's R/C compatible so you can fly it in city and suburban parks, or you can make a free-flight version for larger expanses. Its 5-foot wingspan makes it stable enough for beginners (larger planes are more stable), yet with the wings dismounted it will fit in a small car. I hope you enjoy it!

Set up: p.111 **Make it: p.112** **Use it: p.119**

Ryan Grosswiler is a USAF civilian test pilot and an incorrigible model airplane geek.

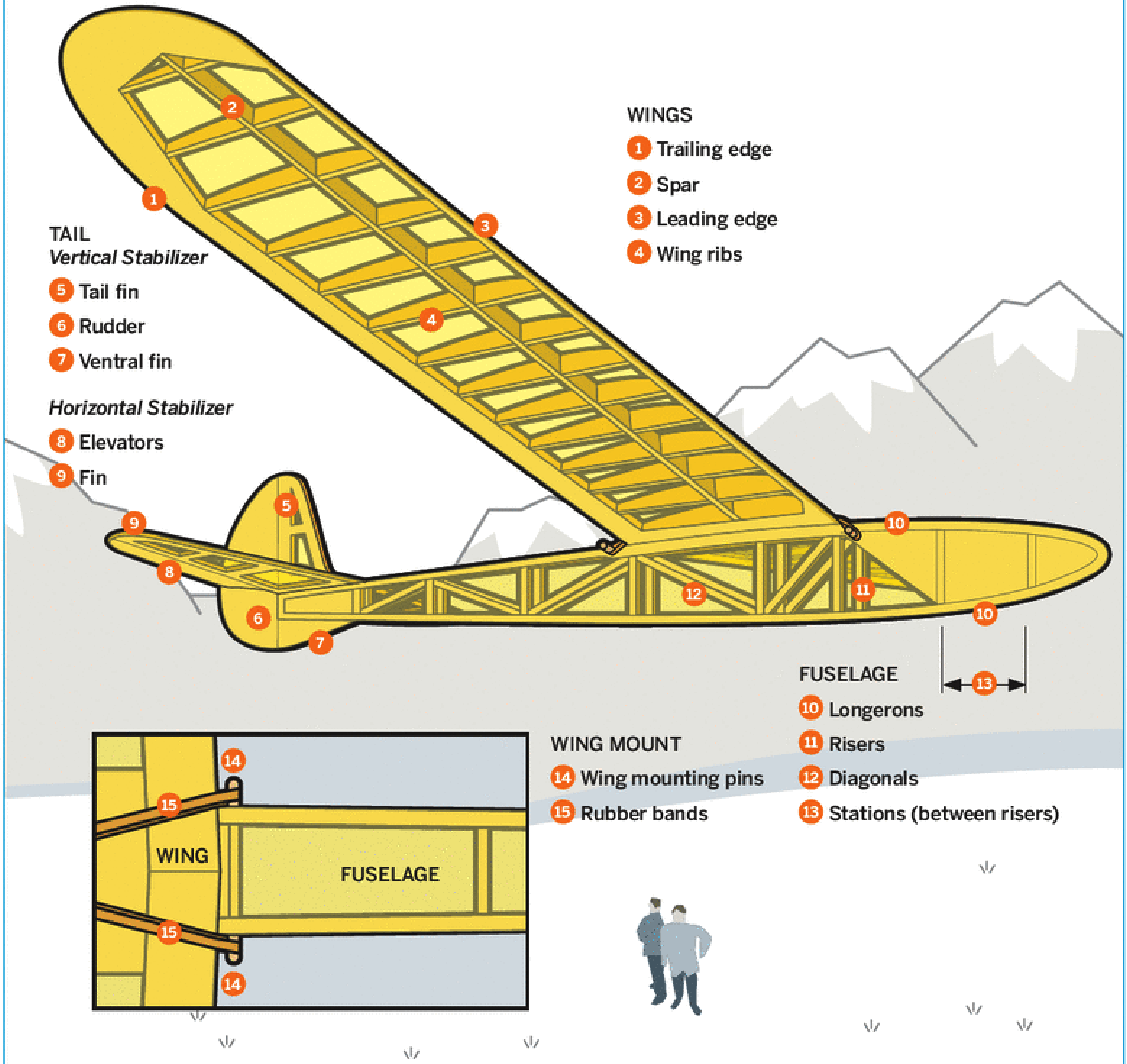
Photography by Ryan and Kristen Grosswiler

FLIGHT FUNDAMENTALS

With its "buildy" structure and light-but-strong design, the Medicine Man is just the plane to cure the modeling world of its instant-gratification doldrums.

Traditional model airplanes are constructed in much the same way that airplanes once were, by building and covering a strong, lightweight wooden frame. Model and full-sized airframes share the same basic parts.

Modelers cut pieces following 1:1 scale patterns on a plan, then glue them together on top of the plan. The larger, curved pieces that dictate the model's overall aerodynamic shape are typically cut out of a flat balsa sheet before any assembly. Smaller pieces are cut from standard-sized sticks called stock, with curves in their edges cut later, after some assembly, so that they blend together smoothly.



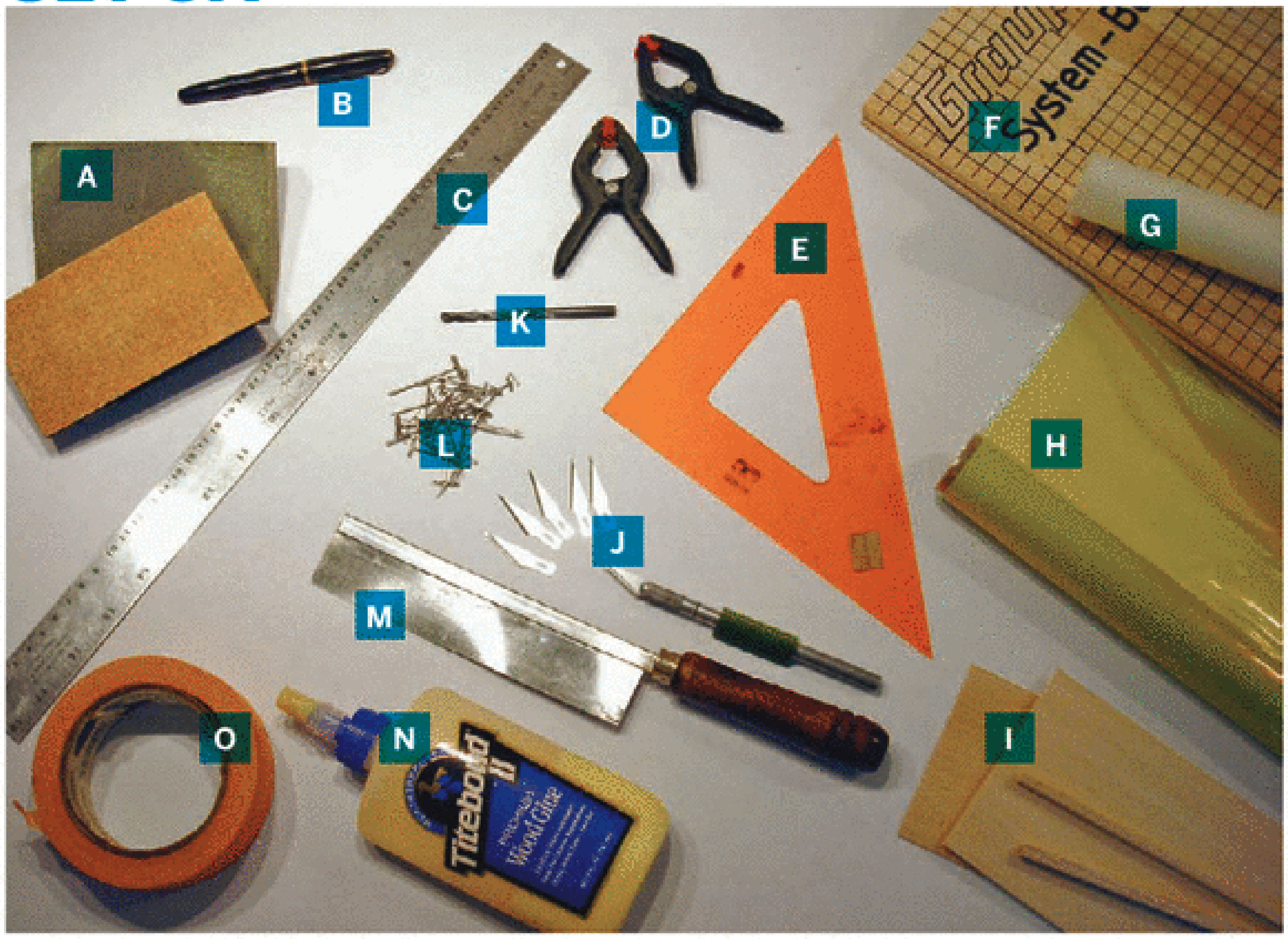
General Building Advice

Before touching knife to wood, study the plan and conduct an "imaginary build" of the model's entire skeleton, visualizing each step. Taking the time to do this first will make the build much easier.

For each section of the plan, you'll follow the same general procedure: pin the plan onto the building board under a sheet of waxed paper. Fit, glue, and pin down the pieces, starting with the perimeter pieces and then filling in, sanding as necessary for a precise fit. Glue pieces only after they're snug; glue should work as a bonding agent, not as filler. Wipe away excess glue with a scrap of balsa — this is easier than sanding it away later. Finally, spray down the assembly with warm water to relax tensions in the wood.

Illustration by Nik Schulz

SET UP.



MATERIALS

[A] Firm sanding block with 80-grit sandpaper for shaping
Soft sanding block with 150-grit sandpaper for smoothing

[B] Ball-point pen

[C] Ruler

[D] Spring clamps (2 or more)

[E] Triangle

[F] Modeling board that you can stick pins into. You can buy from greatplanes.com, but a good working relationship with your local hobby shop is a powerful tool! I use 24"×48" fiber ceiling panels, which building supply retailers sell in 6-packs.

[G] Waxed paper

[H] 2'×6' roll of iron-on plastic covering I used Top Flite MonoKote Transparent (and don't recommend the opaque). Hangar 9 UltraCote is also good. The traditional (and classiest) covering is Silkspan, a heavy-grade tissue paper that you apply with glue and dope, but it's fragile and impractical for landing in dry grass.

[I] Wood You can buy one of my kits, which includes all the wood you need, preprinted with patterns, at realkits.com. Otherwise, you'll need the following, available at Hobby Lobby (hobby-lobby.com) and other hobby shops. Wood quality varies greatly, so first-time builders should seek experienced assistance.
Medium balsa, all 36" long:
- 1/16"×4" sheet
- 3/16"×4" sheet
- 3/16"×3/16" sticks (8)
- ¼"×¼" sticks (2)

Medium balsa block, 1¼"×2"×2¼" or you can laminate a block from 6–7 layers of 3/16" sheet
Triangular cross-section "trailing edge" balsa, 1"×¼"×36" (2)
Hard balsa, ¼"×¼"×36" (2)
Spruce, ⅜"×3/16"×36" (2)
Spruce dowel, 3/16"×5"

[J] #11 hobby knife and spare blades Your best friend throughout construction. Change blades at the end of each phase.

[K] 3/16" drill bit You don't need a drill.

[L] Pack of T-pins or modeling pins $6 for 50 from Hobby Lobby

[M] Razor saw to cut hardwood stock

[N] Wood glue (aliphatic resin) Cyanoacrylate "super" glues are finicky and brittle, and the bottle frequently clogs. Then, when you unclog it, it shoots a stream of glue on a nearby appendage and nearly burns it as it cures.

[O] Masking tape

[NOT SHOWN]

Small weights I just use lead tire weights I find in gutters.

Wood screws, ⅛"×1" (3) with threads that stop at least ½" from the head

Brass strip, ¼"×1/64"×7"

2-channel (or 4-channel) R/C airplane radio with mini servos and a 250–270 milliamp battery pack All must fit in the fuselage, so bring the plan to the hobby shop; I used an old Futaba Conquest radio with Hitec HS-81 servos.

Control horns (1 pack) I used Du-Bro 1/2A nylon control horns, item #107.

Model hinges (1 pack) I used Great Planes Ultra Grip CA Hinges, ¾"×1", item #GPMQ3950.

R/C control pushrods (1 pack) I used 36" Sullivan Flexible Gold-N-Rods, item #S503.

#64 rubber bands (4) or 6 if you use a Hi-Start bungee launcher

Carbon paper (optional) If you don't use the kit, you'll need this to transfer the patterns from the plan to wood.

Plans included with my kit, or you can download and print them from makezine.com/17/model_airplane.

Bar sander such as the Great Planes 11" Easy-Touch, for sanding in notches and making adjustments

Old magazines to cut on

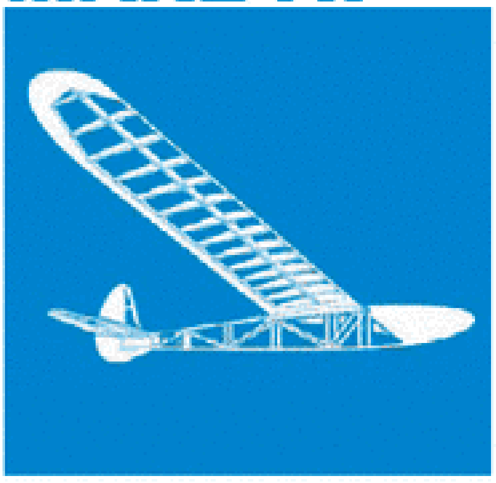
Spray bottle

Iron

Hacksaw blade (optional)

Guidance from an experienced model builder (optional) Highly recommended; one mistake on a model can mean the difference between flying and crashing.

MAKE IT.



BUILD YOUR MODEL AIRPLANE

START **Time:** 3 Weeks of Evenings **Complexity:** Moderate

1. CUT THE SHEET PARTS

This is the tedious part. Do not attempt it while feeling impatient or agitated.

1a. If you're building from plain wood rather than the kit, download and print the plans from makezine.com/17/model_airplane. Trace the patterns onto the sheet using carbon paper, making sure the wood's grain runs in the piece's dominant direction. Mark some pieces multiple times, following the plan. I offer the kit because patterns can be frustrating to a beginning builder.

1b. Cut out each piece using the knife. Cut them slightly oversize, particularly on mating portions, so you can sand them down to a firm fit later. Don't cut through the piece all at once; allow about 9 passes (3 per 1⁄16" of thickness). Where parts are mirrored right and left, cut one and then flip it over to use as a pattern for the other. Old magazines are good for cutting on top of.

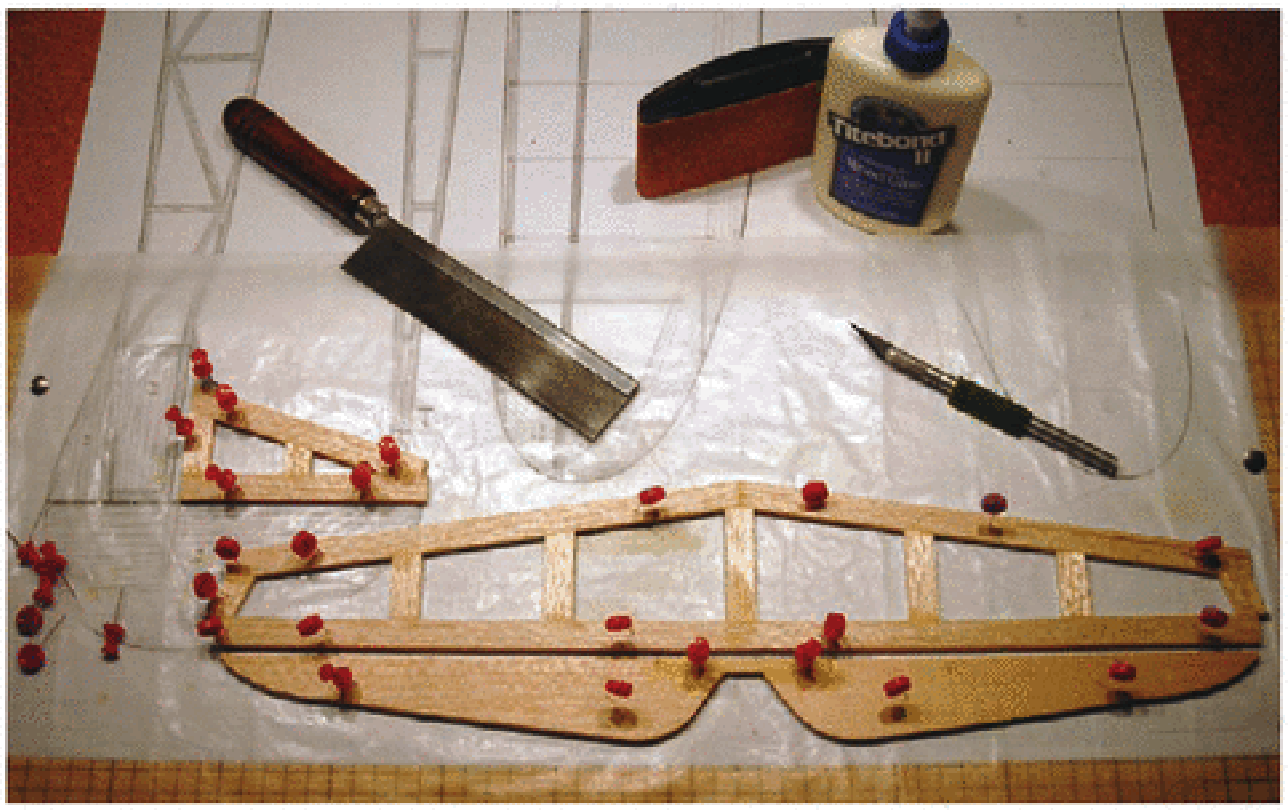
1c. After cutting out each part, number it with a pen. Then trim the parts down and refine their shapes using sandpaper. Save leftover wood.

2. BUILD THE TAIL

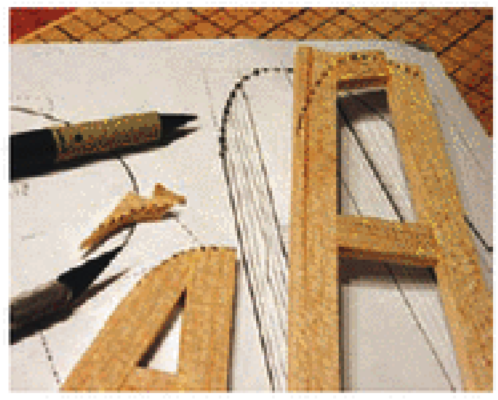
2a. Start with the tail, which is the simplest part. Follow the general building advice on page 110 to trim, fit, glue, and pin down all the pieces. The wax paper will ensure easy removal. Spray with warm water to relax the wood.

2b. Let the tail assembly dry overnight and remove it from the plan.

TIP: **Add 25% rubbing alcohol to the water to relax the wood even more.**



2c. To cut the tail's curved tips, hold the plan up to a light and pin it aligned over the assembly. Lay them down, plan on top, and punch through the paper with a pen at about 1/8" intervals, following the curve to make a dotted line. Remove the plan and make a connect-the-dots cut, following the line. Finish by holding the elevator piece against the fin and blending their combined outline into a smooth curve.



2d. Draw and cut hinge slots for the rudder and elevator, centered as shown on the plan. Use sandpaper to bevel the leading edges of the rudder and elevator along their hinge lines, so they'll rotate freely.

2e. Sand all surfaces to the rounded cross-section shown on the plan.

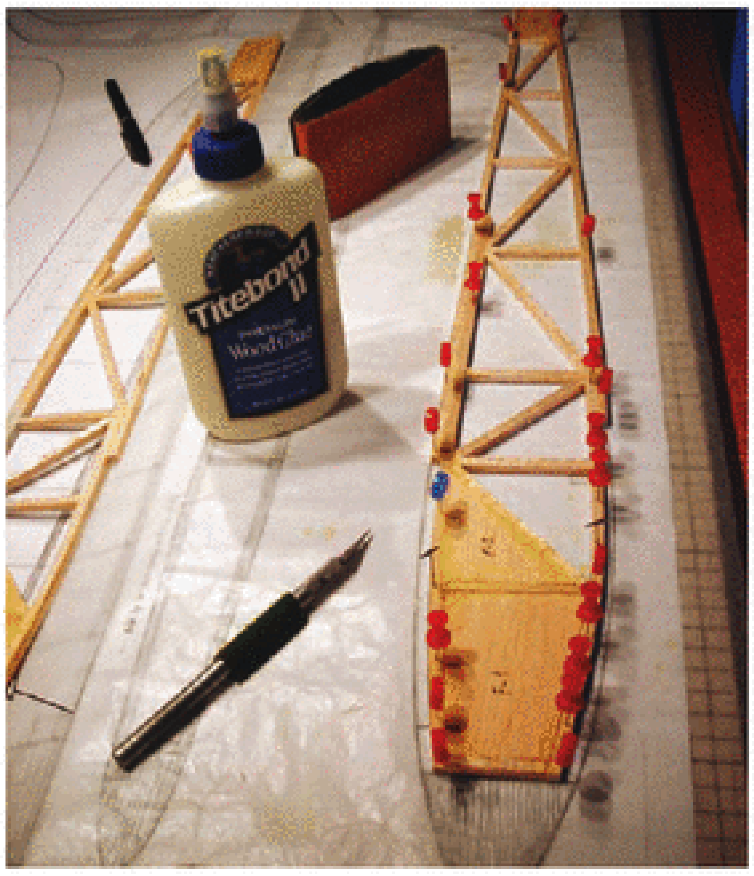
3. BUILD THE FUSELAGE

You'll build the 2 mirror-image fuselage sides one at a time.

3a. For the longerons, soak 2 of the 3/16" square sticks in hot water for 10 minutes to make them more flexible.

3b. Assemble a fuselage side on top of the plan, as you built the tail above. Place perimeter pieces first, then the risers, and finally the diagonals, working in from each end. This sequence gives glue joints a few minutes to set undisturbed.

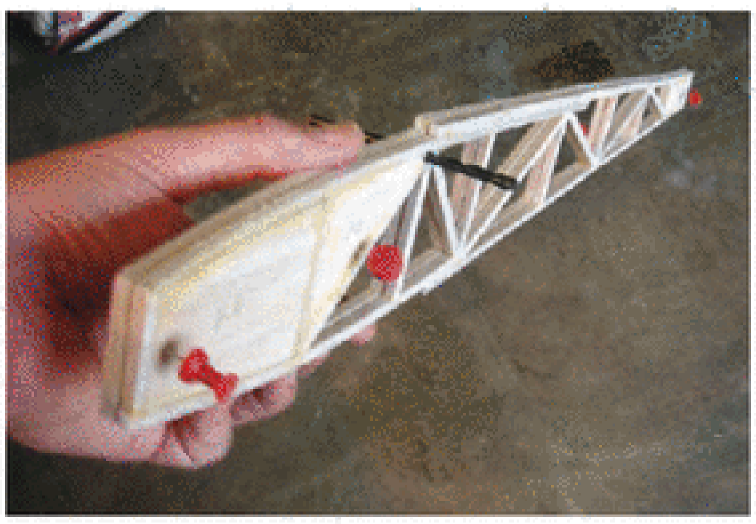
3c. Fit pieces F1, F2, and F3 to each side, spray down the assembly with warm water, and allow to dry overnight.



3d. Remove the assembly from the plan and repeat Steps 3a–3c to build the second fuselage side.

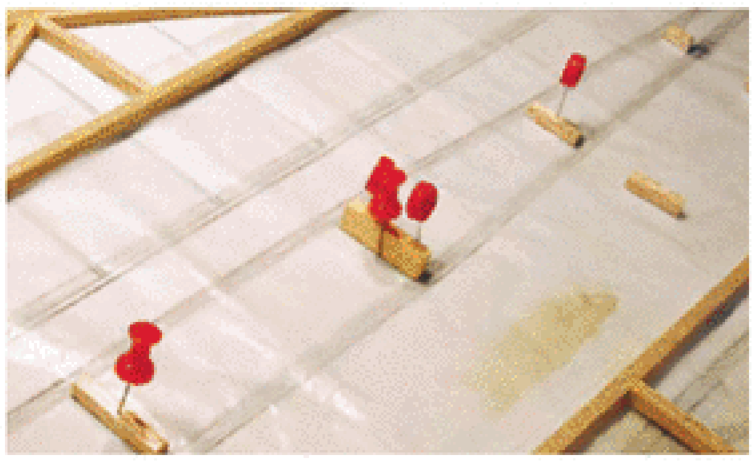
3e. Pin the 2 sides together and sand their perimeters down so they match.

3f. Drill a 3/16" hole in each F2 piece as shown on the plan for the wing mount pegs. You can twist the drill bit through the balsa with your fingers.

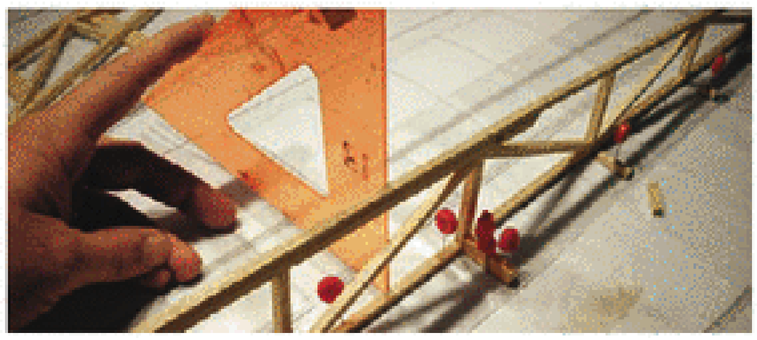


3g. Separate the sides and sand the bevel shown in the fuselage top view into the tail. This makes the 2 sides *handed*, mirror-images rather than identical.

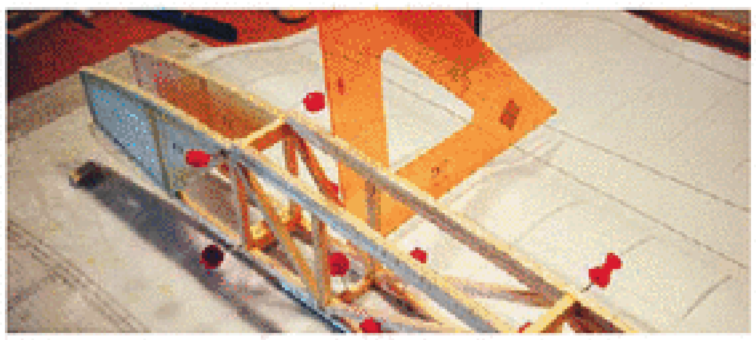
3h. Following the fuselage top view, cut the cross-members for stations 1 through 7. Note that stations 3 and 5 use spruce, and at station 4 the top cross-member sits about ⅜" below the top in order to clear the wing. Pin the bottom cross-members in place on the fuselage top view.



3i. Glue the far fuselage side to the cross-members at stations 4 and 5. Pin it in place through the bottom longeron and make it exactly vertical using the T square.



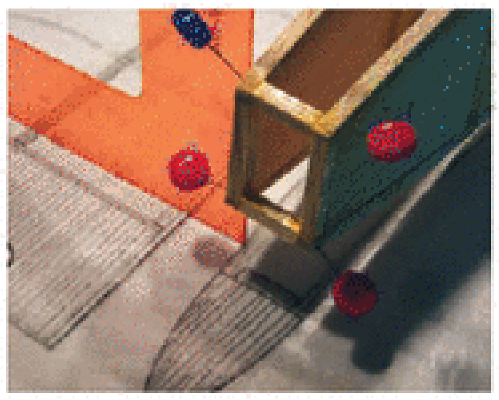
3j. Glue the other fuselage side vertical to cross-members 3 and 4. Add the top cross-members at stations 3 and 5 and re-true both sides, if needed, by adding or subtracting pins. Let dry 1 hour.



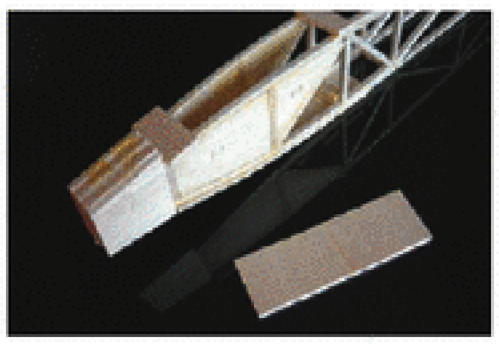
TIP: Spruce cross-members can be pinned into their end grain, and you can daub glue into hard-to-reach locations using a pointy scrap of balsa.

3k. Glue the rear fuselage together in a similar manner, clamping the back (station 9).

3l. Readjust for trueness along both sides. Pinch, glue, and pin the cross-members at the front (station 1). Check that the nose is square, and if it isn't, "persuade" it into position with a heavy, upright object such as a brick or a full bottle. Daub a second coat of glue onto these front cross-members (they're under quite a bit of stress), and allow to dry 1 hour. Spray down the entire fuselage and let it dry overnight, to further safeguard against the dreaded "banana" fuselage.



3m. Glue ³⁄₁₆" sheeting above and below the nose. This will be the equipment bay hatch, so just tack-glue this section. Add top and bottom "slivers" between stations 8 and 9, as shown in the fuselage top view. Sand the front of station 1 flat, and glue on the nose block. Laminate and glue in the tow hook mounting block on the fuselage centerline aft of station 3. Let dry overnight.



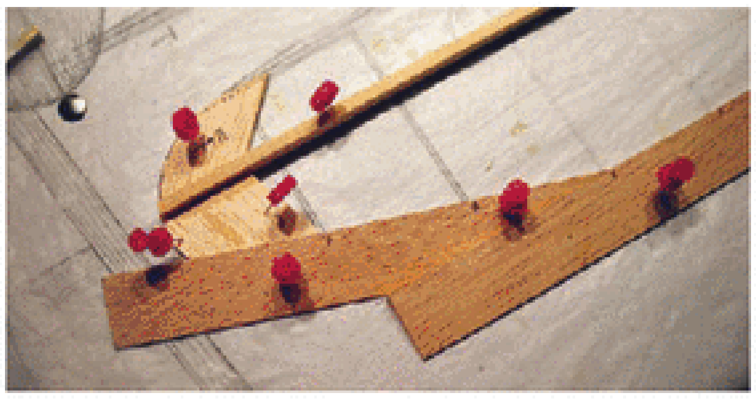
3n. Shape and sand the completed fuselage. You can use the pen trick in Step 2c to shape the nose block. Lightly round the edges of the fuselage, except where the wing and tail will join.

4. BUILD THE WINGS

You can build both wings at the same time if you have room on your building board. Be certain to build a right wing and a left wing, not two of the same!

4a. Pin the 1"×¼" triangular trailing edge sections onto the plan, cutting and fitting the supporting pieces that curve forward at each end. Carefully mark and cut the 1⁄16"×⅛" notches where wing ribs R3–R15 fit into the trailing edge. A knife or razor saw will work, but a loose hacksaw blade is better.

4b. Re-pin the trailing edges to the plan in place. Fit, glue, and pin down the supports, W1 and W2, and the spruce spar, sanding to match the plan if necessary.

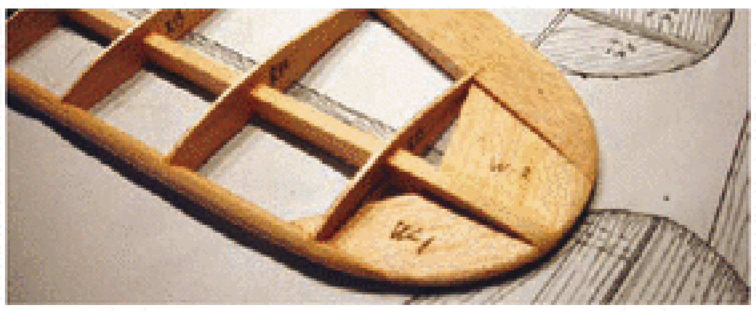


4c. Add (cut, fit, glue, and pin) the bottom center sheet piece that lies aft of the spar and spans ribs R1 and R2 underneath. Add wing ribs R2 through R15. Let the glue set for 30 minutes, then fit and glue the hard balsa ¼" square leading edge into the ribs' triangular front notches. Pin and let dry overnight.

TIP: The ribs' notches may need some sanding, but never force them into place!

4d. Cut the wings' curved tips using the Step 2c method, transferring the curve to the flat undersides. Sand the tips smooth and round.

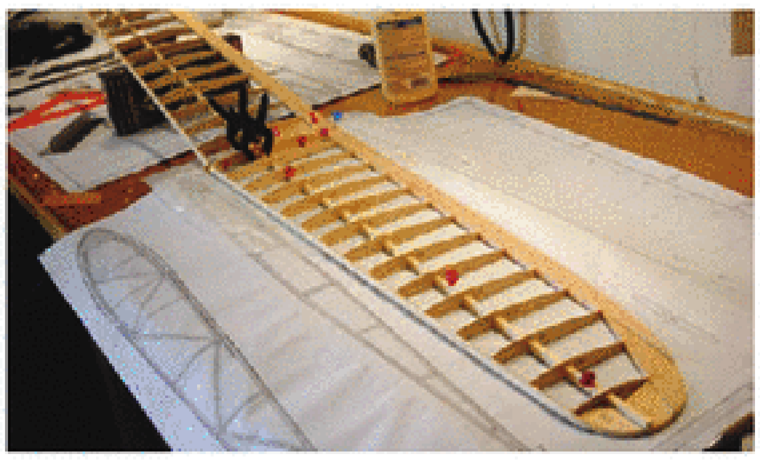
4e. Sand spanwise the leading edge to a uniform semicircular cross-section, as shown on the plan.



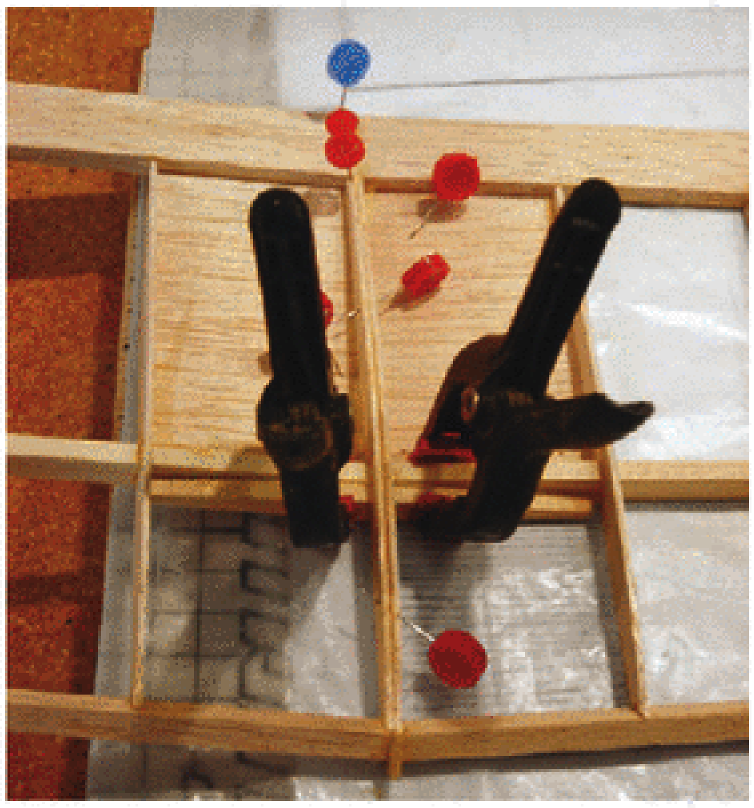
NOTE: A lot of aerodynamic activity occurs at the wingtips, so pay attention and do clean work.

4f. Using the sanding block, sand an approximately 3° bevel into the wing roots where they will mate. Be very hygienic with making clean joints here: the wing center section absorbs more flight stresses than any other part of the aircraft!

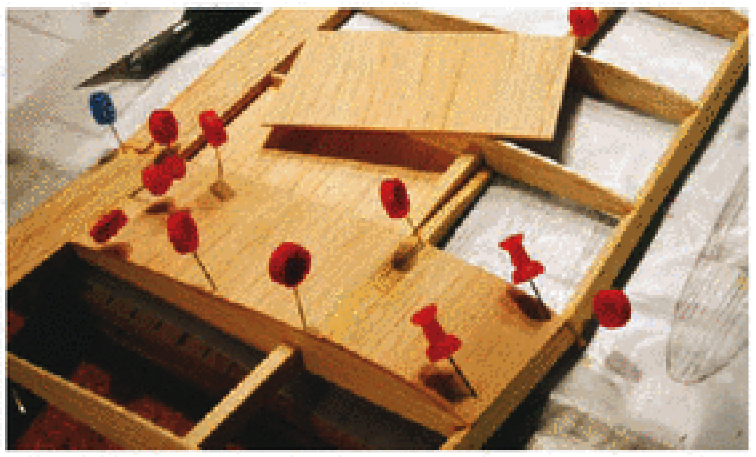
4g. Pin one wing back to the plan and join it to the other wing by gluing together the inside edges of the center sheet pieces. Use a hardcover book or something similar to prop the opposite wing tip 6½" above the building board.

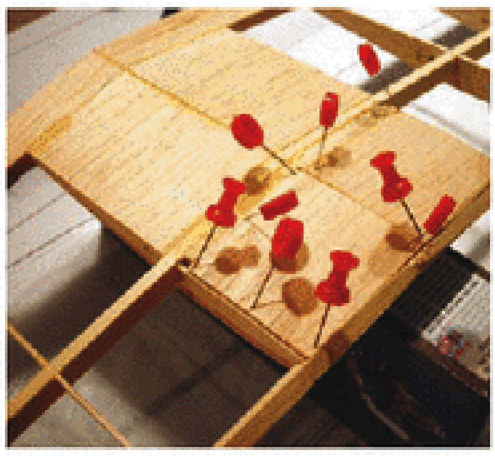


4h. Spread glue generously over one side of the dihedral brace and clamp it into place, binding the 2 spars together. Add the R1 ribs, ensuring they assume an angle symmetrically between the ribs on either side. Let dry overnight. I accidentally cut the inside ends of the leading edges too short, so I filled the gap in between with a bit of balsa.



4i. Use 1⁄16" balsa to sheet the topside of the wings' center sections, then turn the wings over and add the bottom center sheet piece forward of the spar. Allow to dry.





5. TEST ASSEMBLY

5a. Use a foam-block sander to gently remove burrs and hard edges on all external surfaces, except for the hard corners where the wings and tail will mate to the fuselage.

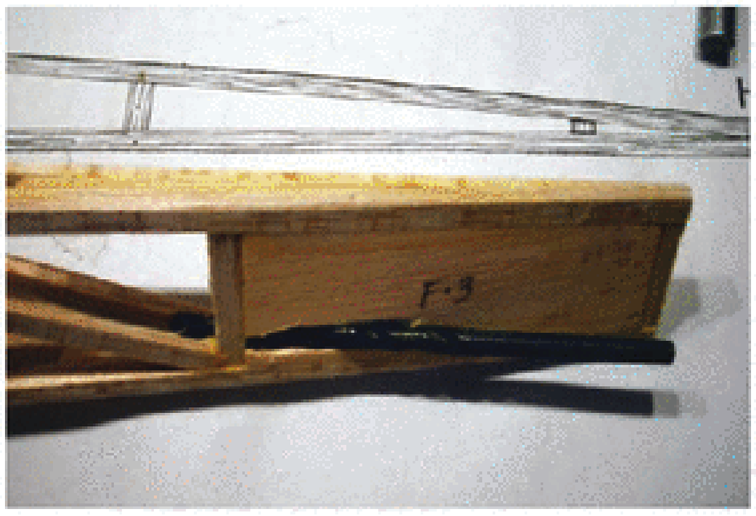
5b. Cut two 1"-long pegs out of the spruce dowel and round the ends. Insert the pegs into their holes in the fuselage. Mount the wings to the fuselage with rubber bands, using the pegs as end posts. Check for straightness both from the top and (especially) from plumb center rear, sanding where the wings meet the fuselage if there's a discrepancy.

5c. Pin the tail components temporarily into place to check the fit, making small adjustments where necessary.

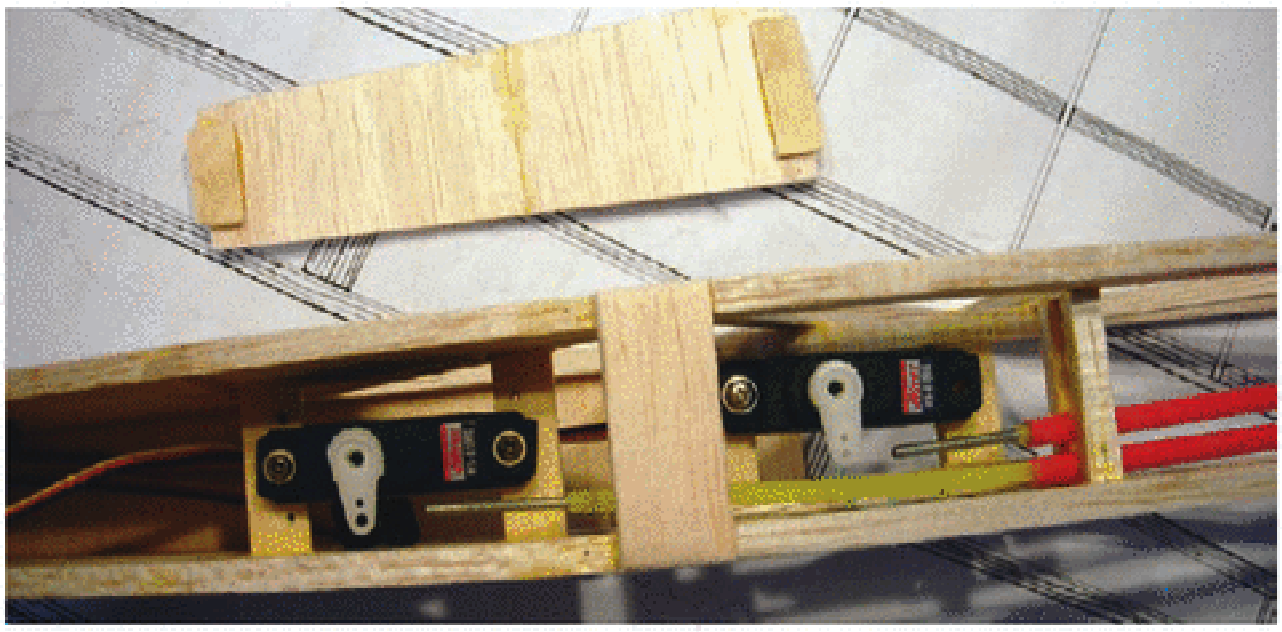
5d. Step back and admire your work. Hey, I built that! Have a beer and just check it out. This is a moment to be savored; allow yourself to do so.

6. EQUIP IT FOR R/C (OPTIONAL)

6a. Drill holes in the fuselage rear for the 2 pushrods to exit.



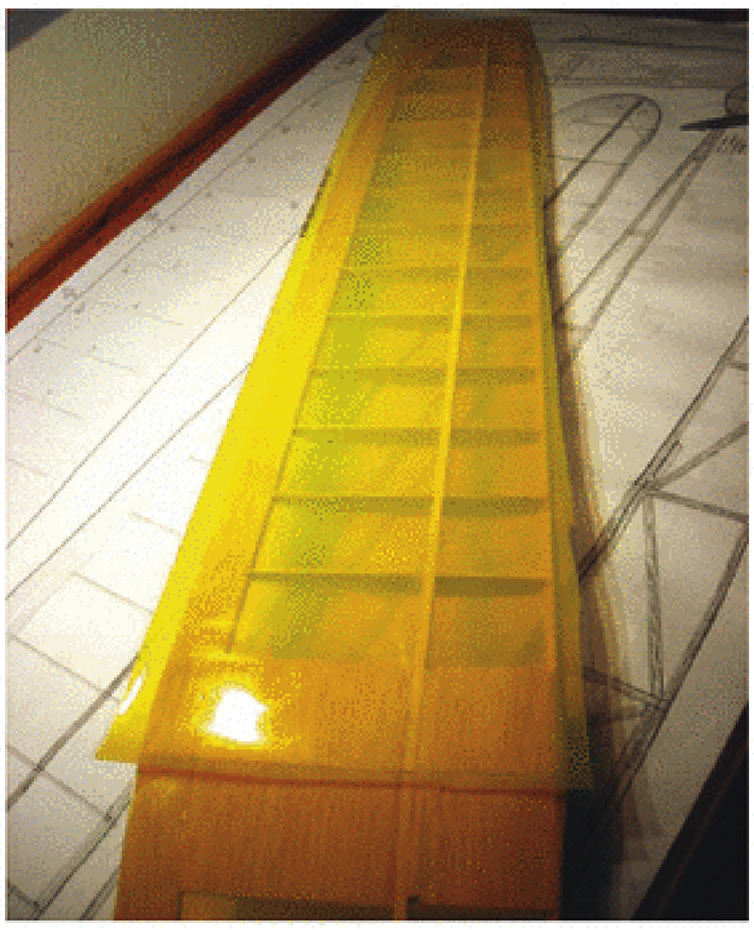
6b. Mount 2 servos approximately where shown on the plan, using 3⁄16"×3⁄8" spruce to conjure up a support framework for your system. Mount the pushrods to run to the servo heads unobstructed.

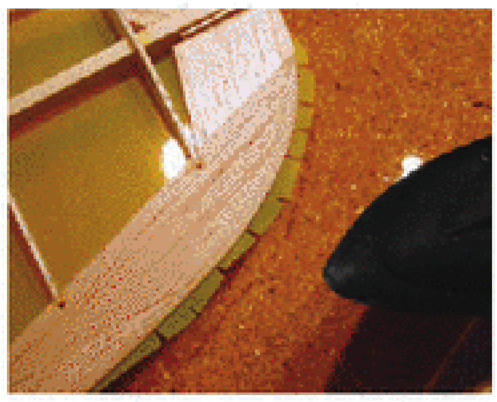


7. COVER IT

Follow the instructions that come with your covering material. A single 72" roll will cover the entire model if you plan ahead. Here's the usual procedure for iron-on plastic.

Cut out and lay a piece of covering over a section of the airframe. Smooth out the covering. Use a 350°F iron to first tack down the corners, then seal down the perimeter. Shrink and smooth the entire section by working the iron gently over the surface. Repeat for all model surfaces.





TIP: Cut a fringe into any curved edges to seal them down without wrinkles.

8. FINAL ASSEMBLY

8a. If you're using R/C, mount the control horns and hinges on the rudder and elevator. Locate the hinge slots you cut in Step 2d and re-cut them through the covering. Wood glue won't stick to plastic, so you need to remove the covering anywhere you're bonding to. For a model this size, I cut the hinges in half lengthwise.

8b. Glue the wing-mount pegs in place in the fuselage. Attach the wings with rubber bands.

8c. Glue the elevator to the tail fin, and glue this assembly in its mount between stations 8 and 9. Attach it to the fuselage with 1 pin centered in its leading edge. While the glue is still wet, center it so each tip measures the same distance to a common midpoint centered on top, and then pin down the trailing end.

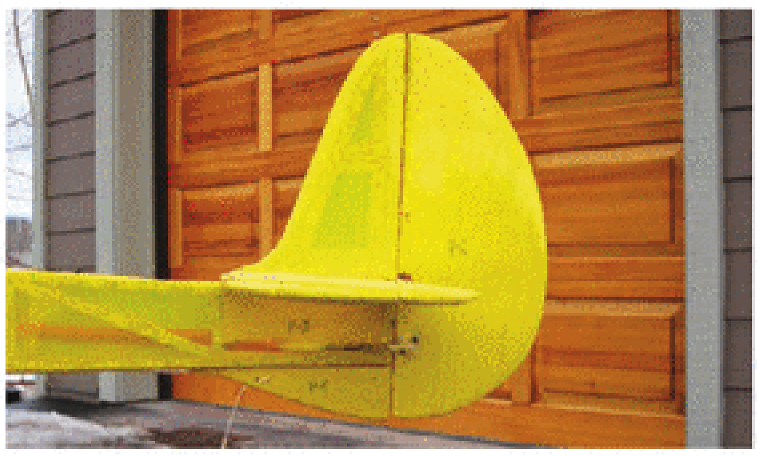
8d. With the glue still wet, adjust and pin the rear stabilizer so that it lines up symmetrically below the wings. Let it dry 1 hour. Glue and pin the vertical fin centered in place, and use a T square to ensure that it's perfectly perpendicular. Let it dry 1 hour.

8e. Trim some hinge material, then glue it to attach the rudder to the vertical fin. Glue the ventral fin to the fuselage and use more hinge material to connect it to the bottom of the rudder. Run a bead of glue around all fixed joints on the model. Check for square along all aspects, and let dry undisturbed overnight.

8f. IMPORTANT! To adjust the wing "washout" for flight at low glider speeds, the trailing edges of the wing tips need to be twisted upward. Prop up the wing trailing edges with scraps of balsa, and then tape or clip small weights to the other 3 corners of each wing. Iron out the resulting wrinkles in the covering, and allow to cool to "lock" the new angle in place.

8g. For R/C, install the radio receiver and battery in the nose, following the instructions. For gliders, I skip the switch and plug the battery straight into the receiver before flying. I had to take my older receiver out of its case and wrap it in plastic to get it to fit, but a modern mini receiver should fit with no problem.

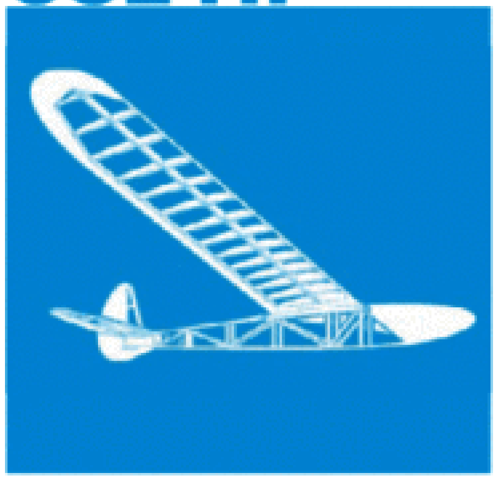
8h. For R/C, connect pushrods to the servo arms, center the trim switches on the transmitter, and turn on the radio. The servos will come alive and center themselves. Install the included hardware to hold the pushrods, then follow them back to place and attach control horns to the elevator and rudder. Connect the rods to the horns. Move the radio's stick to make sure nothing hits anything else.



8i. For the tow hook, drive a 1" screw into fuselage, following the plan. For the landing skid, use 2 more screws to attach the brass strip under the fuselage, then sandwich rolls of masking tape above the middle to make the strip spring. Ensure that the radio is fully charged, and mount the wings to the fuselage. That's it!

FINISH X

NOW GO USE IT »



I'M MEDICINE MAN, FLY ME.

On a day with no wind, find an open area at least 500' square, ideally with tall grass. Established R/C flying sites are good — you're more likely to find help and probably won't run into frequency problems. Finding an experienced flier to help you start out greatly increases your chances of success. But be prepared for stares and incredulous remarks at your hand-built airplane.

PREFLIGHT CHECKLIST

1. **Check flight controls.** Moving the control stick forward and back should make the elevator move down and up. The rudder should match left and right stick movements.
2. **Check center of gravity.** Balance the airplane on both index fingers at the wing root where indicated on the plan. The model should hang balanced, with the fuselage level. For your first flight, you'll probably need to add about 1oz into the nose compartment. I cut lead tire weights down to the right weight using pliers. Do not fly the airplane until it balances level or slightly nose-down.
3. **Inspect the structure** by gently tugging at different parts. This is why I prefer transparent coverings: they make structural problems much easier to spot.
4. **Give the glider a gentle, level toss.** It should fly straight and land level about 50'–75' ahead. If it turns left, detach the rudder clevis and adjust the rudder right a bit, and vice versa. If it tends to pitch down, nose to the ground, adjust the elevator upward.

FLIGHT

Spend a few minutes imagining the flight and your control inputs. For a glider, think of the elevator as a speed control: back means slow down, forward means speed up. Left and right are the same as you'd expect, *except when the model is flying toward you!*

You can launch your glider with kite string and some spirited sprinting, or less foolishly with a Hi-Start elastic towline, which catapults your plane into the sky.

Think of flying a glider less as controlling it and more as making suggestions. If you run into trouble, let go of the controls. Medicine Man is inherently stable, and will right itself if disturbed, with enough altitude.

At first, restrict your control inputs to simply keeping the glider within about 250' of you. Set the input on the stick, wait for the glider to respond, and then let go. When the plane gets within 20' of the ground, just make sure its path 500' ahead is clear, and let it land itself.

Next, practice making figure eights from both directions. Notice that you need to hold up a bit of elevator with each turn, and that this amount increases as you use more rudder. This is called *control coordination*. Strive to use it to keep your turns as level as possible.

Thermalling: Gliders can stay aloft indefinitely in *thermals*, rising columns of warm air that you find over parking lots and plowed fields. Their diameter and strength varies, but you'll know you've hit one when your model starts climbing without a change in attitude. Circle to stay in it.

Sloping: You can sustain a glider aloft in the updraft where wind flows over a slope by flying back and forth parallel to the slope, always turning *into* the wind. This is a more advanced technique.

Further Reading

Model Glider Design by Frank Zaic (1944) is a classic book, available at hrunway.com.

+ Download the plans for Medicine Man and read more about model aviation at makezine.com/17/model_airplane.

THE BEATBEARING TANGIBLE RHYTHM SEQUENCER

By Peter Bennett

STEEL PULSE

The BeatBearing is an exciting and intuitive way to make music. Move the balls on a grid, and you change the beat. Music sequencing couldn't be simpler.

Like countless other musicians, I use a computer to create beats and sequence them into mixes. Pointing and clicking with a mouse is fine for a studio, but what about when you want to sequence rhythms in live performance? Or collaborate with others on a shared rhythm? These questions led me to develop the BeatBearing sequencer.

So what is the BeatBearing? Simply put, it's a computer interface that takes the pattern of ball bearings placed on a grid and translates it into a rhythm. The fun part is that the whole interface is transparent and sits on top of a computer screen, allowing graphics to be shown from directly underneath. The screen highlights which beats are switched on, and what sounds they're playing, as a red line sweeps across the screen to show the current time position. The system is controlled by an Arduino microcontroller, and the screen is an old computer monitor cradled in a milk crate.

Photography by Peter Bennett

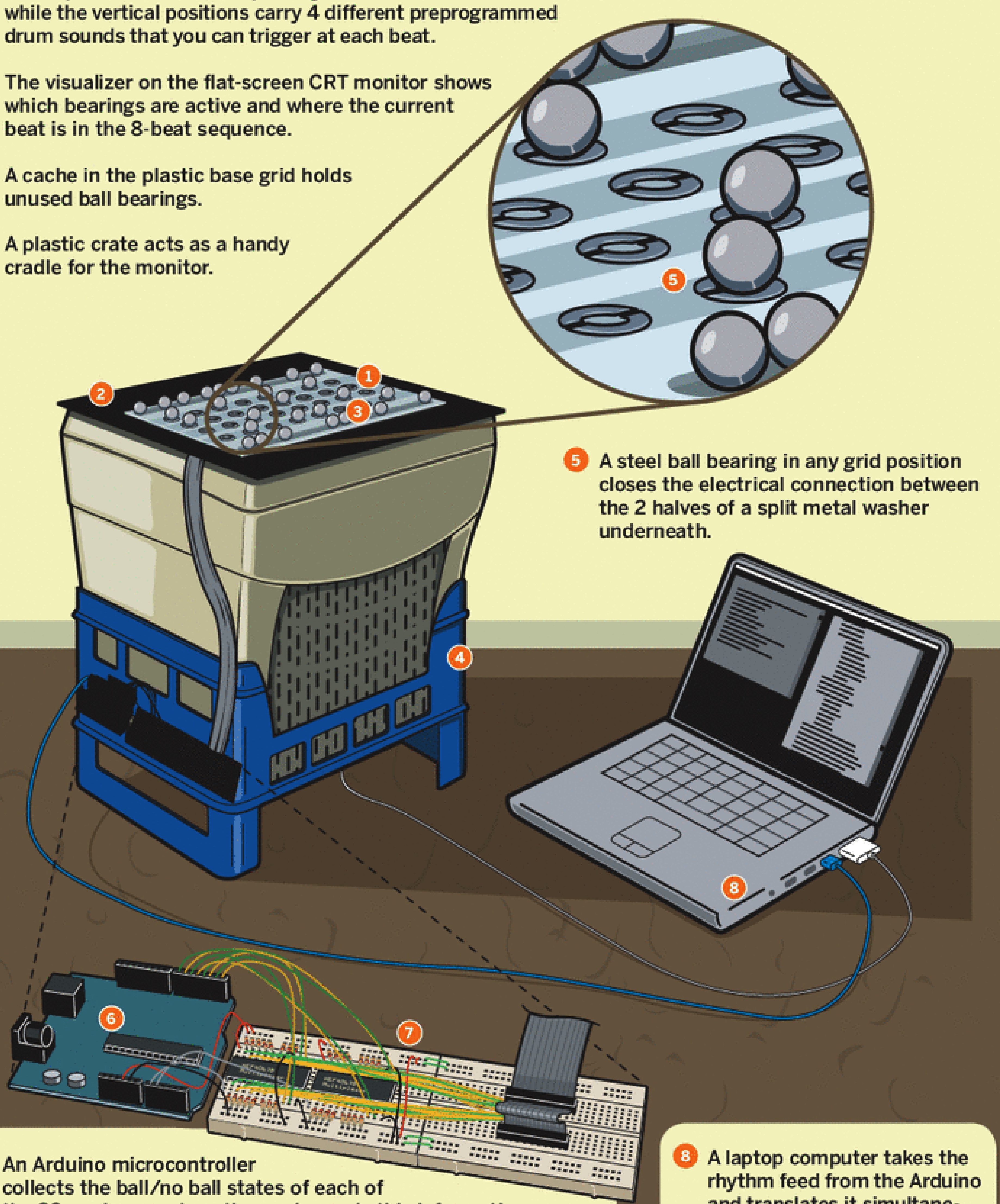
Set up: p.123 Make it: p.124 Use it: p.129

Peter Bennett (pete@petecube.com) is a Ph.D. student in the Sonic Arts Research Centre at Queen's University Belfast in Northern Ireland, where he's researching the design of digital musical instruments. He has previously studied cybernetics, digital-media art, and design, while maintaining a constant interest in musical performance and composition.

MAKING BEATS WITH BALLS

The BeatBearing plays rhythms based on ball bearing placement.

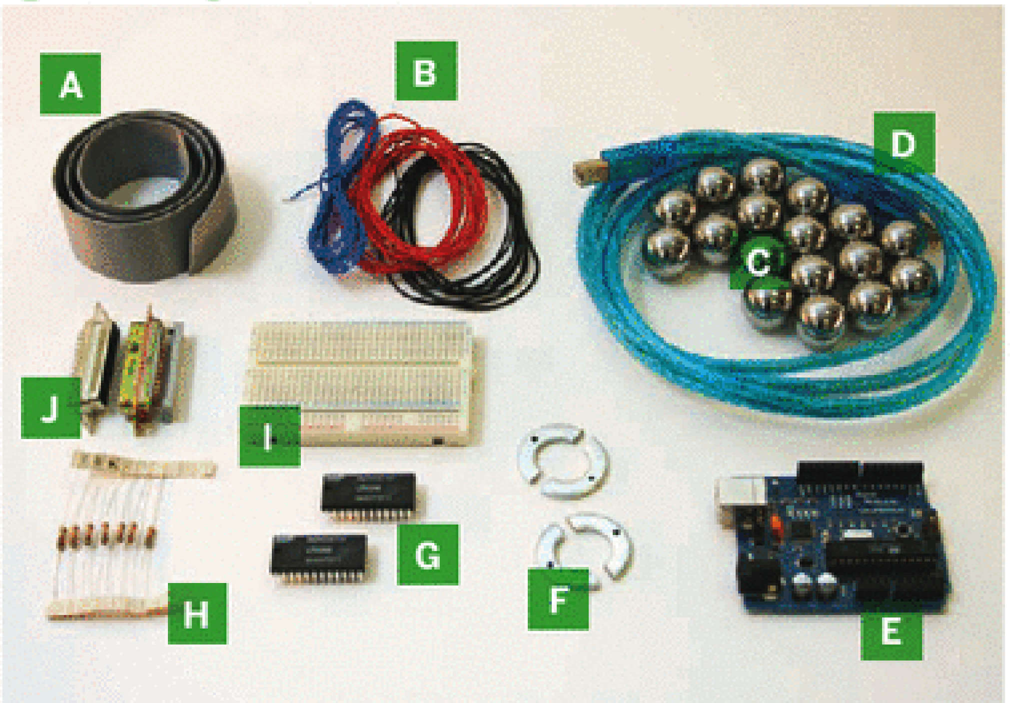
1. A 4×8 grid of transparent plastic acts as a control surface. The horizontal positions define a repeating musical measure with 8 beats, while the vertical positions carry 4 different preprogrammed drum sounds that you can trigger at each beat.
2. The visualizer on the flat-screen CRT monitor shows which bearings are active and where the current beat is in the 8-beat sequence.
3. A cache in the plastic base grid holds unused ball bearings.
4. A plastic crate acts as a handy cradle for the monitor.

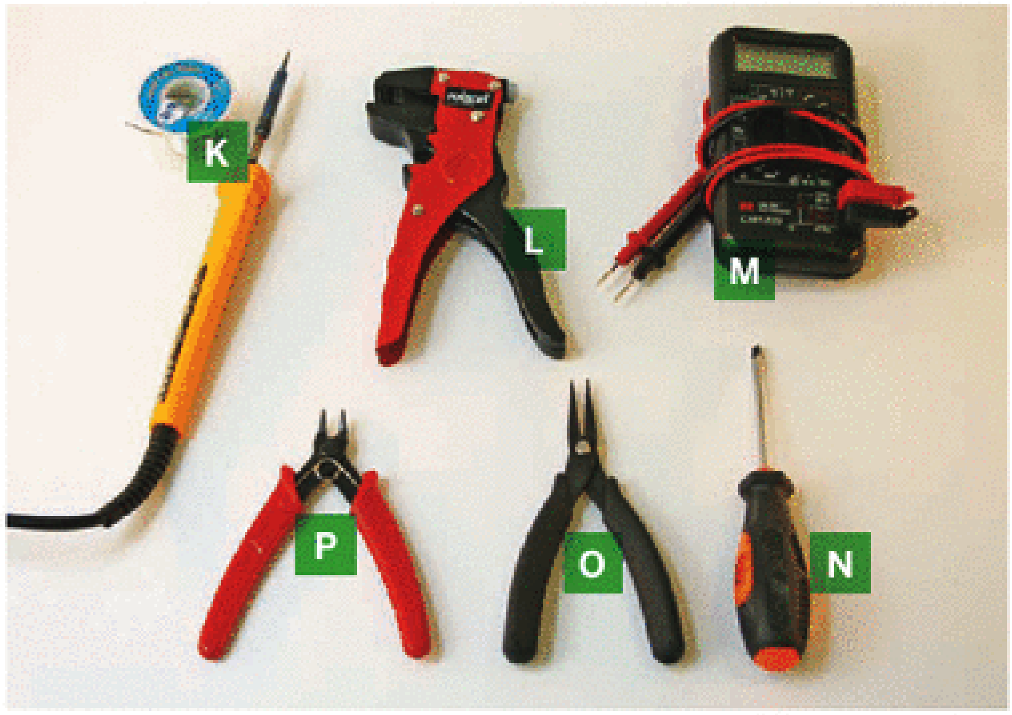


5. A steel ball bearing in any grid position closes the electrical connection between the 2 halves of a split metal washer underneath.
6. An Arduino microcontroller collects the ball/no ball states of each of the 32 washers and continuously sends this information to a laptop computer via USB cable.
7. Two multiplexer chips let the Arduino read values from all 32 washer switches, receiving them in sequence through 2 analog input pins.
8. A laptop computer takes the rhythm feed from the Arduino and translates it simultaneously into both MIDI sound data and visuals for display on the screen underneath the grid. The laptop also runs standard software to convert the MIDI into sound.

Illustration by Tim Lillis

SET UP.





MATERIALS

[A] 20-wire ribbon cable about 2 meters long, or two 40-wire IDE cables, one with a connector in the center.

[B] Insulated solid-core hookup wire in 3 colors to help differentiate ground, power, and signal lines

[C] Ball bearings (32) Mine were 20mm. Use chrome-plated, or they will rust.

[D] USB cable

[E] Arduino Diecimilia microcontroller board It's available from makershed.com. The new Duemilanove board should also work.

[F] Washers (32) to comfortably seat ball bearings; mine were 30mm outer diameter (OD), 17mm inner diameter (ID).

[G] Multiplexer chips, NXP (Philips) HEF4067B (2)

[H] 10kΩ resistors (32)

[I] Solderless breadboard

[J] D-sub (25-pin) connectors, matching male/female pairs (2) Make sure they fit together, that one has solderable pins, and that the other can crimp a ribbon cable. If you're using IDE cables, you'll need three 2×20 male headers to fit.

[NOT SHOWN]

Laptop computer The project software is written both in Processing and on the Arduino, so it's cross-platform.

Flat-screen CRT monitor You can get one cheap or even free these days. Make sure the screen isn't curved!

Solid sheet of transparent acrylic (plexiglass) or polycarbonate cut to the dimensions of the CRT monitor screen. I used 15mm thick.

Screws and matching nuts (64) Size the screws so they fit through small holes drilled in the washers and pass through the clear plastic sheet; I used M2 (2mm diameter).

Solder tabs (64) One end is a flat tab for soldering onto; the other has a hole that should fit the screws.

Scrap corrugated cardboard around 10cm×25cm

Duct tape

Plastic milk crate or some other way to hold the monitor horizontal. Improvise, or construct a simple frame from wood.

Black poster board cut to the dimensions of the CRT monitor screen

TOOLS

[K] Soldering iron and solder

[L] Wire stripper

[M] Multimeter for checking connections

[N] Screwdriver

[O] Needlenose pliers

[P] Wire cutters

[NOT SHOWN]

Band saw

Vise

Drill press and drill bit to match the screw size, in my case 2mm

Metal file

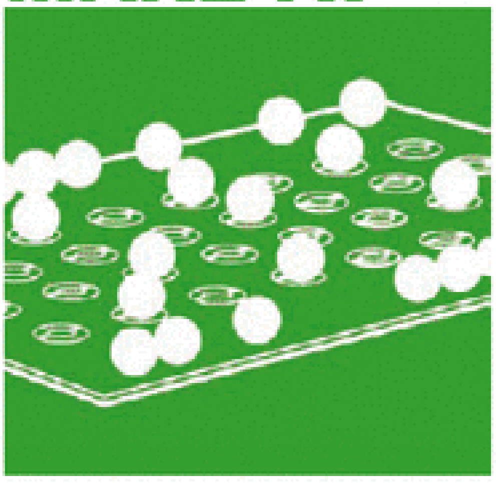
Router

Milling machine (optional) replaces the 5 tools preceding if you have access to a friendly engineering department

Ruler and straightedge

Clear glue and 5mm transparent plastic (optional) instead of the ruler and straightedge. Same type of plastic as the 15mm sheet above.

MAKE IT.



BUILD YOUR OWN BEATBEARING TANGIBLE SEQUENCER

START **Time:** Couple of Weekends **Complexity:** Moderate

1. SPLIT THE WASHERS

I had these washers split and drilled by a milling machine at Queens University Belfast's friendly engineering department, but you can achieve similar results using a band saw and a drill press as follows. Alternatively, you can bypass the washers altogether and make ball-bearing contact switches more easily out of bent wire, or with screws or metal pins arranged in a triangle or square. See makezine.com/17/beatbearing for sketches.

1a. Clamp and drill the washers in a drill press, centering the 2 small holes on opposite sides of each.

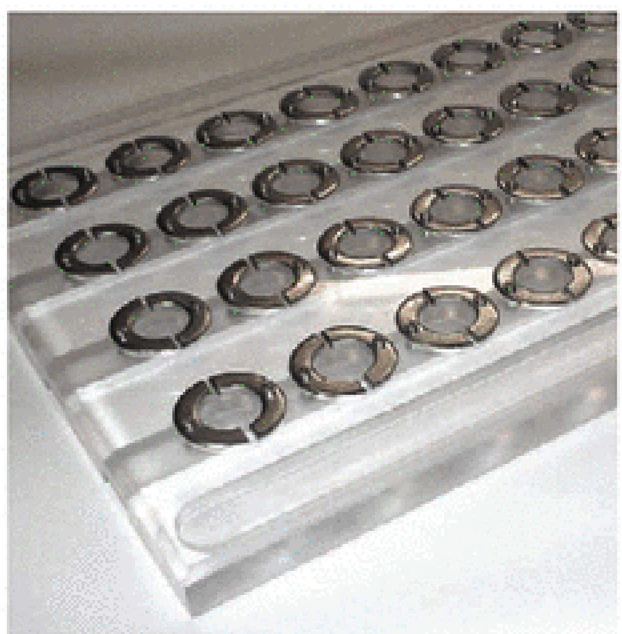
1b. Use a band saw to cut each washer in half, perpendicular to the axis formed by the 2 holes. It's easier if you clamp or screw the washer to a jig of scrap metal or wood.

1c. File off any sharp edges. The washers will be exposed to fingers when installed on the instrument.

2. CONSTRUCT THE TRANSPARENT BASE

Like the washers, the base can be CNC-milled or made by hand. Mine was milled; I sent a CAD file to the QUB engineering department to manufacture (see the plan at makezine.com/17/beatbearing). You can also drill and rout the base as described here, or else bypass the machining entirely by gluing thin horizontal strips of plastic to elevate the washers and make channels for the wires and spare bearings.

2a. Cut the transparent acrylic sheet to just cover your CRT screen.

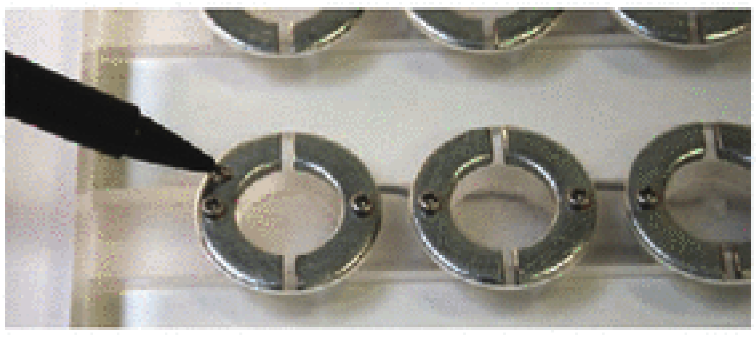


2b. For each washer, following a regular 4×8 grid, drill a hole through the plastic sheet to match the washers' inside diameter.

2c. Countersink another straight-sided hole for each washer that fits its outer diameter and thickness, so the washers will sit flush with the surface of the plastic.

2d. Drill 2 more holes through the plastic for each washer, positioned to align with its screw holes.

2e. On the underside of the base, cut straight channels about 5mm deep running horizontally through each row of holes for the wires. If you're drilling by hand, use a router along a straightedge fence.



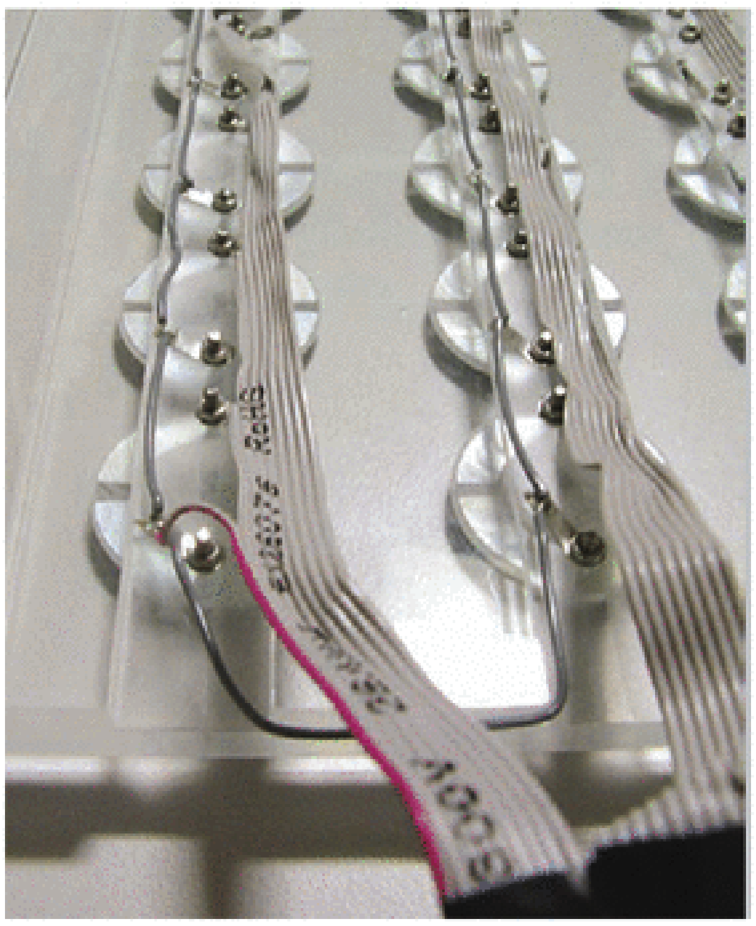
2f. Cut 2 more horizontal channels on the topside of the base, along the top and bottom. These channels will house balls that aren't currently in use.

2g. Attach the washer halves to the transparent base using screws, holding 1 solder tab above each nut on the underside.

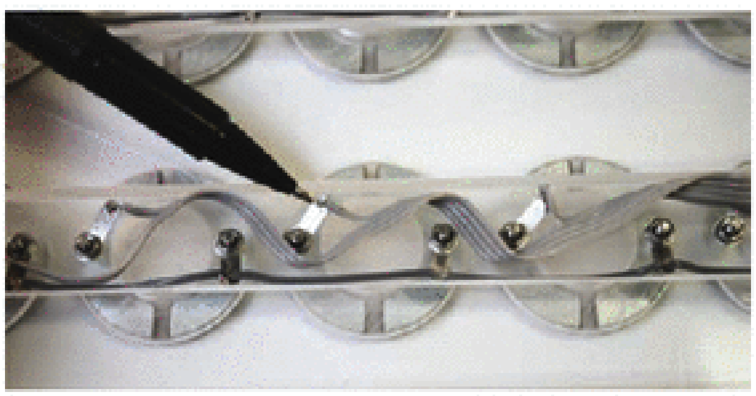
3. WIRE THE BASE

3a. Cut the ribbon cable in 2. With each half, carefully peel the red wire along one side away from the rest of the cable, separating it down to a length matching the grid's width. These will be the ground wires. With 40-wire IDE cable, just use 1 cable.

3b. One side of each washer connects to ground, so run the ground wires from the ribbons down 2 of the rows, soldering each wire to the tabs on all washer halves facing the same way. For the other 2 rows, cut some spare wire and solder it to the remaining ground tabs and to the ground wire.



3c. For each row, peel away and solder 8 more ribbon wires to the other washer halves, trimming them progressively shorter. Each ribbon will have 3 wire connections unused.

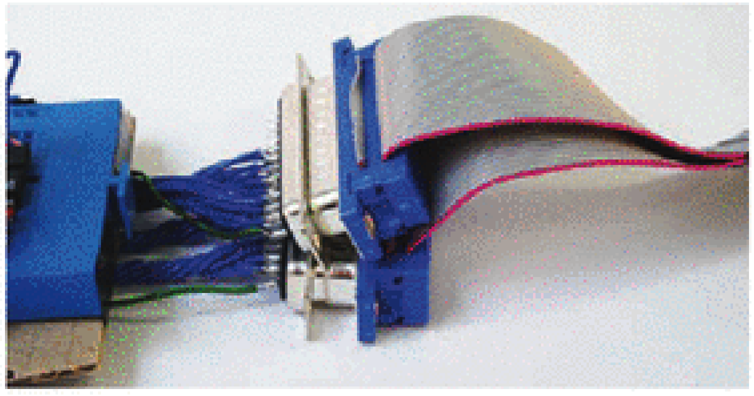


3d. Crimp a D-sub connector onto the other ends of each ribbon, lining them up so that the teeth engage properly with the wires inside. These connectors let you disconnect the grid base from the rest of the electronics.

4. BUILD THE ELECTRONICS

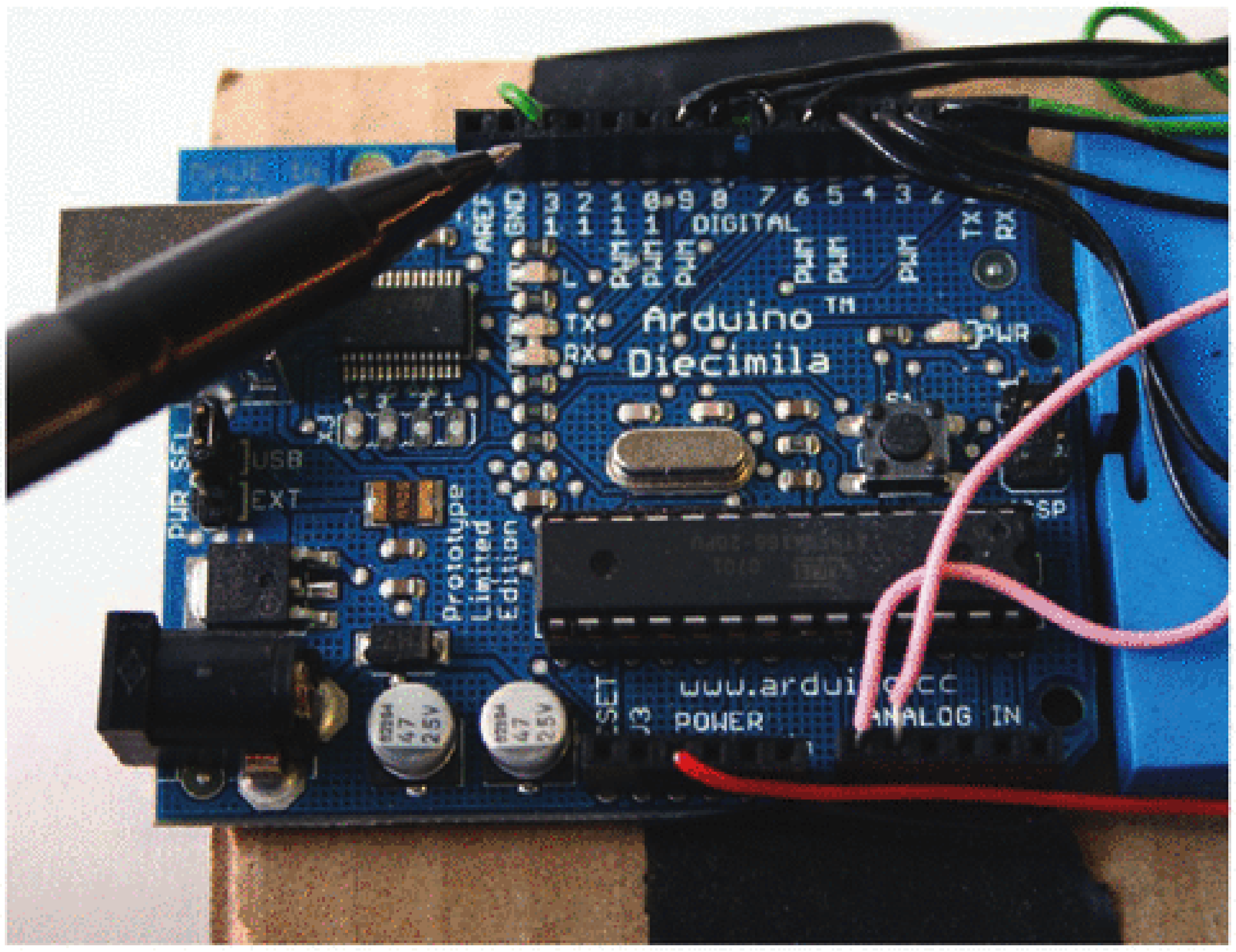
NOTE: For all wiring, follow the schematic at makezine.com/17/beatbearing.

4a. Solder wires about 10cm long to the 2 solderable D-sub connectors. Use a contrasting color for the ground wires, and don't bother with the 4 unused pins.



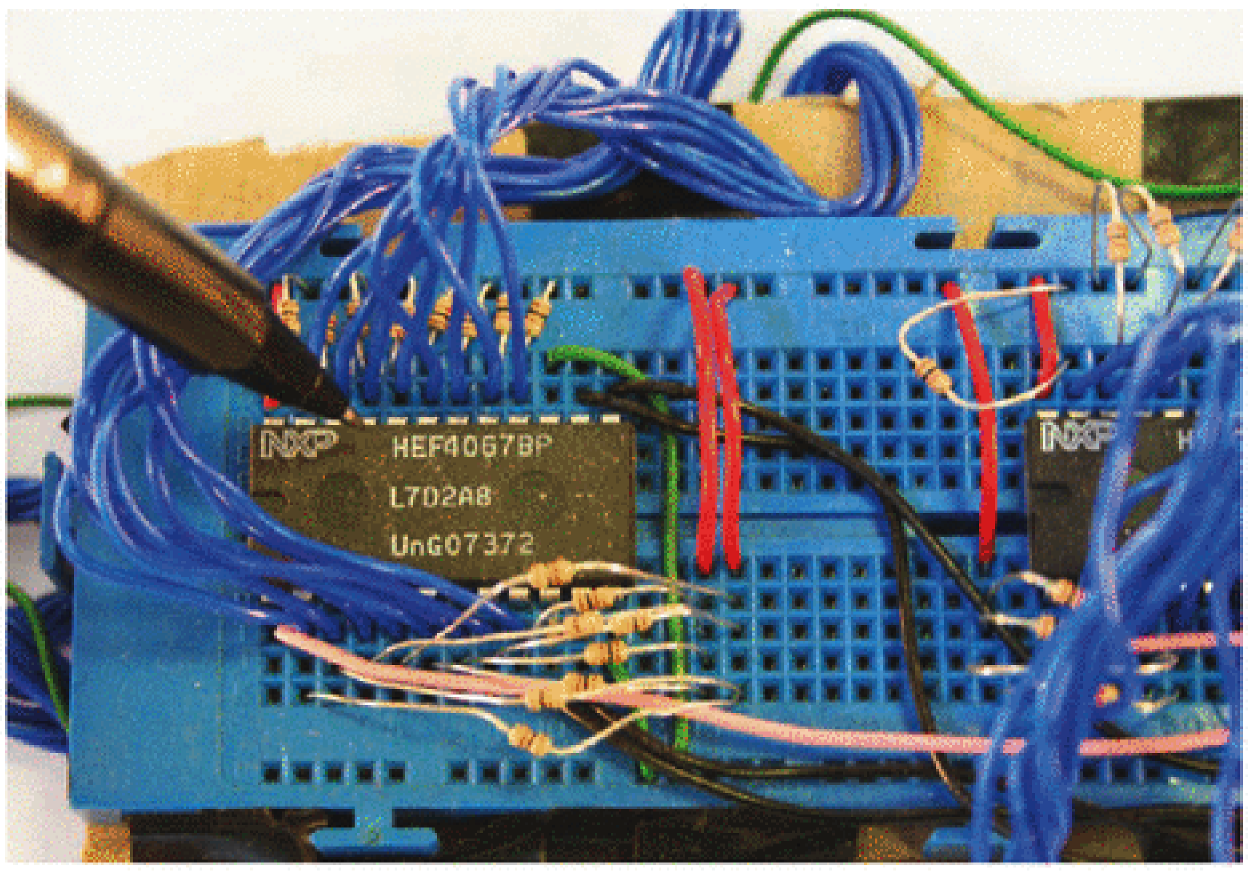
NOTE: With IDE cables, you don't need to solder. Plug the 3-connector cable's center connector and one end connector on opposite sides of the breadboard trench, offset by 1 hole (see diagram online).

4b. Connect the 4 ground wires from the D-sub connectors to 1 edge of the solderless breadboard, establishing a ground rail. Use another wire to connect this rail to the Arduino's ground terminal. To hold the breadboard next to the Arduino, I taped both to a piece of cardboard.



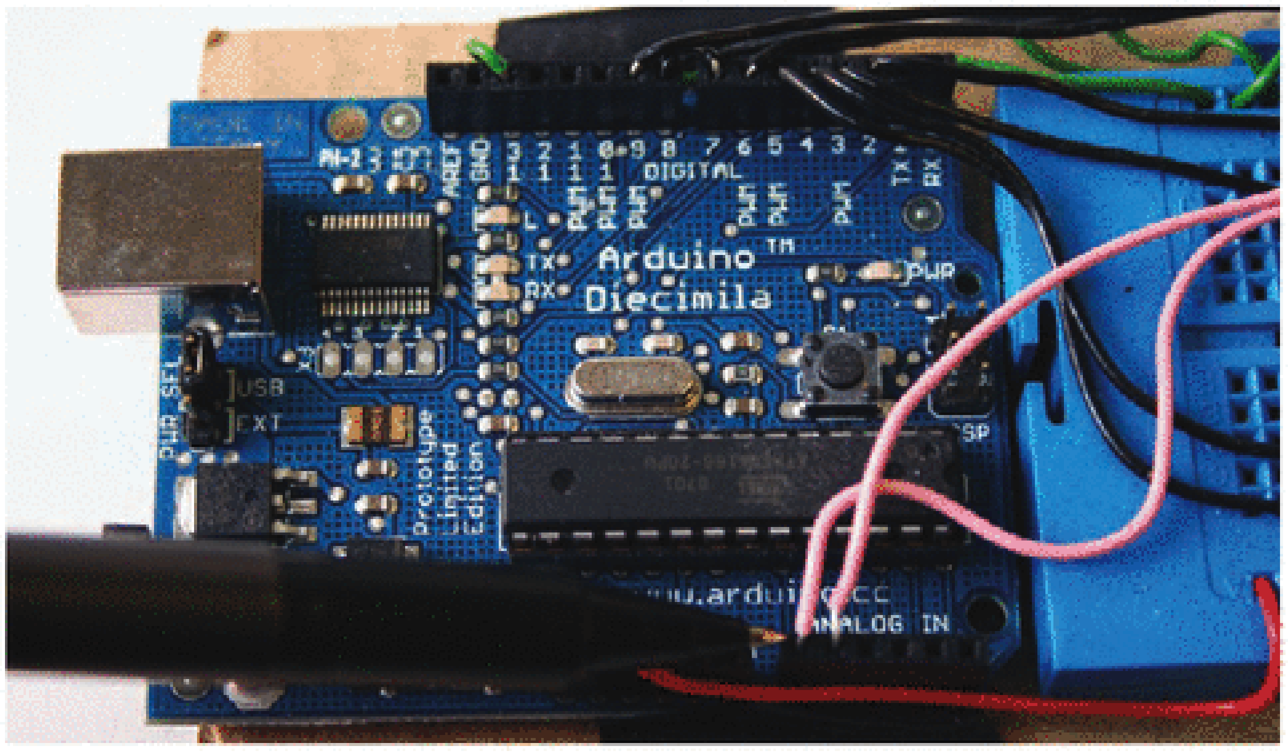
4c. Connect the 5V line of the Arduino to the breadboard along the opposite side from the ground, creating a 5V rail.

4d. Plug the 2 multiplexer chips across the breadboard's central trench and connect them up to the switch wires from the D-sub connectors. With HEF4067B chips, the 16 independent inputs Y0–Y15 run from pin 2 to pin 9 on one side and from pin 16 to pin 23 on the other. Don't worry about the order; comments in the software explain how to sequence the washer inputs there, which is easier than untangling and continuity-testing all the wires.



4e. Connect each multiplexer's 4 address pins (pins 10, 11, 13, and 14) to 4 of the Arduino's digital input/output pins. These let the Arduino select which multiplexer input to receive as analog input. Here again, you can designate the sequence later in the software.

4f. Wire each multiplexer's common input/output Z (pin 1) to one of the analog inputs on the Arduino, A0–A1. Using the analog inputs lets you select the threshold voltage at which the switch is triggered in the firmware. You could use the digital inputs instead for greater speed, but you'd lose the ability to change the threshold.

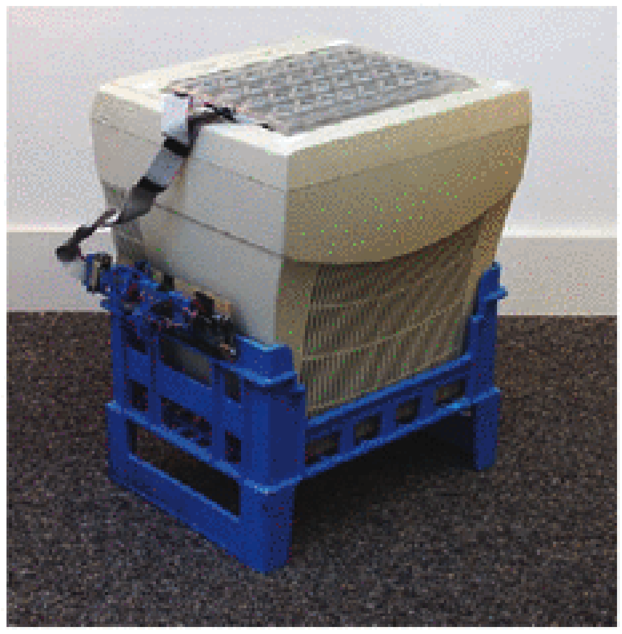


4g. Connect a 10kΩ pull-up resistor from each multiplexer input up to the 5V rail. This ties all the inputs to the 5V line and prevents them from having a floating signal. When a ball bearing is placed on a washer, the circuit is closed and the input voltage is pulled down to ground.

5. ASSEMBLE THE HARDWARE

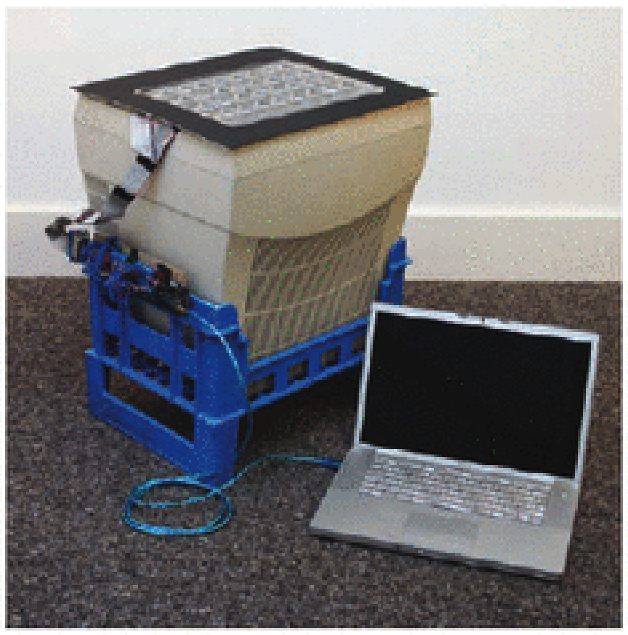
5a. Lay the monitor on its back in the milk crate, or anything else that will cradle it and keep it stable.

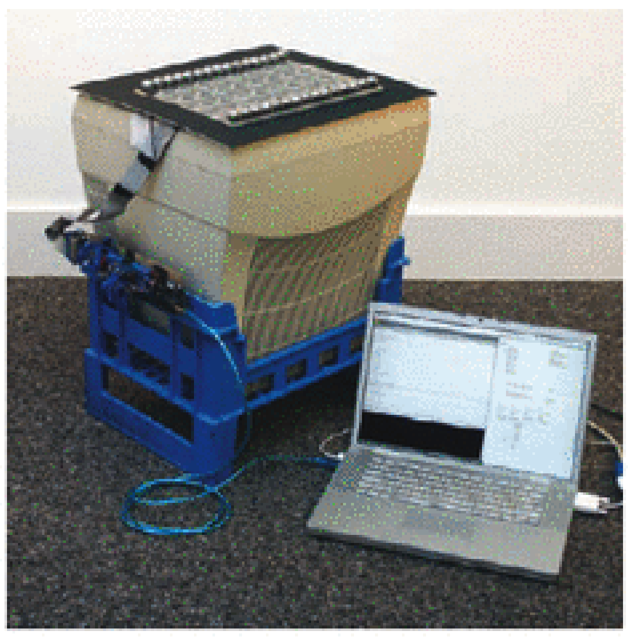
5b. Place the transparent base on top of the screen, and attach the electronics using the D-sub connectors. I taped the electronics to the side of the crate to keep them off the floor.



5c. Size and cut a frame of black poster board to disguise the CRT screen and hide the ribbon cables. (An ideal solution would be to build the screen into a table or cabinet.)

5d. Connect your laptop to the monitor, and to the Arduino via USB cable.





6. INSTALL THE SOFTWARE

6a. Download and install the Arduino programming environment from arduino.cc and the BeatBearing project bundle from makezine.com/17/beatbearing. Launch the programming environment.

6b. Copy and paste the BeatBearing Arduino code into a new Arduino document, then save.

6c. Select Arduino Diecimilia from the Tools ⇒ Board menu, then click File ⇒ Upload to I/O Board. A message should appear in the comments pane at the bottom confirming that the board was successfully programmed.

6d. Download and install Processing from processing.org. The BeatBearing software was created in version 135; it should work fine with the latest version, but if you have problems, switch to version 135.

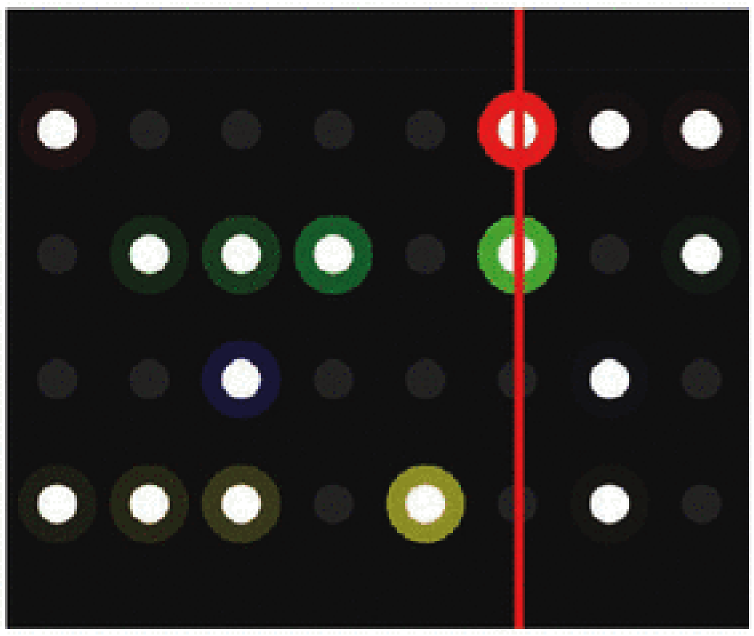
6e. Download and install the ProMIDI library for Processing from texone.org/promidi and the trial version of Ableton Live or Live LE from ableton.com.

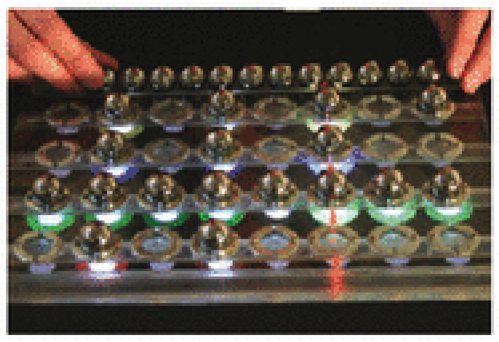
6f. From Processing, open the BeatBearing Processing program, included in the project bundle. This application reads the position of the bells, then creates the MIDI messages and visuals.

6g. Launch Ableton Live (or another MIDI program or soft-synth) to generate the sound output. The free trial version of Live won't let you save settings, but you don't need this to run BeatBearing. On a Mac, configure the program to receive MIDI from Processing via the built-in IAC bus (inter-application communication). With Windows you should be able to route the MIDI using Virtual Audio Cable (ntonyx.com/vac.htm), although I haven't tried this.

6h. From your laptop's display configuration pane, change the second screen's resolution to 640×480, and position it to the left of the primary screen and lined up at the top.

6i. Run the Processing program. No error messages should appear, and the monitor should turn black with an array of gray dots and a sweeping red line. If the monitor turns gray, then Processing might not be connecting to the board. In this case, check that all other Processing applications (shown as applets in the dock) are closed and then re-plug the board in and try again!



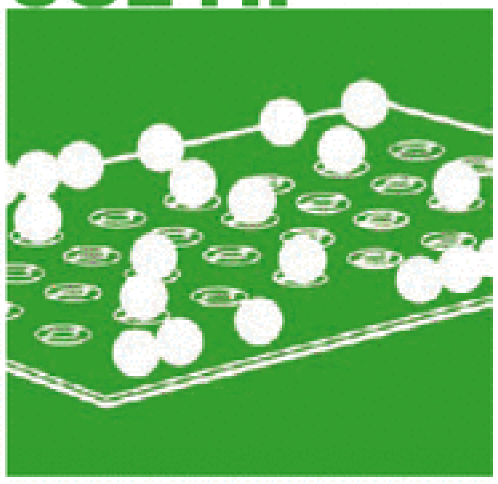


6j. The Beatbearing Processing code may need some tweaking to get things right, such as lining up the virtual grid with the real grid. The code has been commented to make modifications as easy as possible — the only limit is your imagination!

FINISH X

NOW GO USE IT »

USE IT.



DROP SOME BEATS

The BeatBearing is simple to use. Simply place a ball in a hole to start triggering a sound at that position. Remove it to switch the sound out.

TANGIBLE USER INTERFACES

I first encountered tangible user interfaces (TUIs) at the Ars Electronica exhibition in 2003, where I saw James Patten's Audiopad project and Sony CSL's Block Jam. These TUIs, along with others I have since found, inspired me to pursue a Ph.D. to study and develop new musical instruments, and influenced my design for the BeatBearing.

The main idea behind TUI design is that the user should be given a physical handle on the digital data. Importantly, this handle should allow the user not only to feel and see the data, but also to grasp and manipulate it. In the case of the BeatBearing, you "read" and manipulate the sequencer through the arrangement of the balls.

One design challenge I've found with TUIs is how to include a visual display. Typical computer game interfaces (and others) have you look at the screen while manipulating a controller elsewhere. Many TUI researchers create more direct connections by projecting an image onto a control surface from above or below. I've tried top-projection with instruments I've designed, but found it cumbersome, especially if you want a portable instrument for playing live. My solution for the BeatBearing was to ditch the expensive digital projector and show the visuals from below using a cheaper CRT.

I deliberately designed this project to be a base upon which further tangible interfaces could be developed. I believe it has the potential to do much more than this original version.

MODIFICATIONS

Each part of the BeatBearing is simple enough to allow for easy modification. Here are some ideas:

» Tweak the Processing code to change the graphics. How about showing the name of each sample?
» Add a tempo control in the software, or add a dedicated potentiometer to the hardware.
» Build the BeatBearing into a coffee table, wooden cabinet, or my favorite, an old leather briefcase.
» Add extra "sample select" holes to one side of the grid, allowing you to switch between sample banks directly from the board.
» Expand the grid. A 16×4 grid would be large enough to create more serious rhythms.
» Use a flat LCD monitor instead of the bulky CRT — a bit more expensive, but much more portable.
» Write new software. You can use the program provided, but if you want to develop your own firmware, the pseudo-code is:
a. Set address lines on the multiplexers.
b. Read analog pins.
c. Repeat Steps a and b to read all the positions on the grid (cycling from 0000 to 1111).
d. Send out the values of all grid positions over serial.
Different software applications are possible; for example, rather than a sequencer, how about a real-time performance instrument?

Resources

Peter Bennett's home page with BeatBearing news: www.sarc.qub.ac.uk/~pbennett

BeatBearing demo video on YouTube: makezine.com/go/beatbearing

Visit makezine.com/17/beatbearing for BeatBearing code, diagrams, sketches, and links to other resources and inspirations.

BUILD NOTES

How to create your own museum of the bizarre and the beautiful.

Your Own *Wunderkammer*

BY HEATHER McDOUGAL

THE *WUNDERKAMMER* (CHAMBER OF wonders), in its original 16th- and 17th-century incarnation, was a way of housing and displaying collections of natural oddities or curios in a room — usually in the home of someone with wealth or influence, or that of a scholar. The chamber was arranged according to similarities or other groupings, on the whim of the collector.

Collectors then, just like today, were competitive, and tried to gather the strangest, rarest specimens for their displays: the largest bezoar (gastrointestinal mass) found in the stomach of a camel, the most bizarre two-headed animal fetus preserved in fluid, the most unusual fossil or fish skeleton, and fascinating objects from faraway lands. All of these were common wunderkammer content.

Interest in *Wunderkammern* spread throughout Europe into the 18th century, spawning not only rooms, but boxes, cabinets, and other furniture full of curiosities. These collections became something of a requirement for the well-rounded gentleman.

As collections evolved, and European thinking shifted from the theological to the more analytical, the need for a more thorough, universal way of organizing objects emerged. Arguments about the taxonomy of spiritual matters became arguments about the scientific taxonomy of birds and beasts, and the old collections, with their more personal approach, fell out of favor. Great houses went into debt, revolutions rose up and faltered, and the collections were sold off or acquired by government or academic institutions and eventually made public. And so, the modern museum came into being.

Some of the great collections have survived, leaving weird remnants of a different way of thinking, of a time when all things on Earth existed solely for conquest, acquisition, and trophy-like display. The frontispiece of Ole Worm's *Museum Wormianum*, for example, shows the voracious clutter of an early wunderkammer. Peter the Great's famous *Kunstkammer* (art chamber), which included much of Frederik Ruysch's collection of preserved anatomical specimens, seems to us today to be gruesome and horriific, but strangely beautiful at the same time.

My introduction to wunderkammern came in 1996, with a brief glimpse of Rosamond Purcell's photographs of Peter the Great's collection in *Finders, Keepers*. I couldn't get the images out of my head. How could somebody treat other peoples' teeth as something to be beautifully housed and classified? Why would someone trouble to dress a disembodied arm in a frilly sleeve, edged in lace, before pickling it in a jar? It bent my mind. I thought about it for years.

What it came down to was presentation — treating your collection as if it were treasure, to be housed and counted and lovingly arranged. The Renaissance scholars who began these collections came from the world of the church, of splendid reliquaries, saints' bones and holy fragments, and their arrangements are clearly influenced by church culture.

Unlike modern galleries, they don't isolate objects with space but stun you with numbers, with the sheer overwhelming experience of entering a room whose every surface is filled with gloriously strange objects. Only very big or very unusual things get focal treatment. Later collectors, living in the splendor of the Enlightenment, went on to stun instead with their art of presentation, building cabinets and displays of great elegance and artistry.

So what does the wunderkammer mean to us today? Purcell, who's worked with some of the greatest wunderkammern in the world, feels that the term gets thrown around far too often. It's easy to use it to mean any collection, real or conceptual, which startles and fascinates. However, the term has evolved into something more metaphorical: an idea, reclaiming something that's been lost to the strictures of modern science and commodification. To build your own contemporary wunderkammer is to actively imagine authenticity, putting some wonder and mystery back in your life.

Curiouser and Curiouser

The following pages offer suggestions to keep in mind for your own cabinet of curiosities, in the hope that they may help your collection become more unique and satisfying in its presentation.

Fig. A: The author's cabinet shows how dividing shelves into cubbies can add definition. Fig. B: A *Kunstkammer* painted by Frans Francken the Younger, 1636. Fig. C: Peter the Great, emperor of Russia and self-proclaimed dentist, kept a collection of teeth he pulled from friends, assistants, and passersby. Fig. D: Part of Joseph Bonnier de la Mosson's famous cabinet in the National Museum of Natural History in Paris. Fig. E: Ole Worm's cabinet of curiosities, 1655. See Rosamond Purcell's re-creation on page 135.

Photography by (clockwise from top left) Heather McDougal, Kunsthistorisches Museum, Miranda Iossifidis, Smithsonian Institution Libraries, Rosamund Purcell/Peter the Great Museum of Anthropology and Ethnography, Russian Academy of Science, Kunstkamera

BUILD NOTES

Your Own *Wunderkammer*

TIPS FOR AN INSPIRED COLLECTION

The Contents

Display items that are truly special, either singularly or in groups (e.g., your collection of sand from beaches of the world, organized in little glass vials). The contents of the cabinet should inspire aesthetic fascination.

Group things according to your own personal system of organization. Take time to work this out before arranging your pieces. Do rocks go together, or things with holes? Avoid dull classifications, like the date you acquired things, and instead strive for the esoteric.

Collection Dos and Don'ts

» Do collect based on personal whimsy. For example, butterfly wings that look like they have eyes.
» Don't collect based on monetary or perceived value. For example, those mint Cabbage Patch Kids, still in the box.
» Don't put disparate elements together. For example, that plastic shrunken head from the movie set doesn't work if the rest of the collection is old bottles and shells.
» Do have many small collections with idiosyncratic organization.
» Don't cram everything together on a shelf and say you're done.

The Cabinet for Your Wonders

Almost anything will do to house your collection. However, once again materials are paramount — real wood, metal, and glass are always better than materials that speak of cheap modern manufacture. House your treasures in a vessel worthy of them.

Compartmentalization is always good. If your cabinet has drawers, take time to modify them into compartments by inserting dividers, so that you can nestle your finds into custom spaces lined with beautiful tissue paper or silk-wool.

The key is to keep a sense of design and concept in how you display things. How does the whole of a category look together? Making a mosaic of your objects in radiating patterns or neatly arranged clusters can fill spaces nicely. Putting things up in rows looks more scientific, so think carefully about the effect if you choose this route.

Don't worry about crowding — it encourages curiosity and the excitement of the old cluttered and mazelike Smithsonian before it was reorganized, that feeling of delving and discovery, of seeing something new each time.

Labeling

There are several points of view on labeling. Some people prefer not to. Others like the creative aspect, even painting their paper with milk and baking it, or soaking it in tea, to "age" it.

Some collectors like to get fanciful, making up names for specimens or creating labels that are mysteriously blurred or indecipherable. Others prefer precision and clarity, placing neatly lettered labels, sometimes with patterned or gold edges, next to each exhibit.

More Research

Some examples of different kinds of wunderkammern, metaphorical and otherwise:

» The Unknown Museum: makezine.com/go/unknownmuseum
» Joseph Bonnier de la Mosson's extraordinary Cabinet, a piece of which survives at the Muséum Nationale d'Histoire Naturelle, in the Jardin des Plantes, in Paris: makezine.com/go/delamosson
» Peter the Great's *Kunstkamera*: kunstkamera.ru/en (and particularly, makezine.com/go/peterthegreat)
» Shelley Jackson's internet-based *My Body: A Wunderkammer*: altx.com/thebody
» The Museum of Jurassic Technology: mjt.org
» The mind-bogglingly fascinating Cryptozoological Scientific Art of Alex CF: alexcf.com

Selected Readings

» *Finders, Keepers* by Rosamond Purcell and Stephen Jay Gould
» *Owl's Head* by Rosamond Purcell
» *Cabinets of Curiosities* by Patrick Mauries
» *Mr. Wilson's Cabinet Of Wonder: Pronged Ants, Horned Humans, Mice on Toast, and Other Marvels of Jurassic Technology* by Lawrence Weschler

F

G

H

I

J

K

THAT'S WUNDERTAINMENT! Fig. F: Lay out your objects and start grouping them into categories. Fig. G: Try to arrange your objects effectively. Fig. H: Whimsical elements, like the ball of string and bird matches, add humor to the mix. Fig. I: A glass case lends museum quality to your arrangement. Fig. J: You can tag your finds to give them the feel of something categorized and left in a drawer. Fig. K: This "dusty museum" label stands upright. It's aged by painting it with milk and heating it in a toaster oven.

Photography by Sam Murphy, and Heather McDougal (bottom two)

THIS OLD CABINET

I found this cabinet at a junk shop. It was wonderfully battered and just the right size. I had to replace one of the shelves.


L


M


N


O


P

THOUGHTS, COMPARTMENTALIZED:
Fig. L: This shelf is full of natural oddities found on land. Since I was laying the objects horizontally on shelves, I put larger objects at the back, rather than arranging them in patterns. Fig. M: This shelf contains man-made oddities, such as fetishes and Prince Rupert's drops. Fig. N: Natural oddities from the sea. Fig. O: Remnants of a lost civilization? Fig. P: The finished cabinet with all objects in place. I had to paint the bottom shelf to match (and bash it up a bit) before I adorned any of the shelves.

An author and blogger (cabinet-of-wonders.blogspot.com), Heather McDougal attended one of the first summer craft schools in the United States. She has an MFA in sculpture, writes clockpunk fiction, and likes mechanical chickens.

Photography by Heather McDougal

OF NARWHAL SKULLS AND BABY POLAR BEARS

INTERVIEW WITH ROSAMOND PURCELL

Museum photographer and author Rosamond Purcell (rosamondpurcell.com) speaks about re-creating Ole Worm's famous cabinet of curiosities for her exhibition *Two Rooms*. She worked from the engraving *Musei Wormiani Historia*, which is the frontispiece of the *Museum Wormianum*, a catalog of the items in Worm's collection published in 1655, after his death.

Photography by Dennis Purcell

Heather McDougal: Who was Ole Worm and why did you recreate his wunderkammer?

Rosamond Purcell: Ole Worm was a natural philosopher and teacher, and he wanted to show his students what nature really looked like. He wanted them to handle the things, to make their own deductions about what they were actually seeing.

The reason I did the Olaus Worm room is because the room is very, very specifically described by the artist. On every shelf you can see what is there: boxes that are labeled "fossils," "earths," "salts," "roots," for example, and in the engraving you can even see that those things are in those boxes.

You can see all sorts of animals on the shelves; the way that things are arranged across the ceiling; and how, on one side of the room, there are horns and tusks and teeth.

You can see how things were being classified by this teacher, in his rather pared-down, simple museum — which you could call a cabinet of curiosities, but which was also a teaching collection.

The reason you could call it a cabinet of curiosities is because he included iconic specimens in his room that are also found in many of the other collections of the same period — the crocodile, the big snakeskin, the narwhal tusk, which was a real prize.

A friend of his found the tusk embedded in the skull — so that when Worm collected it from the man's basement, he got the skull and tusk intact. Which meant he could say, "You see — it isn't a horse, it's a North Atlantic seagoing creature, and this is his tusk."

HM: So normally, if you'd gotten a narwhal tusk, would you have gotten it from a trader?

RP: They were slipped through Europe from the North Atlantic by merchants, and sold to rich people.

HM: Was it difficult to find the items for your Ole Worm room? I mean, not everybody can get hold of a polar bear.

RP: Yes! It was incredibly difficult. Natural history museums are not crazy about lending things. And curators have an unbelievable lack of understanding about why you would want to do this.

They think, "This is not science. Why would you want to hang a seagull next to a murre next to a pigeon next to a parrot, beside an alligator?" They didn't really necessarily appreciate the notion that you could look at a drawing and then bring it to life again.

And then every time the exhibition moved, the curators would reclaim their collections. And you couldn't send anything to Denmark, because that's crossing invisible lines.

We had to rent a polar bear — which turned out not to really be a polar bear — from a prop shop in Burbank for the entire North American tour of the room. He cost $90 a month, but he looked absolutely great when slung from a harness from the rafter in this room, so we kept him. He wasn't even a polar bear, he was some kind of other bear — we took a sample of his fur, which wasn't hollow-shafted, like a polar bear's. And he didn't have those great big snowshoe foot pads, either.

HM: You know, I'm looking at the picture here, and the polar bear is so tiny! That has got to be the smallest polar bear I have ever seen.

RP: Well it is — it's a baby bear! When we were in Denmark, we got this baby bear [from a girls' school] and we put him up, and he's like a dog, he's not big enough. It shows that the ceiling has been really stretched.

I think I want to optically revisit this thing someday when we all have lots of time. I mean, you don't know what the guy who drew it was actually doing. We don't know from what point of view the room was actually drawn. We knew that it was probably drawn with a wide-angled viewing device, and that it was probably drawn from a higher angle than a person would actually be standing. ...

Dennis [Rosamond's husband] made a little shadow box, and he optically stretched the walls, and then we made that into a box so that the walls didn't look stretched anymore. But even so, we always argued about point of view.

+ To read the interview in its entirety, go to makezine.com/17/wunderkammer.

1+2+3 Mechanical Image Duplicator By Cy Tymony

Before Chester Carlson invented photocopying, inventors engineered various mechanical devices to replicate images. With a few everyday items found in the home, you can make a pantograph, an image duplicator that allows you to use one pencil to trace an image while another pencil follows its path in parallel to produce a near-identical copy.

YOU WILL NEED

- Thick white cardboard
- Pencils (2)
- Paper
- Paper clips (4)
- Paper clip boxes (2)
- AA battery or other small weight
- Marking pen
- Transparent tape
- Scissors

1. Cut out and position cardboard strips.

You'll need 4 cardboard strips. Cut 2 strips measuring 2"×4" and another pair 2"×8", as shown in Figure 1. Place the 2 pairs of strips at right angles to each other, with the smaller pair lying on top of the larger pair.

2. Link cardboard strips with paper clips.

Cut 4 holes in the strips and slip 3 paper clips into them, as shown in Figure 2. Bend up the end of another paper clip, as shown, and tape it to the top of a paper clip box.

3. Add pencils and secure to table.

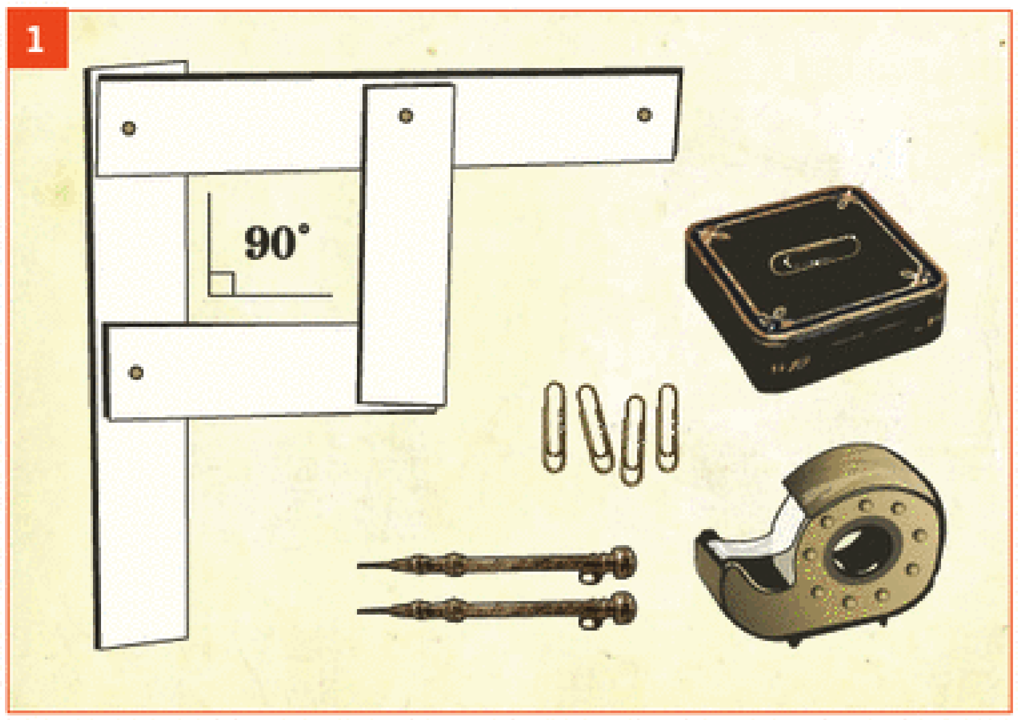
Cut 2 holes in the image duplicator strips large enough for 2 pencils to fit snugly and stand erect, as shown in Figure 3. Turn the cardboard strips over and slip the hole at the end of the left-hand strip over the paper clip that's taped to the top of the paper clip box.

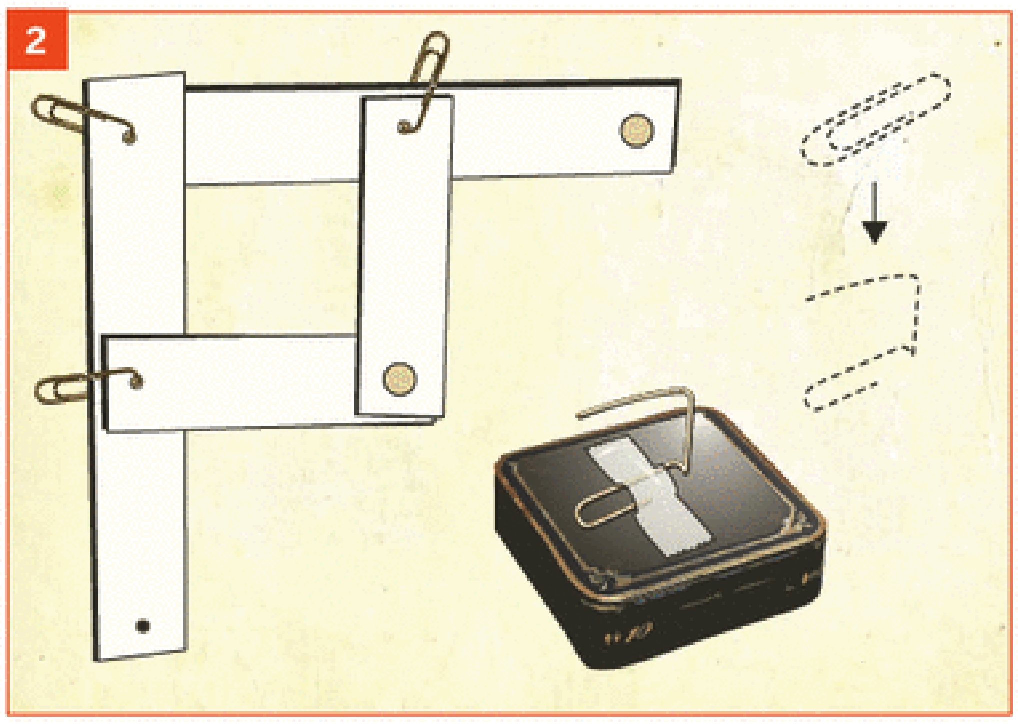
Place a second paper clip box under the image duplicator where the 2 large strips meet, to keep it level. To ensure that the drawing pencil (B) presses against the paper properly, you can add weight to the cardboard strip by taping a AA battery underneath it.

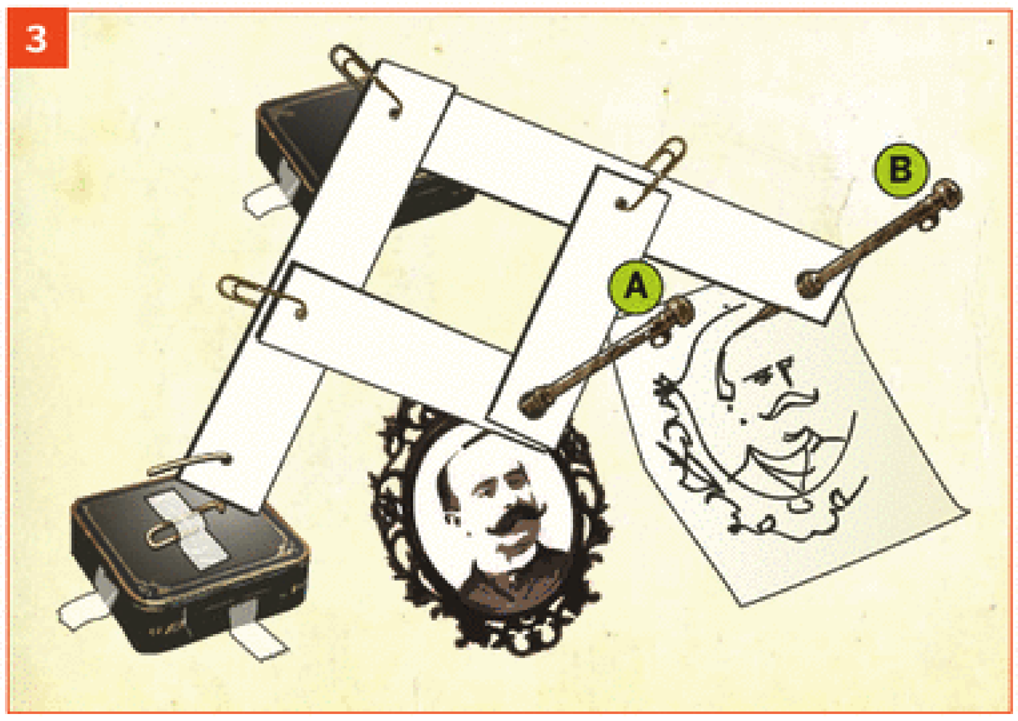
Use It.

Place the original image under pencil A, and a blank sheet of paper under pencil B. Trace the original design with pencil A. Pencil B will follow along, drawing the image on the paper.

Experiment with different lengths of strips to make larger and smaller copies of the original design.







Illustrations by Alison Kendall

Cy Tymony is the author of the *Sneaky Uses for Everyday Things* book series. He lives in Los Angeles. sneakyuses.com

Photograph by Matt Blum

ELASTIC STRING BASS

Optically amplified rubber band twang.

By Len Keeler

I'm always inventing new demonstrations for school. To show how inductive pickups work, I once built a comically large guitar that I strung with steel cable. Later I decided that optical sensing is more versatile, since it works with strings made from any material, and it's also actually easier.

So I came up with this rubber-band bass. Plug it into a standard guitar or bass amplifier, and you can play amazingly low frequencies and cool sounds. Each rubber band sits between a paired infrared LED and receiver, and as it vibrates, it varies the amount of light detected. Each string's signal is then amplified and mixed with the signals from other strings.

Rubber bands sound very different from steel or nylon strings. Their tone is rich in harmonics, and the high frequencies damp out fast. Rubber's high elasticity also means you can generate unusually low notes out of short lengths of band.

Because the amplifier requires both positive and negative voltages, I power the guitar using two 9V batteries, which are switched with a single dual-pole toggle. A red LED indicates when power is on.

My original version had 4 elastic bands, one much longer than the rest. For simplicity, this article shows how to build a single-string version, which you can easily extend to accommodate multiple strings.

1. Plan the overall layout.

Figure out how you'll fit the circuit board, components, and batteries into your guitar body (Figure A, page 139). My sandwich maker's interior measured 4"×4"× $1\frac{1}{4}$", so I had to trim the board a bit (Figure B). I used a saw, but you can also score a line with a file or Dremel and snap the board along the line. If you're building your own guitar body, leave extra room for wires and components; it's easy to underestimate.

MATERIALS

Resistors, ⅛ watt: 100kΩ (2 per string), 1kΩ (1 per string), 440Ω
1μF capacitors, ceramic, not polarized (1 per string, +1)
741 op-amp chip, DIP style **RadioShack part #276-007**
T-1¾ (5mm) red LED
T-1¾ (5mm) infrared LED (emitter) and phototransistor (detector) **RadioShack #276-143 and #276-145, or Jameco #106526 and #112169. You can also buy a matched pair, RadioShack #276-142.**
22-gauge solid-core insulated wire
Prototyping PC board **RadioShack #276-150**
8-pin DIP socket **RadioShack #276-1995**
1MΩ or 100kΩ trim potentiometer **preferably 1M, to allow wider output range adjustment**
Dual-pole toggle switch, DPDT or DPST
¼" female audio output jack
9V batteries and battery snaps (2)
Standoffs with matching screws (2) **one about ¼" and the other 1"**
Scrap of hard plastic tubing or wood dowel **I used a short length of the clear tubing that ICs are shipped in.**
Electrical tape
Elastic bands **preferably the black, fabric-covered bands from office folders, but plain rubber bands will work in a pinch**
Something for the guitar body **I used a Coleman Camp Cooker sandwich press, which is a good size and has a nice metal container with easy access to the inside. You could use a toy guitar, a frying pan, anything that will hide the electronics and extend out to stretch the strings. For my original multi-string bass, I machined the body out of aluminum stock. Shape, size, and strength don't matter much because string tension is low — a toy plastic ukulele will generate notes more typical of an upright bass!**

TOOLS

Drill and drill bits
Soldering iron and solder
Wire strippers and cutters
Multimeter or oscilloscope
Small saw, file, or Dremel rotary tool
Pliers
5-minute epoxy

2. Build the circuitry.

The instrument's mixing electronics are based on a classic op-amp summing amplifier circuit. An input capacitor for each string blocks DC voltages to make sure you're amplifying only the vibrations (AC). Then potentiometers adjust each string's output signal to less than about 0.5V, for uniformity. The adjusted outputs are added via a shared connection and then fed into an integrated circuit amplifier, a 741 op-amp, which boosts the combined signal. An output capacitor blocks any DC signals from entering your guitar amplifier.

Power for the op-amp comes from switched 9V batteries. The op-amp, capacitors, potentiometers, and resistors all connect on the circuit board itself, while the batteries, switch, LEDs, detector(s), and audio jack are outboard components.

Use solder and hookup wire to assemble the mixer/amplifier components on the circuit board, following the schematics at makezine.com/17/diymusic_elasticbass. (The schematics show the single-string instrument in black and optional strings in red.) Any layout will work, so long as the connections are correct; I centered the op-amp and put the capacitor-resistor-potentiometer input sequence along the left side of the board, and the output capacitor on the right (Figure C).

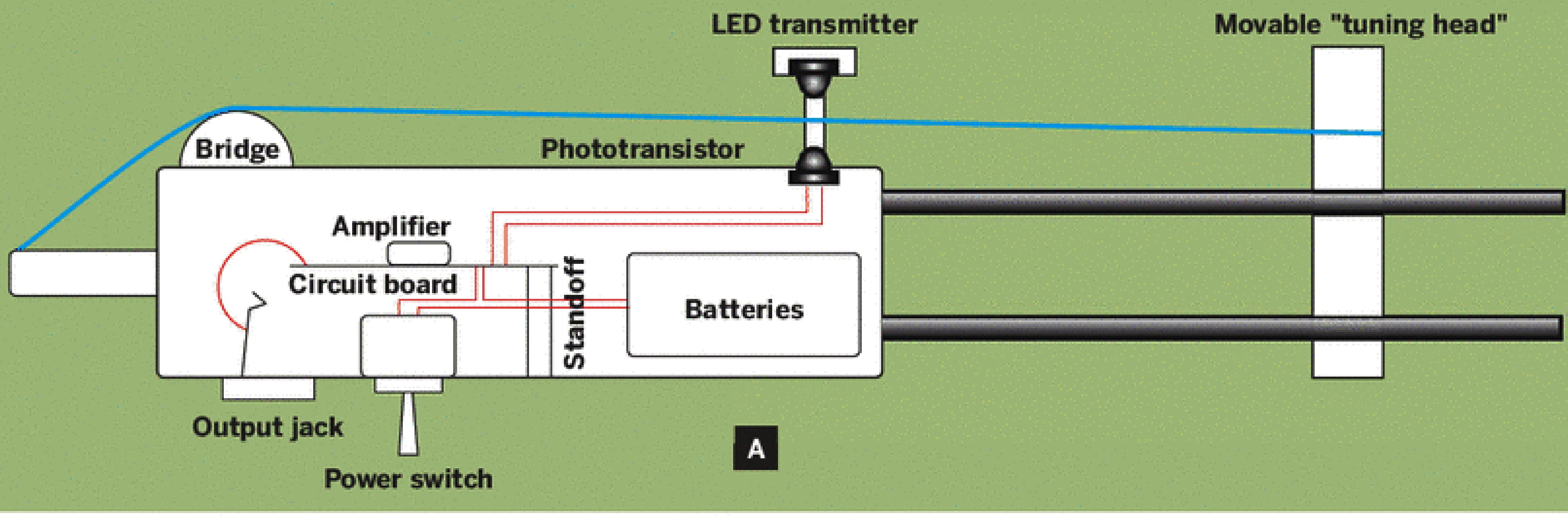
The 2 battery snaps connect in series, with each end connecting back to the board through one side of a double-pole toggle switch and with a ground lead at 0V between the 2 batteries.

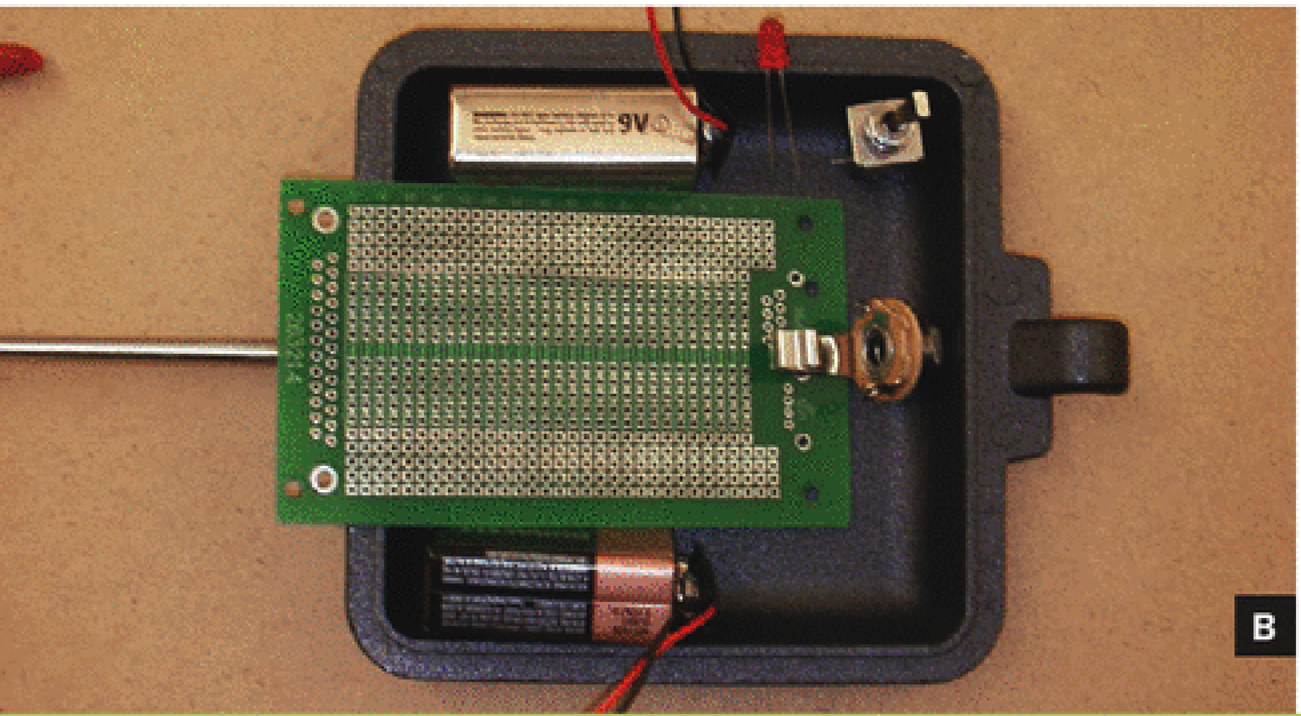
Recalling that IC pins are numbered counterclockwise from the dot or notch, connect the op-amp's pins 4 and 7 to the −9V and +9V sides of the power, respectively. Pin 3 connects to the negative input (ground) and pin 2 connects to the positive (signal). The op-amp's output, pin 6, connects through a capacitor to the tip of the ¼" audio jack, and the ring of the jack connects to ground. Solder more leads from the board to connect out to the power indicator LED, the infrared transmitter(s), and the phototransistor(s).

3. Test the circuitry.

It's prudent to test the circuitry before assembling it onto the body. If you're building a multi-string instrument, test 1 transmitter/receiver pair with a rubber band before forging ahead with rest. I spread the circuit out on a table and taped the transmitter and receiver down so they sat slightly above the surface and pointed directly toward each other about 1" apart (Figure D, page 140).

Plug in the batteries, stretch an elastic band between the emitter and receiver, and test for output from the jack using a voltmeter on an AC setting or an oscilloscope. The output should jump a few tenths of a volt when you pluck the band. If you see signal, you can hear it by plugging into headphones, an amp





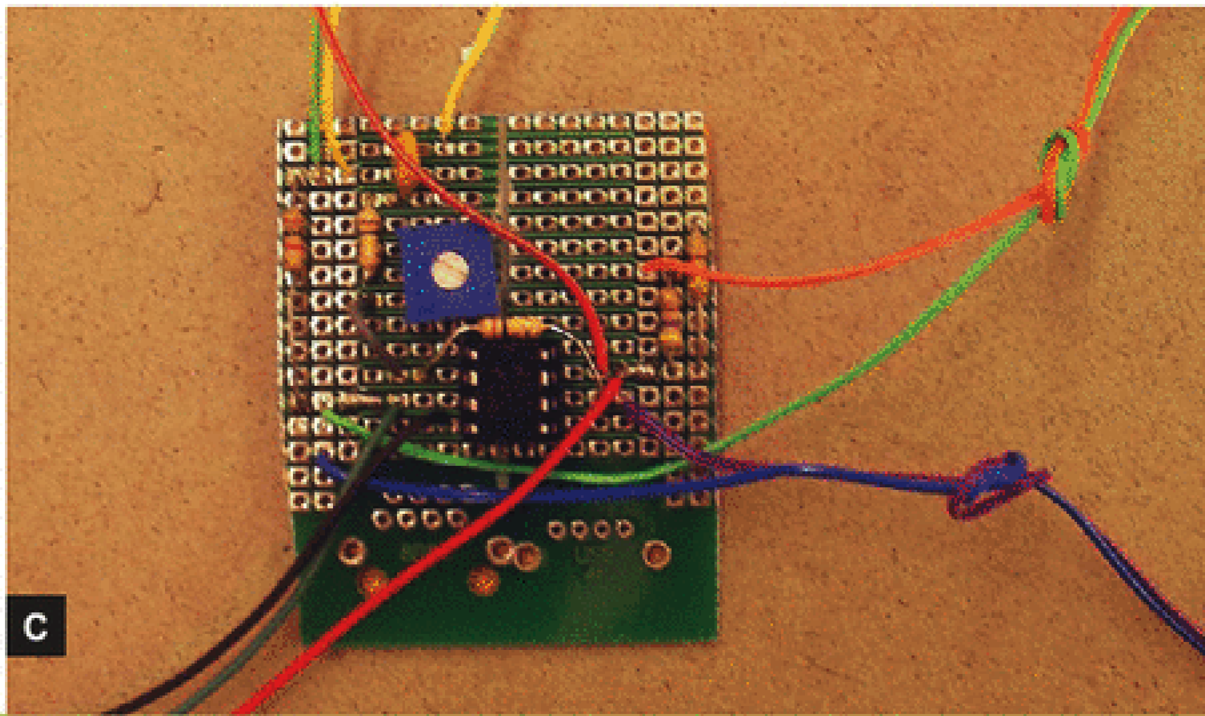


Fig. A: Functional overview of the optical guitar. Fig. B: Lay out components and trim the protoboard as needed to fit in your guitar body. Fig. C: Mixer/amp wiring. From batteries (lower left): black = –9V, green = GND, red = +9V. From phototransistor (upper left): red = signal, green = GND. To IR LED (upper right): orange = +9V, green = GND. To output (lower right): purple = signal, blue = GND.

(begin with the power turned down), or a cheap set of powered computer speakers.

If you don't hear an amplified tone from the string, try turning up your amp, but if you go past 5, something else is probably wrong. Check that you haven't inadvertently swapped the transmitter and receiver, which look similar, or reversed the polarity of either. Test the detector by illuminating it with a bright incandescent source, such as a 60-watt bulb or old-fashioned flashlight, instead of the IR transmitter. Direct the light into the receiver, and pluck the rubber band close to and in front of the receiver.

If you still get no signal, test the voltage between the phototransistor's emitter and ground, across the 1kΩ resistor. If the DC voltage there is zero, chances are the phototransistor is backward. The AC voltage at this point should also increase when you pluck the rubber band. If the detector generates signal at the 1kΩ resistor but the amplifier output still doesn't work, double-check the connections and solder joints on the board.

Photography by Len Keeler

4. Assemble the body.

Once the circuit is working, it's time to mount the components onto the body. First comes some drilling. Conveniently, my Coleman Camp Cooker was made of soft metal and its 2 halves come apart easily, making it easy to work with. I put holes in the case for the power switch, power indicator LED, output jack, and a standoff that holds the circuit board away from the case, to prevent short circuits (Figure E).

For the photodetector, I drilled another hole centered on the body, just below the guitar's neck. At one of the neighboring corners I drilled 2 more holes for the emitter, one for the 1" standoff and the other for the wires. Then I cut a short length of IC shipping tube to use as an arm that cantilevers the emitter over the detector (Figure F).

I drilled 2 holes in the arm, one to attach to the standoff, and the other to mount the transmitter. Take care to position the holes such that the transmitter is directly above and aimed at the receiver. All of the LED-style components — the indicator light, emitter, and receiver — press-fit easily into holes drilled with a #9 (0.196") bit.

5. Add the string, bridge, and tuning head.

I tied one end of the elastic band to the cooker's hanging hole, opposite the handles. For the bridge, I used a piece of IC tubing with a notch in it to prevent the elastic from sliding from side to side (Figure G).

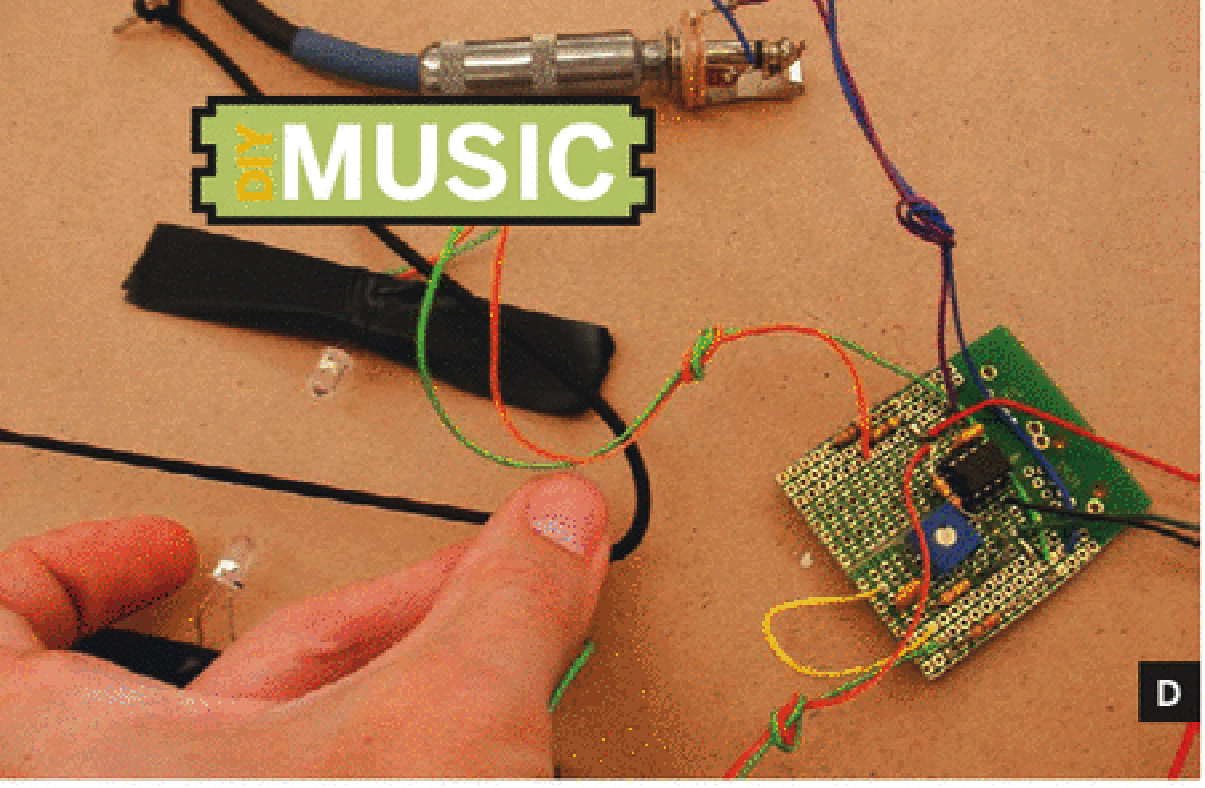
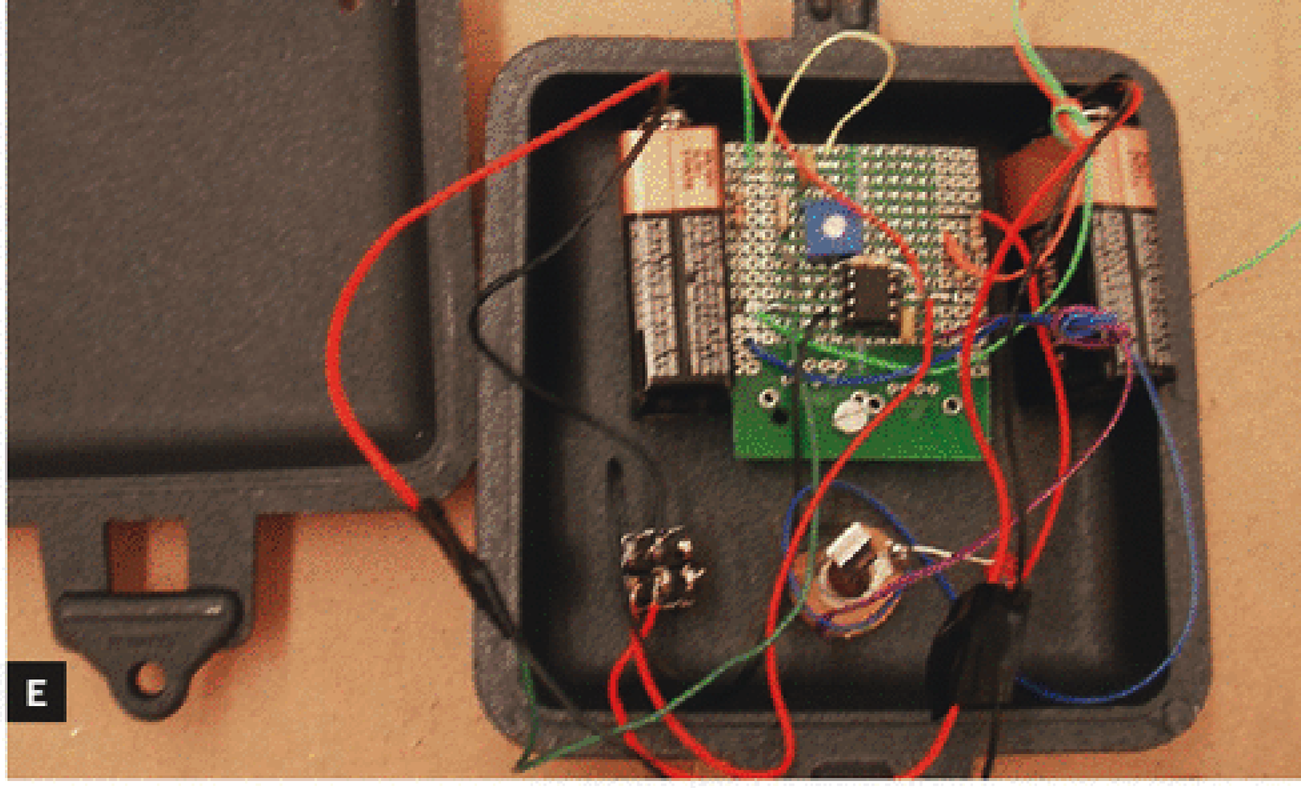
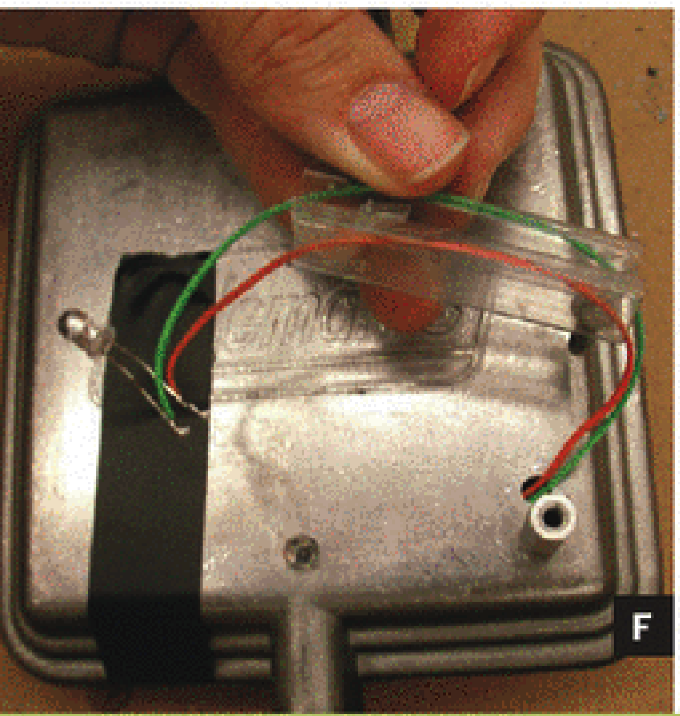
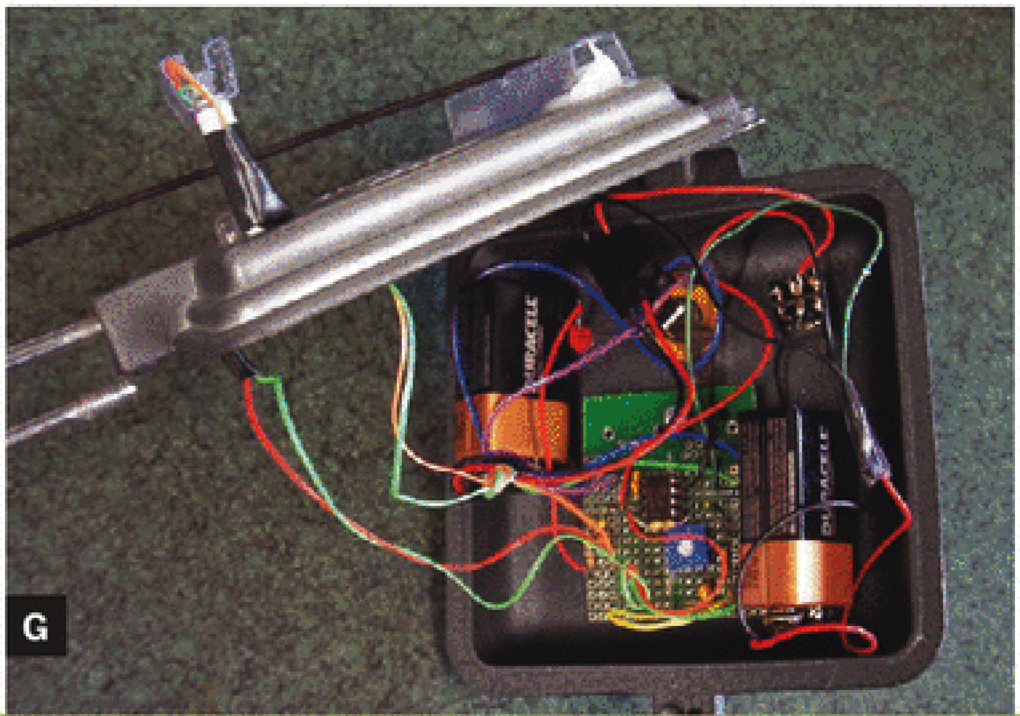
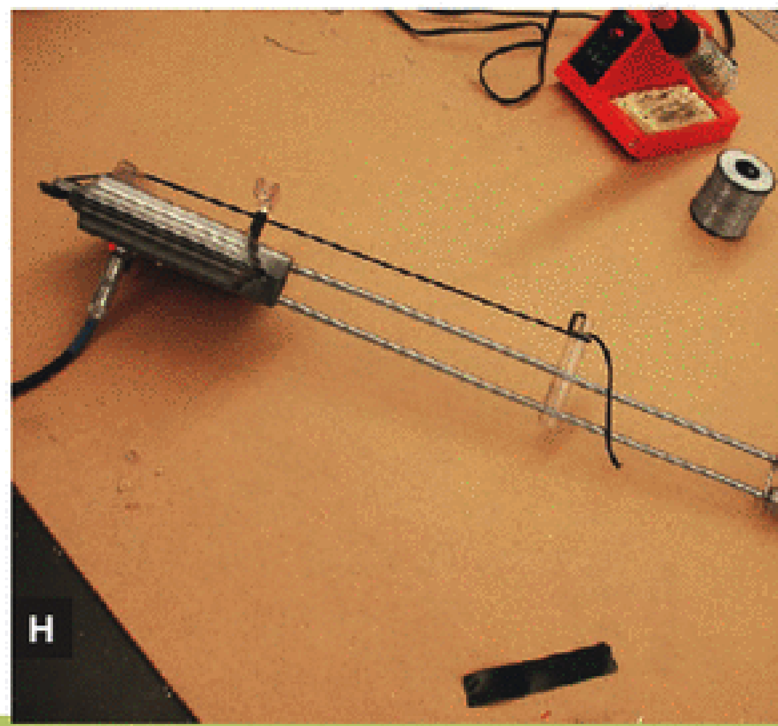






Fig. D: Test your optical pickup before installing. Fig. E: Drill holes in the case bottom for the power switch, indicator LED, output jack, and circuit board standoff. Fig. F: Drill the case top for the photo-detector, then mount an arm to raise the emitter LED directly above it. Fig. G: The bridge is notched plastic tubing. Fig. H: The tuning head is more tubing that slides up or down the handles.

To hold the other end of the elastic, I made a movable "tuning head" out of more tubing. I drilled 2 holes in the plastic for the cooker's handles to pass through, and another hole higher up to tie the elastic to. This arrangement lets you easily slide the head back and forth to adjust the tension in the elastic, while the torque against the handle prevents the head from sliding on its own (Figure H).

The guitar is ready to play! If you have multiple strings, the potentiometers let you even out the volumes (the signal level increases for very low notes), and otherwise protect your amp if the gain is high. The other thing to play with is the alignment of the emitter and detector. Rotating the emitter's mounting arm may increase the signal level.

6. Play the fantastic elastic.

Due to the low tension, you can play incredibly low notes with just a short length of elastic. It also makes this instrument sensitive; depending on how you pluck or strike the strings, their tuning might change. Rather than play the elastic bass like a guitar, changing the notes by fretting against the neck, try tugging on the elastic at the neck, like with a washtub bass, or squeeze down on it behind the bridge.

You can also control the tone using your fingernail as a sliding fret, lifting the string just enough to give it a new vibrating length. Apply just slight pressure.

Notes also have a different character depending on whether you pluck them hard or soft, with the "hard" notes containing more high-frequency components. It's easy to make a lot of cool sounds with this, but challenging to play a song. The best way I found to keep a consistent tone was to play the multiple-string instrument and gently hammer on its strings with chopsticks rather than pluck them.

Finally, remember these are optical pickups, so you can experiment with almost anything! Plucking the tines of a plastic comb held between the sensors produces a really creepy sound. Even tapping on the base of a wineglass can be amplified. For my next experimental instrument, I plan on optically amplifying the motion of glass rod.

+ Schematics plus videos and audio recordings: makezine.com/17/diymusic_elasticbass

Len Keeler teaches physics and electronics at the University of Minnesota in Morris. He's an electronics hacker devoted to the idea of DIY and making things for less.

RANDOM MUSIC BOX

Microprocessor organ and servo drum play an endless song. By Kevin Weekly

Here's a fairly inexpensive ($30–$40) project that uses a microprocessor to generate a constant stream of random but pleasant-sounding music. A Microchip PIC16F685 generates 5 square waves that are amplified and combined to play on a small speaker.

A lookup table in the software stores chord progressions common in Western music. As the music runs from chord to chord, 3 oscillators play the chord itself, 1 plays a tonic-dominant (1-5) bass pattern, and 1 plays random notes from the underlying scale as a melody. Potentiometers adjust how much of each component (chord, bass, and melody) is mixed into the final output.

To keep the beat, the microcontroller also generates output for driving a servomotor to strike a drum or equivalent.

Assemble the Circuit

Download the project schematic at makezine.com/17/diymusic_random. You can solder it onto protoboard or put it together temporarily on a solderless breadboard. I placed and connected the components in this order: sockets, resistors, capacitors, power wires, signal wires, potentiometers, and finally the off-board connections to the speaker and servo (Figure A, following page). The web page has sketches showing each step.

Program the Microcontroller

Download the project code from makezine.com/17/diymusic_random and use your PIC programmer to burn the firmware onto the microcontroller. You can either program it directly from the hex file *main.HEX* or compile the program from the source code *main.asm*.

Photography by Sam Murphy

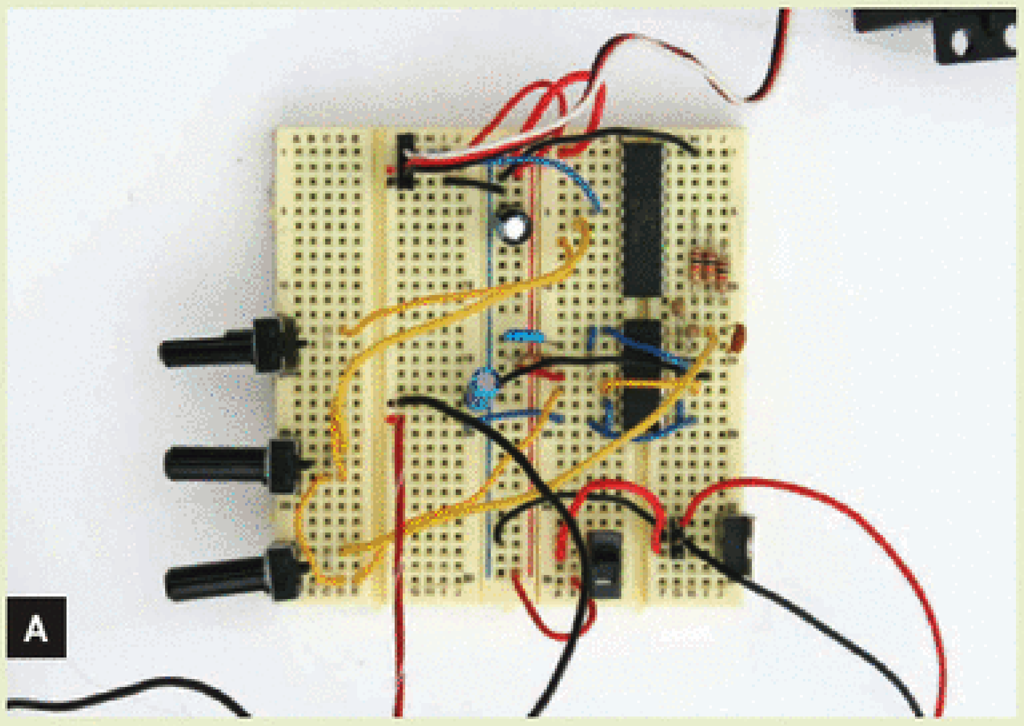
MATERIALS

PIC16F685 microprocessor, 20-pin DIP $3 from Digi-Key, digikey.com
Op-amp (amplifier) chip, OPA4342, 14-pin DIP $5 from Digi-Key, or use another quad op-amp, like the cheaper LM324
Capacitors: 20nF, 10μF, 1μF, 100μF
Potentiometers: 50kΩ (3) or other value, but all 3 must be identical
Resistors: 4.7kΩ, 10kΩ (6)
Small speaker, 8Ω RadioShack #273-092
0.1" header, 3-contact
DIP sockets: 14-pin, 20-pin
Hookup wire
Protoboard or 2 solderless breadboards
5V power supply I used a 4xAA battery pack with a voltage regulator.
Masking tape

For the drum (optional):
Servomotor, Hitec HS-422 from a hobby shop. Other servos would probably work, but they must handle PWM (pulse width modulation) input. I tried an HS-325HB and it did nothing but twitch.
Drumstick and drum, or equivalent For one version, I used a metal rod and a cardboard box.

TOOLS

PIC programmer available from microchip.com
Digital multimeter
Soldering materials (optional) if you're building on protoboard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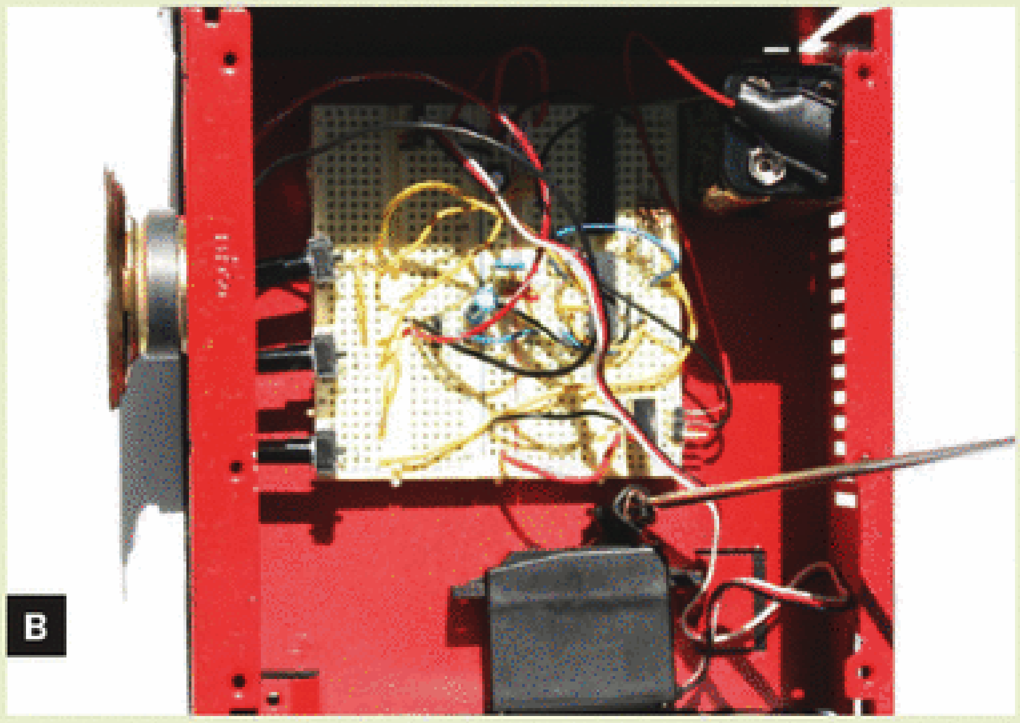
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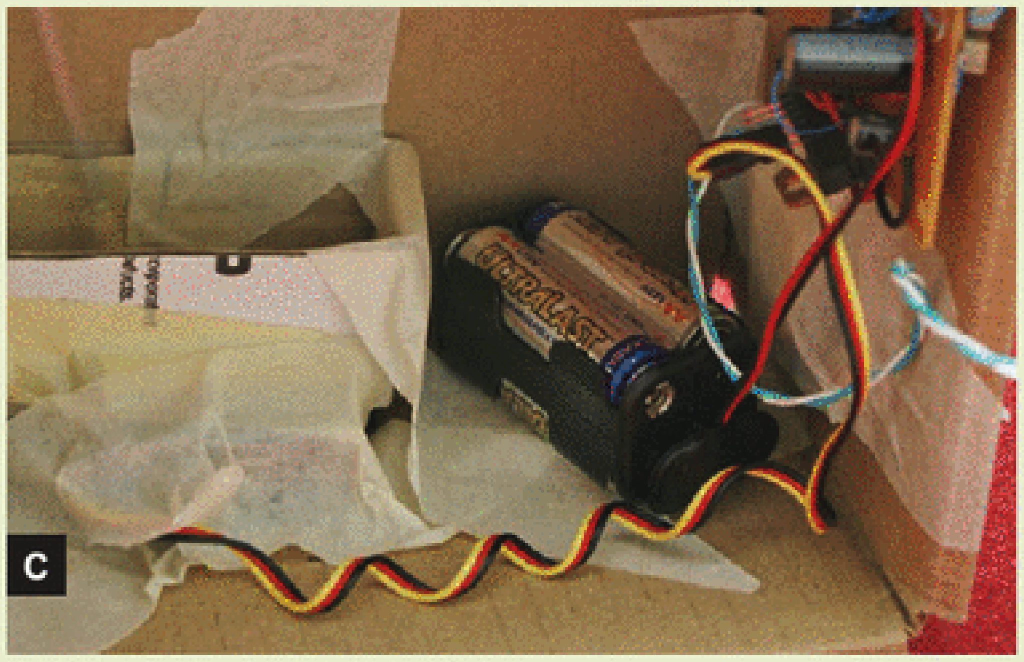

C

Verification

Before inserting the ICs into the sockets and powering on, it's important to make some sanity checks, to avoid destroying the expensive ICs. First, check connections on the circuit with the digital multimeter. Next, make sure the power and ground rails aren't shorted out. Then power on the circuit and make sure each chip's power pin (Vcc) is getting 5V. Finally, plug in the ICs. If you don't hear music output, disconnect power immediately to avoid any magic smoke.

Add the Drum

You should now have a noisy circuit happily playing chords. To add percussion, the servo output alternates between maximum and minimum deflection every beat. The music box MAKE built uses a metal case as both project box and drum (Figure B). For my original version, I soldered the circuit onto protoboard and taped everything into a cardboard box (Figure C).

For those with some PIC coding experience, the source code for the firmware is mainly driven by lookup tables, which you can easily modify to do other musical things such as playing songs, scales, etc.

For the schematic, a GIMP file with wiring, compiled firmware, source code, and an audio sample, go to makezine.com/17/diymusic_random.

Kevin Weekly studies electrical engineering and computer science at the University of Texas at Dallas. In his spare time he builds circuits, writes programs, and composes music.

EGG HEADS

Construct an interlocking puzzle with 30 identical pieces. By George W. Hart

As a retirement present for Joe Malkevitch, a geometer friend who likes puzzles, I designed and built this 1'-diameter Egg Heads puzzle from ¼" walnut.

Many of my sculpture and puzzle designs require laser-cutting or other computer-guided fabrication technology to accurately produce intricate parts. But this design is simple enough that you can make the parts yourself with ordinary shop tools such as a band saw and belt sander.

The ease of fabricating the parts doesn't imply ease of assembly, however. After cutting out the 30 parts, you'll find it requires all of your puzzle-solving skills to interweave and interlock them into a symmetric structure. Here are instructions for making and assembling your own copy.

1. Start with a paper template.

The template can be scaled up to be 11" long using a copier, or you can download the full-sized PDF version from makezine.com/17/diyhome_eggheads. The shape fits diagonally on a standard 8½"×11" sheet of paper.

I designed a simple egg-shaped head that's easy to saw, but you can personalize the face of yours if desired. However, don't modify the neck notch or the 90° notch at the back of the head, which are carefully positioned for proper assembly.

2. Transfer the template to clear acrylic.

You could just trace the paper outline, but a more accurate technique is to do a hot toner transfer. Either print the template with a laser printer or, if you use an inkjet printer, photocopy the printed template so you have a toner-based copy. Tape it, toner side down, to the acrylic and warm it with a heat gun as

Photography by George W. Hart

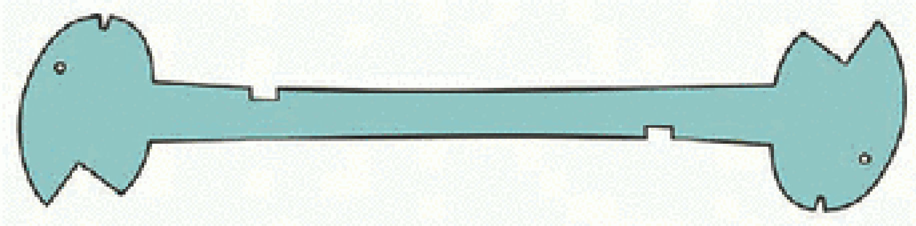
MATERIALS

4ft^2 of ¼" hardwood or plywood
3"×12" scrap of clear acrylic plastic aka plexiglass
Wood finish
Templates (at right) Copy and enlarge, or download them from makezine.com/17/diyhome_eggheads.

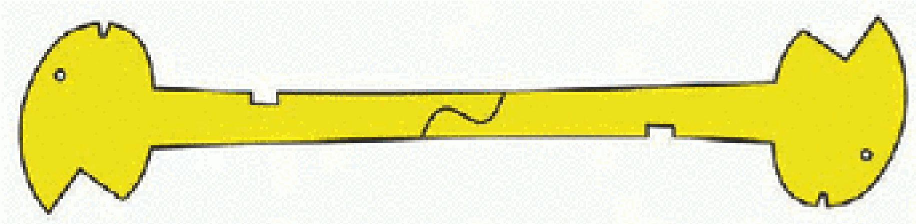
TOOLS

Copier or computer and printer
Heat gun (optional) for toner transfer
Band saw
Belt sander
Drill or drill press
Scroll saw or fine coping saw

Template (30 pieces plus extras)



Key (1 piece)



you rub the paper with the back of a spoon (Figure A). Hot toner will melt and attach to the plastic.

3. Cut out the acrylic template.

Cut it with a band saw, just outside the line, and then sand it down exactly to the line (Figure B). You will trace this 30 times, so be sure it's accurate. As a check, you can trace it onto paper, then rotate it 180° and trace it again.

4. Trace the 30 parts.

With a pencil, lay out and trace 30 copies on ¼"-thick wood. Make a couple of extras, too. One advantage of using a clear acrylic template is that you can see through it to position it where you want, relative to the wood grain, thus avoiding knots.

TIP: For strength, align the template the long way, along (not across) the grain.

5. Cut the 30 parts.

Use a band saw to cut the 30 parts just outside the pencil lines (Figure C). Then sand to the line (Figure D). Any disk or belt sander is fine for the convex portion at the tops of the heads. A thin belt sander with no backing is ideal for the concavities.

6. Drill the 60 eyeholes.

For drilling the eyeholes, first make a simple drilling jig that you can clamp to your drill press table. A 1" square of wood glued to a larger scrap of wood is sufficient for the jig. You can hold the notch at the back of each egg head against this square to position the parts consistently under the drill bit (Figure E).

7. Sand for finish and feel.

Depending on your woodworking tastes, you may round the edges slightly, belt-sand the flat surfaces to remove any planer marks, and/or use an orbital sander with progressively finer grits, for a sensuous feel. Don't alter the geometry of the crucial mating points at the backs of the heads and the fronts of the necks.

8. Cut the "key" part in half.

Use a scroll saw or fine coping saw to cut 1 piece along the line indicated in the key template. Be sure not to cut the reverse of this curve, with the head facing the opposite direction. This is the final piece in the assembly (Figure F).

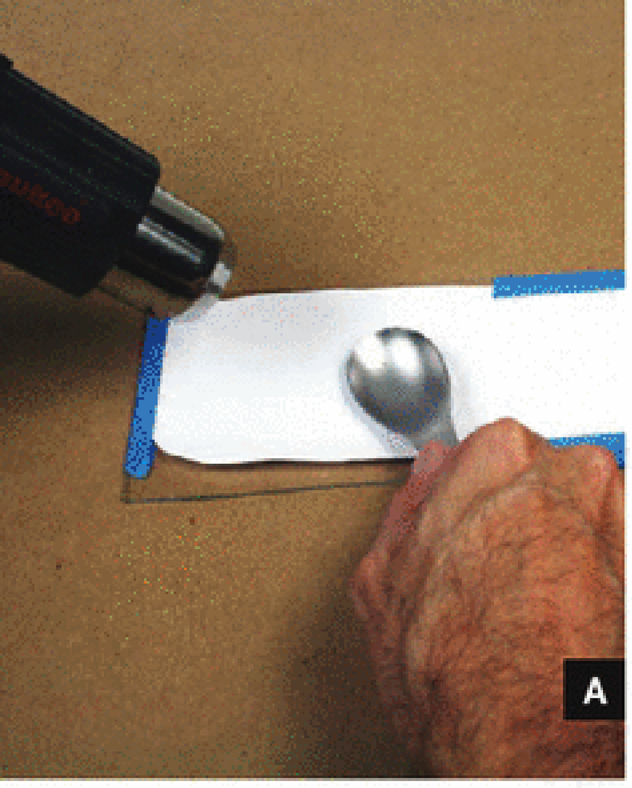
9. Finish.

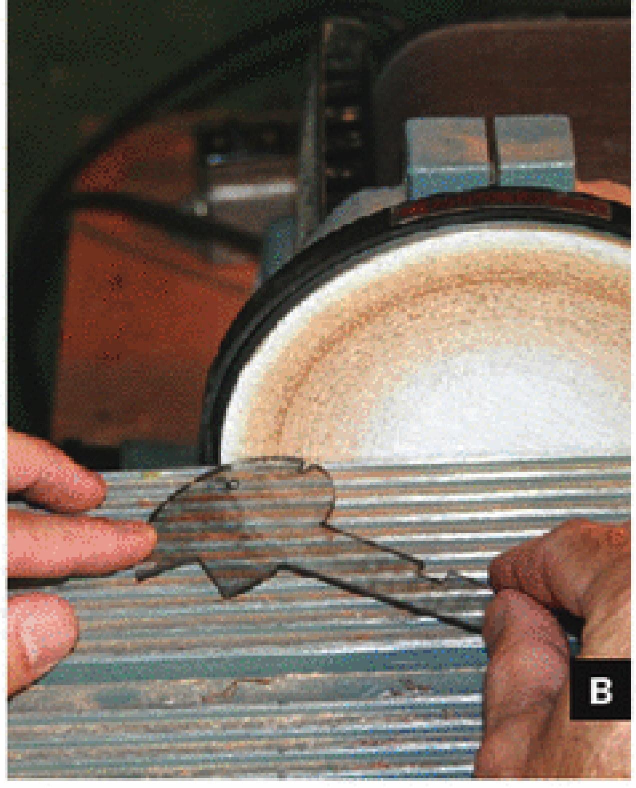
Apply an appropriate wood finish, e.g., tung oil, and allow it to harden (Figure G).

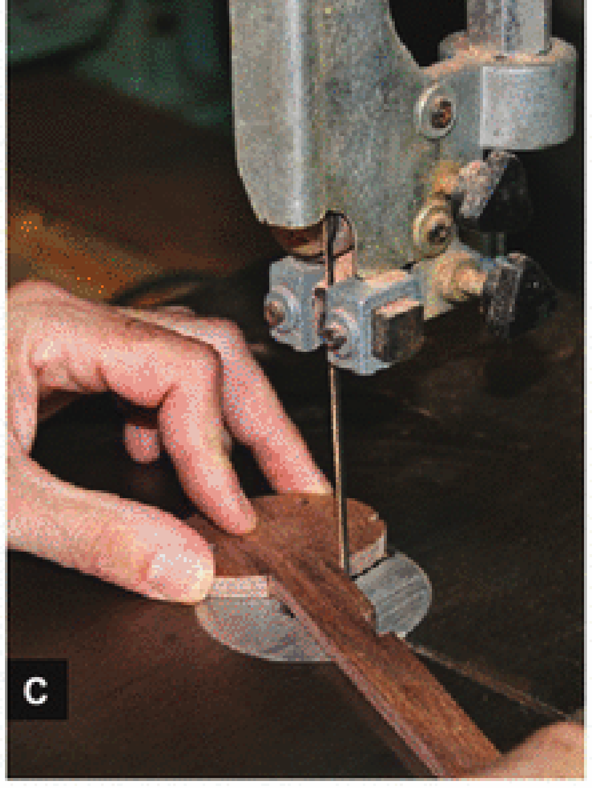
10. Assemble!

While the above steps are largely mechanical for woodworkers, I guarantee you'll find the assembly step to be a new intellectual challenge.

It would be easier if you were an octopus. When it's done, the parts all interlock without any glue, but the whole thing wants to fall apart until the final pieces are positioned. So this is the true test of dedicated nerdiness. I'm sure you'll succeed, because you have so much time already invested!







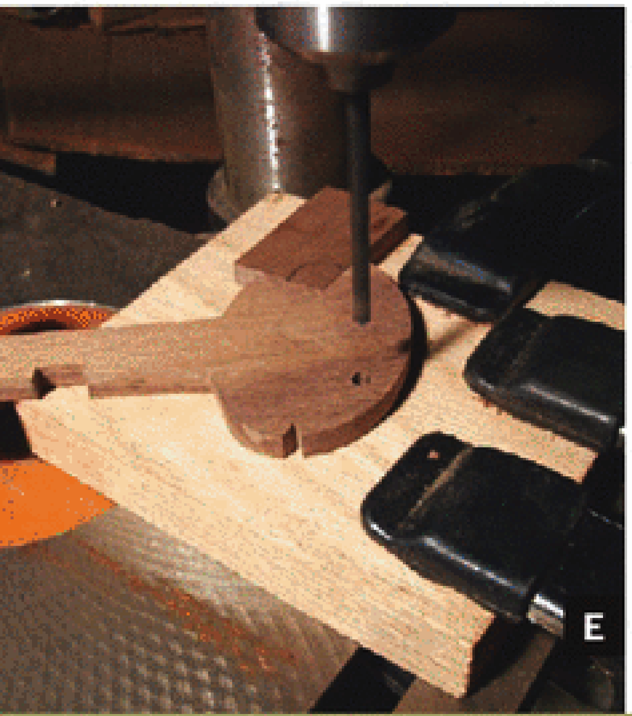


Fig. A: Transfer template art to acrylic with a heat gun. Fig. B: Cut out and sand down the template. Fig. C: Cut out 30 identical wood parts with a bandsaw. Fig. D: Sand each part with disc and belt sanders, or by hand.

Fig. E: Drill 2 eyeholes in each part. Fig. F: Cut one of the parts in half, as shown. This is the puzzle's "key" part, which will be added last. Fig. G: Apply an appropriate wood finish, e.g., tung oil, and allow it to harden.

Or perhaps have an Egg Heads party so you have lots of hands available to hold everything in place.

NOTE: The entire puzzle can be scaled up or down, but you must scale every dimension, including thickness; for example, you might triple the size to a diameter of 3' using ¾"-thick wood. Send me a photo if you do!

Resources

The mathematics underlying this puzzle is described in my paper for Joe Malkevitch's Festschrift: George W. Hart, "Egg Heads: A Puzzle/Sculpture" in *Geometry, Games, Graphs, and Education: The Joe Malkevitch Festschrift*, ed. Sol Garfunkel and Rishi Nath, Consortium for Mathematics and Its Applications (COMAP), 2008.

Maximum Puzzle Challenge

If you'd like to test your puzzle prowess, stop reading and try to assemble your Egg Heads based only on the final assembled image on page 143. If that fails, follow the step-by-step assembly instructions and photos at makezine.com/17/diyhome_eggheads.

a. First observe how 3 back-of-the-head notches can meet and "mind meld" like the corner of a cube, with all 3 heads facing either clockwise or counterclockwise. You can assemble the puzzle in either of 2 mirror-image solutions, but all mind melds must be the same. After finishing, you can disassemble it and try the other handedness. (For the other set of instructions, just look at these pictures in a mirror.)
b. Use 5 twist ties to hold together 1 pentagon cycle.
c. Make another pentagon interlocked with the first.
d. Position the 2 pentagons so that 2 heads of one do a mind meld with 2 heads of the other. At the opposite end of the pentagons, you can do the same thing. A rubber band around the mouths can keep the heads together.
e. Continue adding parts, one at a time, making twist-tied neck pentagons and rubber-banded mind melds. The final few parts have to be carefully steered into position, but no force is needed.
f. The very last part goes in as 2 halves, one from each side, and locks together.

George W. Hart (george@georgehart.com) is a research professor at Stony Brook University and a sculptor. Examples of his work can be seen at georgehart.com.

VOLTS HURT, AMPS KILL

Excerpts from *Rules of Thumb: A Life Manual*. By Tom Parker

A rule of thumb is a homespun recipe for making a guess. It's an easy-to-remember guide that falls somewhere between a mathematical formula and a shot in the dark. The following rules of thumb are excerpted from MAKE contributor Tom Parker's book *Rules of Thumb: A Life Manual* (2008, Workman Publishing).

» You can determine whether a ghost is real by crossing your eyes. If the image doubles, the ghost is there. If not, it's all in your mind.
—Scott Parker, data specialist

» Volts hurt, amps kill.
—Waldo Weyeris, engineer

» You get about half an hour of flight in a hot air balloon per 20-pound tank of propane fuel.
—Barbara Frederking, balloonist

» To roughly convert Celsius to Fahrenheit, double the temperature and add 30. Thus 10°C is 50°F, and 20°C is 70°F.
—Stephen J. Lambrechts-Forester

» Snapshots encourage memories; videos replace them. After watching a video of your vacation, your memory of the vacation will be what you saw on the video.
—Rulesofthumb.org Review Board

» You have to wait about 30 minutes after cracking your knuckles to crack them again. That's how long it takes for the vaporized joint fluid to go back into solution.
—Jim Crissman, veterinary pathologist

» To avoid lunatics on city buses, sit in the middle. The friendly lunatics sit as close to the driver as they can, and the unfriendly ones sit as far away as they can.
—Keith Allan Hunter

» On a good road bicycle you can travel 50 miles per day at a leisurely pace.
—Alwyn T. Perrin, editor of Explorers Ltd. Source Book

» When you are planning a house, make the angle of the roof noticeably more or noticeably less than a right angle; otherwise, the appearance lacks charm and is curiously depressing. In general, the steeper the roof, the more charm the house will have.
—Susan Pitkin, librarian

» The easiest way to quiet a drunk is to whisper to him.
—Rulesofthumb.org Review Board

» If you think you saw a mouse, you did.
—Rulesofthumb.org Review Board

» If you can control the center of a chessboard early, you control the game.
—Rulesofthumb.org Review Board

» Use ammonia for a bee sting, vinegar for a wasp sting.
—Dr. Bill Grierson, professor emeritus at the University of Florida

» In most cases, a lithium battery will last as long as four alkaline batteries, and an alkaline battery will last as long as ten carbon-zinc batteries.
—W. Price

» Time goes by faster from the moment one starts paying one's own bills.
—Franklin Crawford, writer

» If you haven't made an important discovery in the field of mathematics by the time you're 22, you probably never will.
—Gerald Gutlipp, mathematician

» Drivers who customize their cars with bumper stickers and other adornments are more prone to road rage than others.
—Rulesofthumb.org Review Board

» Don't stand within 16 feet of the lion tunnel when the lions are entering or exiting the ring. They will pee on you.
—Todd Strong, circus school student

When Tom Parker (parker@rulesofthumb.org) isn't tinkering with junk, he's flying a 1956 Cessna 180 bush plane.

DIY WORKSHOP

HOW TO REMOVE ANYTHING FROM METAL

Glean gleaming treasures from rusty trash. By John Todd

Photography by John Todd

I love using old machine parts for my projects; often their workmanship surpasses that of anything new, and you can get them cheap or even free. Find a junkyard full of ancient, rusty industrial equipment, and you can build almost anything — or at least be inspired to, which is half the battle!

But many older machine parts, especially cheap ones, have rust, paint, or other coverings that make them ugly and difficult to work with. Over the years, my salvage habit has turned me into something of an expert in amateur metal restoration. I am by no means a metalsmith, but I have collected a library of easy techniques that can enable any moderately equipped hobbyist to turn neglected lumps of metal into shiny, working components.

Rust, the oxidation of iron, takes up far more volume than the metal it grows from, so the parts underneath look surprisingly undamaged after treatment. The same goes for old paint, which protects the surfaces underneath it.

There are 3 basic ways to remove oxidation or paint from metal in a home shop: mechanical, chemical, and electrochemical. (Thermal methods, and exotic techniques like dry ice blasting, molten salt dips, and bacterial siderophores, require specialized equipment.) Here I describe some home methods, and how to construct one of the most effective rust-removal tools of all: an electrolytic conversion tank.

Mechanical Methods

These work well for smooth surfaces with paint or other coatings, and some light rust. For surfaces with cracks, pits, or fine texture, the only effective mechanical method is abrasive blasting (aka sandblasting). But to get into the cracks, you can also follow other mechanical methods with chemical methods.

Sandpaper Use on smooth, painted surfaces in good condition with no corrosion. Good for preserving delicate metal.

» Start with heavy grits (80) and work down to a finer grit (200). Always sand wet — submerged or under a constant stream of water — to prevent the paper from clogging.

Steel wool Removes superficial "flash" rust, surface imperfections, powder coats, and some thinner paint layers. Very fine wool (#000) will also remove stains from chrome and even windshield glass without noticeable scratching (but experiment first).

Scouring or sanding pads (manual) Remove organic residues such as grease or oil buildup on engines, or sticker or tape gunk (use with solvent). Good for mild to medium surface rust in some cases.

» 3M scouring pads are the only good ones I've found.

Scouring pad discs (powered) At 13,000rpm, these discs are darn near miraculous against paint and light rust on any large, smooth surface.

» Use scouring pads rather than sanding pads, which will sand away the metal itself. A die grinder will spin them faster and work better than a drill. 3M makes effective Roloc brand pads for die grinders. You can also try my hack of attaching a cutout rectangle of manual scouring pad to the bottom of an orbital sander in place of paper, which works wet or dry for cleaning boats, awnings, outdoor furniture, etc.

Angle grinder with wire cup brush A low-cost, fast way to clean rust, paint, or other coatings from reasonably wide-open surfaces on large parts.

» Will gouge aluminum and other soft metals and leave swirl marks on most steel. Very noisy and dusty, and wires can fly off and embed into arms, legs, etc. Less effective alternatives: drill with a wire brush bit, bench-mount wire brush grinder.

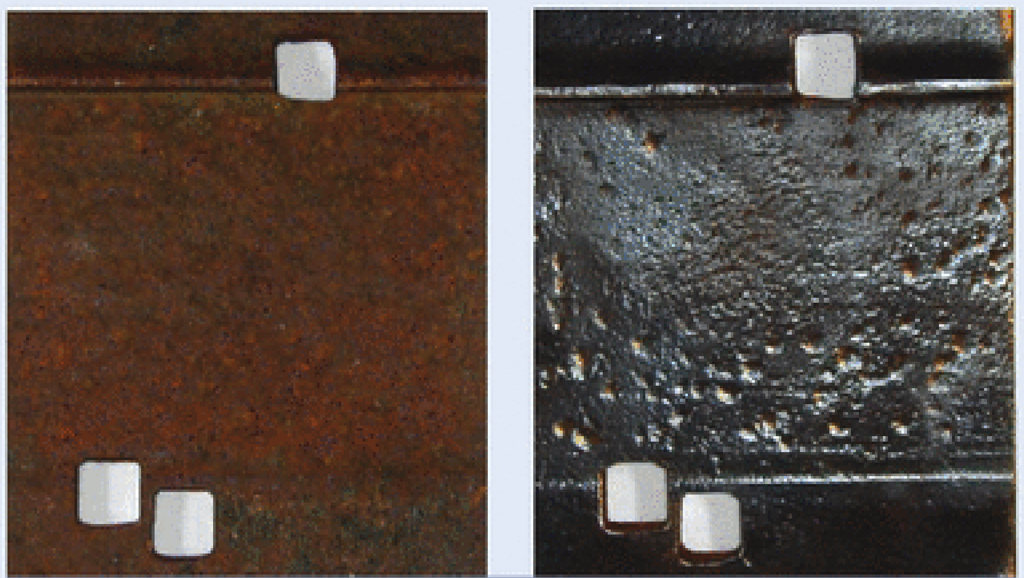
SAFETY FIRST

In the shop, I almost always **wear leather gloves**. A minor slip with a 12,000rpm wire brush will lead to a discouragingly wasted day at the emergency room.

I wear goggles 100% of the time that I'm working with any type of tool or liquid. It's easier to just leave them on rather than trying to remember, do I have them/where are they/do I need them for this task?

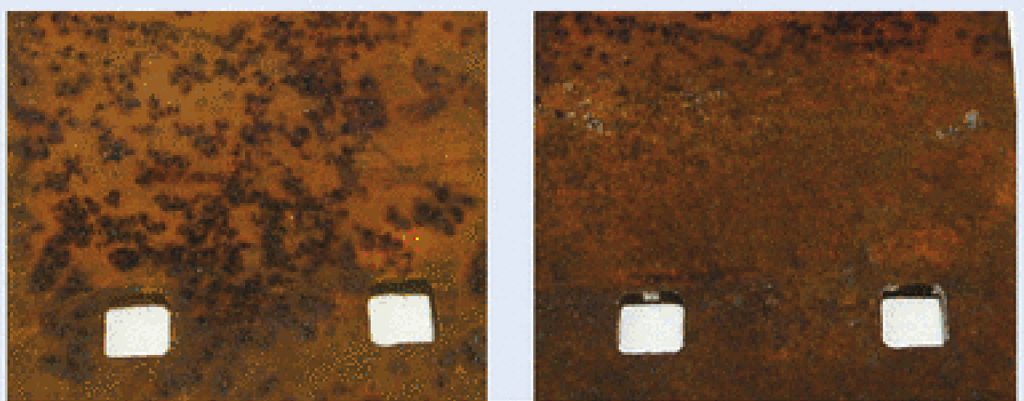
Some of the chemicals used here have nasty fumes, so don't use more than you need, and **use chemicals outdoors**, where there is less risk of fume buildup.

Keep a fire extinguisher handy, in case sparks or other heat sources cause flames. A related hint: *Do not* grind surfaces that are still wet with flammable cleaning liquid. Learn from my mistakes!



Angle grinder with wire cup brush

Sand blasting



Naval jelly

Angle grinder with flap wheel Reduces thick paint buildup or heavy rust over large, flat areas. Best as an initial prep step. Removes everything rapidly, including the metal itself, so be careful!

Wire brush (manual) Removes petrified grease from vehicle parts. Helps remove loose or powdered oxidation alongside other, more effective methods.

Needle scalers These earsplitting devices have a high-speed wheel of thin, hard rods that successively slam forward a few millimeters with each rotation. They're only useful on large rust that comes off in scale form, such as on ships and bridges.

Abrasive blasting Excellent for removing paint, rust, or other hard imperfections from any surface, though less effective against softer coatings like rubberized paints or heavy grease.

» The downsides are that this method is messy and the equipment is expensive. You can use a 5hp/50gal air compressor ($200 on eBay or Craigslist) with a small blasting gun, but more power and volume are better. A $100 benchtop blasting cabinet will speed the process, keep you clean, and save you from having to sweep up abrasives from your driveway.
» Do not use actual sand, ever, for "sandblasting," due to the risk of silicosis. Safe abrasives include glass beads ($20 for 25lbs), aluminum oxide (more aggressive; $50 for 25lbs), and ground walnut shells (gentler but slow; $25 for 25lbs). While blasting, keep dust out of your lungs by wearing a real respirator with replaceable filters, not a disposable mask.
» Moisture in your compressed air will cause more rust later. A good cheap hack is to coil a long length of the hose through a trash can full of cold water and install a water trap at the downstream end.
» Filter your abrasive medium thoroughly for reuse with a good sieve, or a series of 2 with decreasing mesh size. Paint, grease balls, or other impurities recycling through your gun will quickly lead to poor performance and require gun disassembly.

Soda blasting This newer variant on abrasive blasting uses water-soluble baking soda. Soda is amazing for paint removal and for fragile materials like brass, copper, aluminum, and glass, but not so good with rust. Its solubility lets you blast pieces and clean them up easily in place, without having to remove them from engines or other locations where loose grit would cause problems.

Soda blasting requires specialized equipment, but prices (without the compressor) have fallen below $300.

Chemical Methods

"Homebrew" acids Vinegar, lemon juice, or cola can remove light surface rust.

» These won't work on heavy rust or paint. Stronger acids do the job better, with no sugary mess to clean up later.

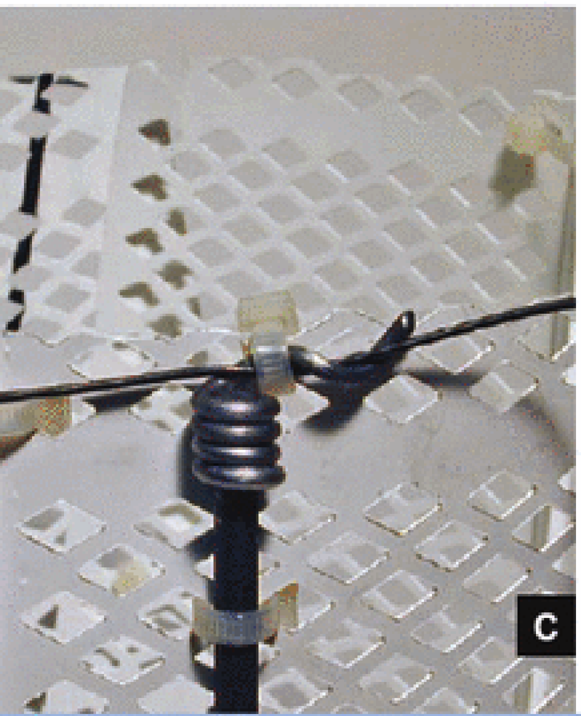
Paint remover Removes paint (duh) but not rust or corrosion. The best choice for painted, unrusted parts, since it won't affect the underlying metal.

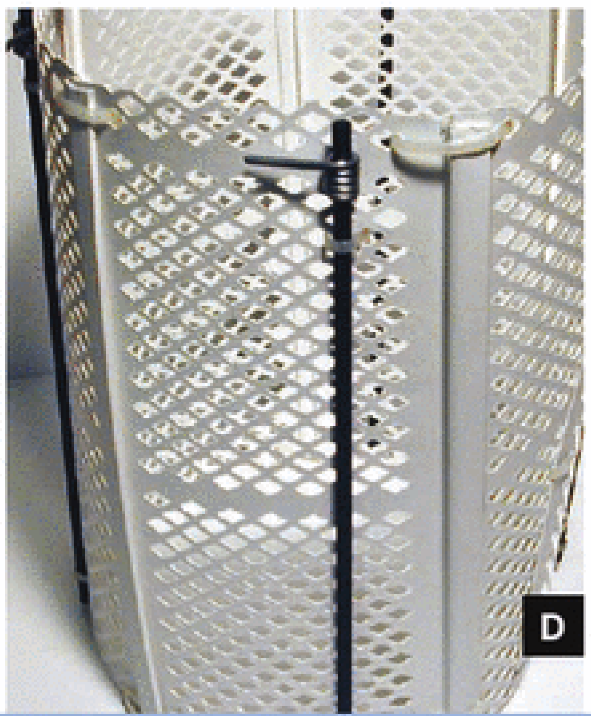
» Less effective on powder coats; for these, try multiple thick applications.

Alkaline rust removal (aka dip tanks or caustic dips) *Not recommended.* This process involves sodium hydroxide (lye) and chelating agent solutions that are heated to near-boiling temperatures. It produces nasty toxic vapors and waste, and unless you have the right mix of chemicals, temperature, and experience, it's not as effective as the electrolytic method on the following page.

Phosphoric acid and naval jelly Works alone to remove light surface rust or as a secondary stage following mechanical treatments.

» Heavy rust requires high concentrations of acid and long immersion, which still might not work on rust that has bloomed or turned to scale. With lighter rust, spray the acid and let it sit for 30 minutes, covered with cling wrap to prevent drying. For faster results, the object should be warm.
» Phosphoric acid is very effective as a secondary prep after mechanical treatment. It gets into miniscule cracks (especially on cast iron) and cleans out the bits of oxidation that even abrasive blasting can miss.
» Auto parts stores carry phosphoric acid and zinc preps for car body painting (e.g., POR-15 Metal-Ready), which seal the metal surface with zinc phosphate. Naval jelly, which can't be sprayed, is strong phosphoric acid in a thick medium to keep it in place.





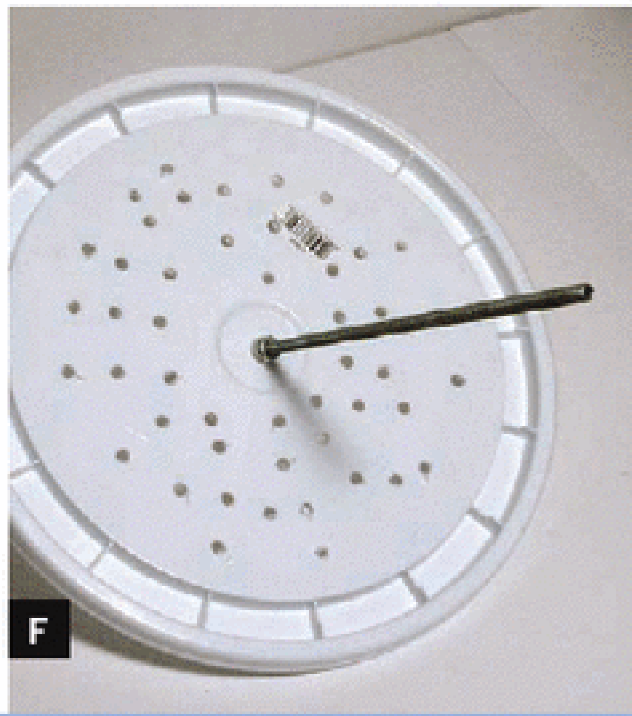


Fig. A: Cut mesh gutter leaf guards to fit inside the bucket. Fig. B: Position 6 leaf guard sections around the interior of the bucket. Fig. C: Place 4 steel or carbon rod "anodes" around the assembled mesh cylinder, and connect all 4 anodes with a wire. Fig. D: Use zip ties to connect the anodes to the mesh. Fig. E: Drill a hole in the center of the lid and insert the threaded rod. Fig. F: Drill lots of ventilation holes for gases to escape.

MATERIALS

5gal plastic bucket with lid
Sodium carbonate, aka washing soda or soda ash
Used for fabric dyeing and adjusting pH, it's available from craft, aquarium, and home improvement stores. I paid $6 for a 2lb jar of Balance Pak 200 at a pool supply shop.
Mild steel rods or carbon welding rods, 12"×¼" diameter (4) **for the anodes. Carbon rods last much longer. Do not use stainless, chrome, or galvanized steel, which will leach out toxic chromate.**
Plastic mesh gutter leaf guards, about 40" long (3)
¼"×16" threaded steel rod
¼" washer
¼" female/female threaded rod butt joint
¼" ceiling hook
¼" nut
12V DC battery charger, or other DC power source
If your charger's ammeter doesn't go up or its hum doesn't increase when you dip your part into the bath, you may need an older, "dumber" charger without a safety interlock, that won't test whether it's connected to a battery.
Steel wire, 10'
Plastic zip ties, one package (30–50)
Water
Tin solder (optional) **for soft-clamp anode connection**

TOOLS: Tinsnips, wire cutters, drill with ¼" bit, wire brush

Electrochemical Method

Build an Electrolytic Conversion Tank

This is a surprisingly simple way to remove heavy rust using DC electricity, a tank of sodium carbonate solution, and some sacrificial anode rods. After several hours of bubbling, the rust loosens or falls away.

I've used it on mechanisms so corroded that you couldn't even make out their outlines, and after treatment the individual parts were easily disassembled with hand tools. You can even run electrolytic conversion on painted rusty surfaces, although it takes longer. (See Resources on page 152 for an explanation of the chemistry involved.)

With other homebrew electrolytic tanks I've seen, the objects just hang from a board in a 5-gallon bucket. I like my setup better because it uses plastic mesh to prevent short circuits between the anodes and the object being treated, and it all packs away neatly in the bucket.

1. Install the mesh ring.

Cut the ends off each gutter shield to make 6 pieces that just fit inside the bucket (Figure A). Use zip ties to connect the pieces together into a ring that

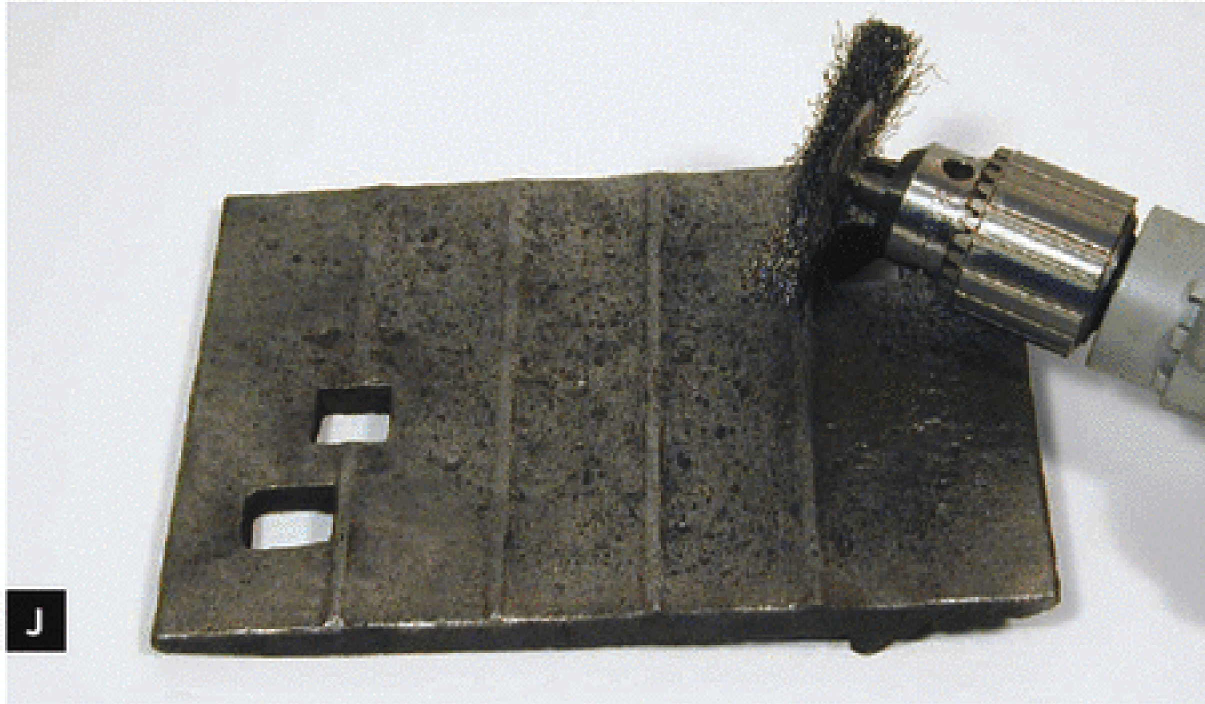


Fig. G: Put the mesh ring into the bucket and thread the conductor wires through the hole in the lip of the bucket. Fig. H: Put the rusty object on the hook and submerge in sodium carbonate solution. Fig. I: Connect the red cable to the anode wires and the black cable to the rod in the lid. Fig. J: The scale and surface rust will be converted to a black powder that can be removed with a wire brush, wire wheel, or light abrasive blasting.

lines the inside of the bucket, with the factory-cut ends against the bottom. If your bucket is tapered, overlap the pieces to follow the taper. Trim the top portion of the mesh if needed to let the lid fit snugly (Figure B).

2. Connect the rods.

Wind and zip-tie a length of steel wire around the top of the mesh ring, connecting it to 4 anodes hanging down outside the mesh, one at each compass point (Figure C). I used 4 because the process works in a "line of sight" manner between the anodes and the object's surface.

With steel anodes, you can just tightly wrap the wire around the rod ends directly. I used carbon rods, which can shatter, so I attached them to the wire with small coils of softer tin solder. Zip-tie the anodes to the mesh (Figure D).

Finally, drill a hole in the lip of the bucket for the 2 ends of the steel conductor wire to pass through.

3. Modify the lid.

Drill a hole through the center of the lid and insert the threaded rod. Secure it with the washer and nut above the lid, and screw on the butt connector and ceiling hook at the bottom of the rod (Figure E).

Drill lots more holes in the lid for ventilation (Figure F) — the flammable oxygen and hydrogen byproducts need to escape during cooking!

4. Put it together.

Insert the mesh ring in the bucket. The addition of the anode rods should make it a snug fit. Pull the conductor wires through the hole in the lip of the bucket (Figure G). Construction is complete.

5. Time to zap some rust!

5a. Set up an area with good ventilation. Fill the bucket with hot water to a level about 2" below the conductor wire. Add sodium carbonate, 1Tbsp per gallon of water. Stir.

5b. Put your rusty object on the hook, and adjust the nut so that the object and hook are completely submerged when you put on the lid (Figure H).

5c. Connect the red (+) battery charger connection to the anode wires sticking out of the side of the bucket, and connect the black (–) cable to the threaded rod in the lid (Figure I). After about 20 seconds, lift the lid a bit and sneak a peek at the object. You should see some very small bubbles forming on the surface. If not, check your connections. You may need to scuff the rust where the object touches the hook. Depending on the amperage of your DC supply, a full treatment may take up to 1 day or so, but you can't damage an item by leaving it in too long.

5d. Remove the object and dry it. The visible scale and surface rust will have been converted to a black powder that can be removed with a wire brush, wire wheel (Figure J), or light abrasive blasting. This oxide dust doesn't cling to the metal like rust.

5e. Treat the object with a phosphoric acid and zinc prep solution. The acid removes any flash rust left by the bath, and the zinc protects against future rust and adheres well to primer. Dry, prime, and paint or clear-coat the object as soon as possible.

5f. Before painting or coating, mask off any gear shafts, keyways, or other high-tolerance fittings, and swab gear faces and other working surfaces with oil so you can wipe the paint off later. A metal detailing finish can preserve the metallic look, and for antiquing and other effects, miniatures catalogs carry a spectrum of paints for die-cast figurines.

Before applying a clear coat, it's very important to remove all oils and other potentially corrosive materials. Brass, copper, and smooth cast iron are particularly sensitive to the acids in finger oils, and you don't want to have a fingerprint showing up months later! Wearing plastic gloves in a well-ventilated area, apply acetone or another thin evaporative mineral spirit.

You can coat with Rust-Oleum spray, or try POR-15 Glisten PC for more durability. For enclosed gears and mechanisms where dust isn't a problem, you can also coat parts with way oil, a heavyweight oil used to grease machine tools.

Hints and Notes

» The electrolytic bath is basic (caustic), like lye, so wear goggles and rubber gloves and keep a bucket of water or a hose nearby in case you spill or splash some on yourself.

» Alligator clip cables work well for suspending small parts like nuts and bolts from the hook.

» Painted rusty objects can take much longer because paint impedes electricity. For better results, scratch up the paint first, or use a paint remover before treatment.

» Ordinarily, you can dispose of the used bath liquid down the drain. But if you removed lead paint or you suspect that heavy metals (chrome in particular) have leached from your items, let the water evaporate to form a sludge (not a dust!) and bring it to a local toxic materials processor.

Resources

» *Metals Handbook, Volume 5: Surface Cleaning, Finishing, and Coating*, American Society for Metals, various editions and years — an excellent general reference

» Wolfgang Jordan's Small Tool Museum explains the chemistry of electrolytic conversion: xrl.us/rustremoval

» Bill's Antique Gas Engines explains the chemistry of electrolytic conversion: antique-engines.com/electrol-details.asp

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John Todd is a networking-and-VoIP Dr. Jekyll during the workweek, and a diesel-and-steam Mr. Hyde on the weekends. He's currently building the world's most over-designed vegetable-oil-powered home electric plant, and he manages the freenum.org alternate telephony numbering system.

Make: TIPS!

Disc Sander Cover

I don't often use the disc section of my big belt/disc sander, so I made a simple cover so I don't have to worry about things (or me) falling against the rotating disc when I'm concentrating on using the belt.

—*Frank Ford*, frets.com/homeshoptech

Magnetic Pocket

Toss one of those strong neodymium magnets in your pocket, and you can stick a whole load of screws or nails on the outside for easy access when you're doing a bit of shop maintenance.

—*Frank Ford*, frets.com/homeshoptech

Find more tools-n-tips at makezine.com/tnt.

Photograph by Sam Murphy

CASE REOPENED

Repurposed packaging for electronics experimenters. By Thomas J. Arey

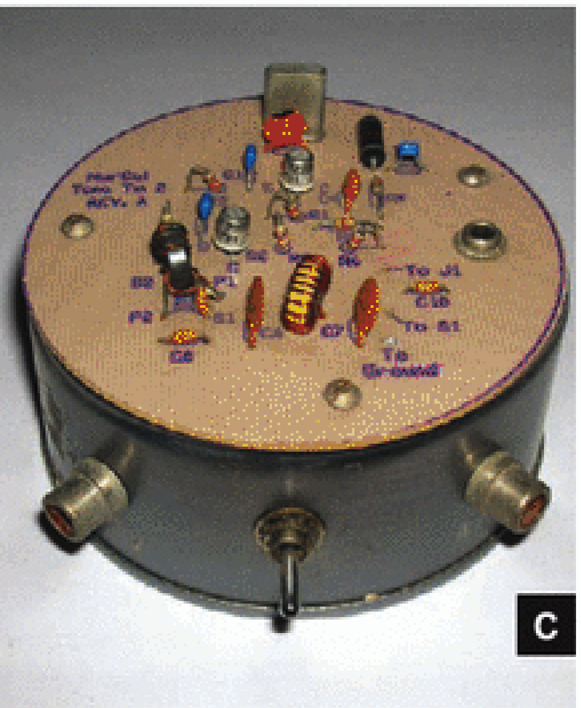
Great electronics projects can be found in so many places. Magazines new and old, textbooks, and websites provide the electronics hobbyist and experimenter with literally hundreds of exciting possibilities. However, while you may find a great schematic for a power amplifier, audio oscillator, or other project, finding a suitable case for your electronics experiment is another story.

Commercial project boxes are expensive and usually must be ordered from suppliers. Gone are the days when everyone had a neighborhood electronics parts outlet with a broad supply of experimenters' resources. But, the maker perspective provides many possibilities. You need look no further than your recycling bin to resolve almost any project case dilemma. Why recycle when you can repurpose?

Audio and radio experimenters have learned to love the common mint tin. Several projects have appeared in MAKE making excellent use of this ubiquitous case. The Altoids tin has become such a standard form factor for small electronics projects that some designers actually lay out their printed circuit boards to fit its 3⅝"×2¼"×¾" interior. Folks have managed to cram quite a lot of electronics onto this very small piece of real estate.

Many other small metal containers found "in the wild" can easily be turned into project cases. One of the most famous of these was the Tuna Tin 2 designed by the late Doug DeMaw W1FB in the 1970s and still built by hobbyists today (*see MAKE, Volume 12, page 167*). However, it's by no means the earliest example. In the golden age of vacuum tube design, it was common for hobbyists to turn pie and bread pans into chassis for their projects.

Once you open your eyes (and your mind) to the possibilities, you'll spot small metal containers of



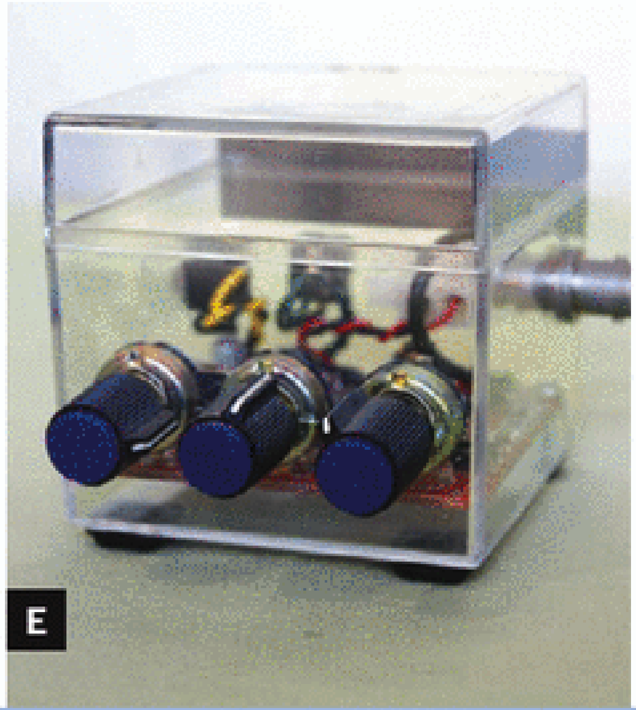


Fig. A: Any small metal container can become a project case. Fig. B: The author's version of a radio transceiver in an Altoids mint tin. Fig. C: The Tuna Tin 2 amateur radio transmitter, an early example of a project using a recycled food can as a chassis. Fig. D: A shortwave receiver in a tea tin. Fig. E: A 20-meter transceiver built into a 2½" plastic watch display case. Fig. F: A castoff milk jug makes a fine speaker enclosure.

many shapes and sizes. If you can't find a case to fit the original project design, consider breaking the circuit down to several smaller boards to fit in the case you have on hand. More than once, the discovery of a small metal box during one of my scrounging sessions has led me to spend many enjoyable hours trying to come up with just the right circuit to cram in.

Surface mount technology (SMT) can allow for even more complex projects. More and more home electronics builders are experimenting with these ultra-tiny component packages. The limiting factor with SMT case choices is often the size of the control components (switches, potentiometers, input/output jacks, etc.) and not the board-level parts themselves.

SMT lets you break free of the mint tin form factor to explore other recovered case solutions. And if your circuit doesn't depend on a metal case for shielding, a nearly infinite number of recycled plastic items become possibilities.

One of my first efforts at repurposing a found container to electronics use goes back to the days when fellow MAKE author Nick Archer (*see MAKE, Volume 13, page 172*) and I were teenagers, riding our bikes to local junkyards and trash heaps in search of broken electronics. Nick found the idea to use discarded gallon milk jugs as speaker enclosures in a long-forgotten electronics magazine. I have continued to use this idea for nearly 40 years!

The spout of the jug proves to be an excellent bass reflex port, and sometimes I even build a crossover circuit and add a small tweeter on the side of the jug. You can weight the jug's base with some plaster of Paris to give it stability. Great sound and a great conversation piece.

One additional note about using found project cases: if you make a mistake cutting or shaping the case to suit your needs, you're not out anything but the time it takes you to return to your recycling bin. The money you save by using repurposed cases can go toward the purchase of the parts you need to build the design.

Don't let the lack of a case stop you from trying out your next electronics experiment. Just open your eyes to the many possibilities the world around you provides.

T.J. "Skip" Arey has been a freelance writer to the radio/electronics hobby world for more than 25 years and is the author of *Radio Monitoring: A How-To Guide*.

Photography by Thomas J. Arey; and Sam Murphy (Figures B and E)

ELECTRONIC ROADKILL

Scrounging useful components on your two-wheeled travels. By Thomas J. Arey

My articles for this magazine about scrounging and repurposing found items are not limited to describing how to dig through trash bins and dumpsters for maker gold.

I'm an avid bicyclist and, on my training rides, I've discovered that all too many people take the notion of living in a throwaway society to its worst conclusion. The roadsides are littered with many things.

I must remain aware of such effluvia as a matter of self-preservation when cycling. While keeping my eyes on the road for things that might pierce my tires or send me over the handlebars, I am discovering an increasing amount of what I have come to call "electronic roadkill."

On a recent 30-mile loop I found no less than 3 castoff electronic devices that were worth stopping for: a cellphone, a partial electronic calculator, and a slightly damaged portable CD player.

Let's see what a maker can do with these recovered gadgets.

Roadkill Cellphone

The found cellphone was a discount/convenience store "pay as you go" model, banged up and inoperable, but intact. Apparently, when the owner ran out of minutes they just pulled the SIM card and tossed the unit out the car window. The battery is a nice compact 3.7-volt 920mAh lithium-ion unit that can be put to work in many electronics projects.

I also pulled a few other pieces off the phone to add to my parts piles. The eccentric motor used to vibrate the phone when it rings has potential, as does the ultra-mini speaker.

The majority of the phone circuit was proprietary surface-mount devices with little hope of easy recovery but I was happy to come up with the free

Photography by Thomas J. Arey

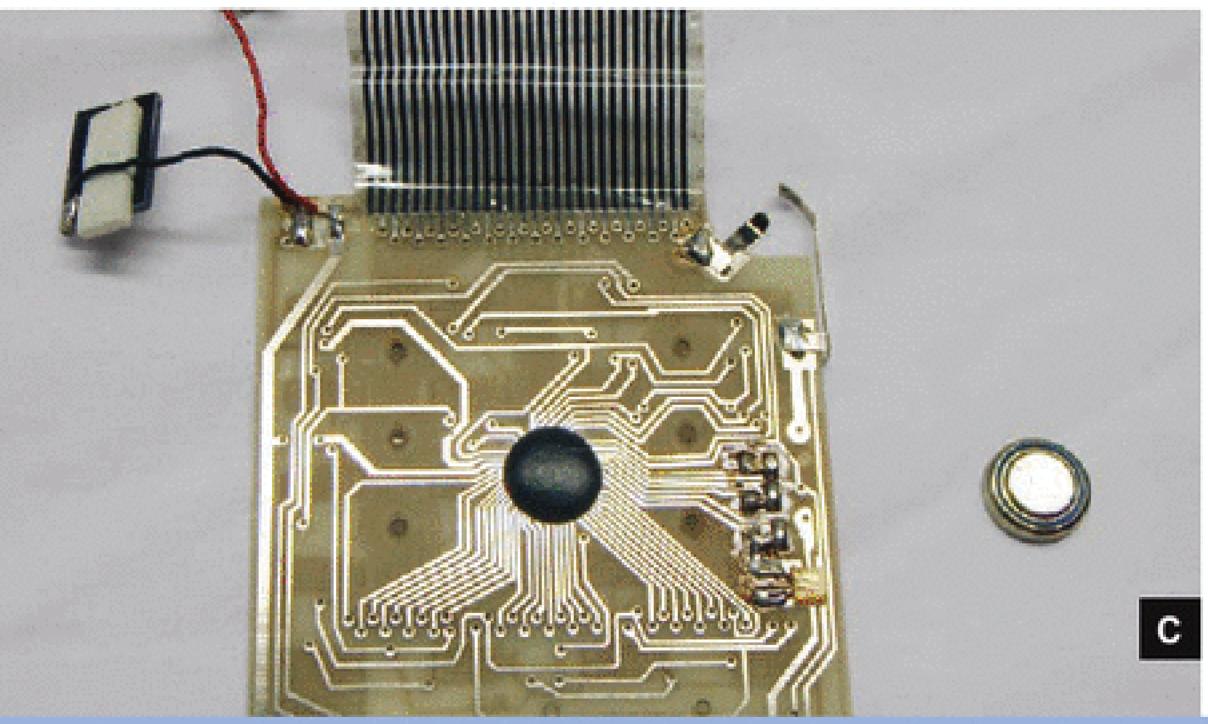


Fig. A: Electronic roadkill: Cellphone, calculator, and CD player, abandoned but worth recovering.
Fig. B: The battery, vibrating motor, and speaker make the cellphone worth stopping to pick up.

Fig. C: Nothing but a button cell and a bit of manufacturing knowledge to be found in the broken calculator.
Fig. D: Jackpot! The CD player is full of useful parts.

battery and a couple of other parts with potential. Some folks might also try to make use of the keypad and the LCD screen.

Roadkill Calculator

The pocket calculator had seen better days. It had been run over quite a few times. The LCD display was missing and, sadly, the part with the most immediate potential, the solar cell, was broken into 3 pieces. So it goes. While I recovered no usable parts other than the key tops, I learned a lot about how these low-cost calculators are put together. It's not always just about recovering parts. Basic knowledge has value to any maker as well.

The PC board was essentially the switch contacts all traced back to a "potted" blob in the center of the board. No doubt the blob contained one or more proprietary ICs that did all the thinking and power management, a very elegant and simple solution. Once you look inside, it's easy to see how these units can be made for pennies and sold for dollars.

I was glad to pick the calculator off the road just to recover the "button" cell for proper recycling. These cells often contain toxic metals that should not end up in the environment. No parts, but a warm feeling that I helped the planet out a bit. Recovering and repurposing electronics for environmental (and fun) reasons should be added to the Maker's Bill of Rights (downloads.oreilly.com/make/MAKERS_RIGHTS.pdf).

Roadkill CD Player

While the pickings were slim on the first 2 found devices, I hit the mother lode with the run-over CD player. While the case was split open, the circuit board, motor, and laser reader appeared intact. If the case wasn't integral to the proper alignment of the CD, the unit might have still worked.

But I was more interested in what components could be recovered and repurposed in future projects. I found 2 small slide switches, 7 momentary push-button switches, 10 capacitors, 4 SMT transistors, and a small LCD screen. I also recovered a stereo earphone jack and external power jack as well as a 2xAA battery case. I also kept the motor for future use.

My bike-riding finds have not been limited to electronic roadkill. Over the miles I've also found hand tools, various small hardware, and once even a full sleeve of heavy-duty tie wraps. Keeping your eyes on the road doesn't just make for safe riding, it can provide a maker with many opportunities to recover, reuse, and repurpose what others have left behind.

ANIMAL DETECTOR

A webcam captures animals who visit while you sleep. By Bob Goldstein

Photography by Bob Goldstein

My 4-year-old son comes up with some funny ideas. A few months ago, he asked for a piece of cheese to leave outside for animals. We gave him a slice of cheddar. The next morning he jumped out of bed and hurried to the window. The cheese was gone, but who had taken it? He was guessing all day. We looked for footprints or tiny hairs, but found no clues.

Then we got more ambitious. I knew that some webcam programs can record video only when there's visible motion. That might record visitors in daylight, but not in the dark. So we got an inexpensive infrared-sensing floodlight — a standard home security device — at a hardware store. I figured that in theory, a warm animal moving in front of the device should make the light turn on, and then the webcam program would see movement and start recording.

That evening we tested it, with the webcam pointing out a window and the floodlight just outside. The next morning, my son and I raced to the laptop. A white cat had visited at 4:30 a.m., and the video caught it flinching as the light came on, looking quizzically at the contraption, and then starting to eat. My son was fascinated, and we were both hooked on our new hobby.

Lights, Webcam, Action!

Instead of a plug, most motion sensor lights have loose wires for connecting to house wiring. We wanted to plug ours in outside, so we drilled a hole in the plastic casing for a 2-wire plug cord, twisted the corresponding wires in each pair together, and insulated the connections with twist-on connector caps. Then we sealed the space between the cord and the hole with crazy glue.

MATERIALS

- **Motion detector floodlight** We used a Cooper Regent MS35, $13.
- **Floodlight bulbs (2)** $3 each
- **2-conductor cord with power plug** about $5
- **Wood board, 12"×18"**
- **Wood dowels, 1" diameter, 9" long (4)**
- **Wood screws (4)**
- **Empty tin can** with ends removed
- **Computer** We used a Mac laptop.
- **Webcam** if the computer doesn't have one built in
- **Motion detection software** We used BTV Pro (bensoftware.com, $34, free 15-day trial). Other similar programs exist for both Mac and PC.
- **Duct tape**
- **Cyanoacrylate glue** aka super or crazy glue
- **Bait** such as pet food or old fruit
- **PVC pipe (optional)**

TOOLS

- **Power drill and drill bits**

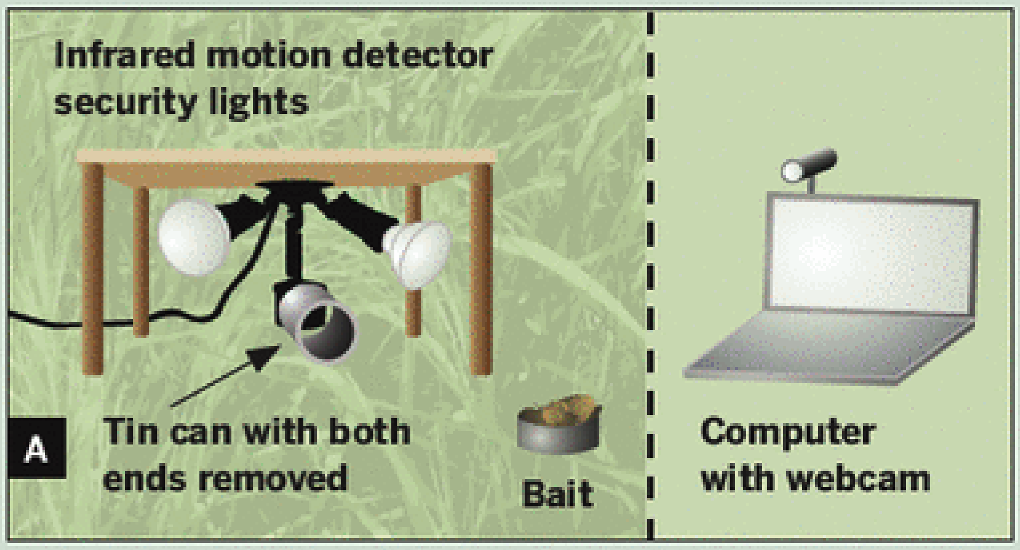


Fig. A: The setup is very simple. Fig. B: Closeup of a nighttime visitor. Fig. C: Backgrounds added for comedic effect.

NOTE: I really don't know what I'm doing playing with wires and electricity. Please take care to protect yourself appropriately.

The lights and motion sensor are designed to work outside, but rain dripping into the sockets can be a hazard. So we mounted the device under a protective platform built by simply screwing 4 wooden dowels into the corners of a board. We attached the motion sensor light underneath, following the included instructions. We also bought some PVC pipe to fit around the legs, to use as stilts if we ever want to raise the platform.

Motion sensors detect movement over a wide angle, so we duct-taped an empty tin can with both ends removed over the sensor (see Figure A). This serves as a blinder so that only animals right at the bait will make the light turn on.

To capture video from inside the house, we used a Mac laptop and a webcam running BTV Pro. This Mac-only software has a motion detection setting, plus a nice option to show the time in the corner of the video image (Figure B).

For bait, we've successfully used inexpensive cat food, old fruit, or scraps from dinner. Before we retire for the night, we just start up BTV Pro and put out the bait. Then it's like the old Easy-Off oven cleaner ads: it works while you sleep!

Results

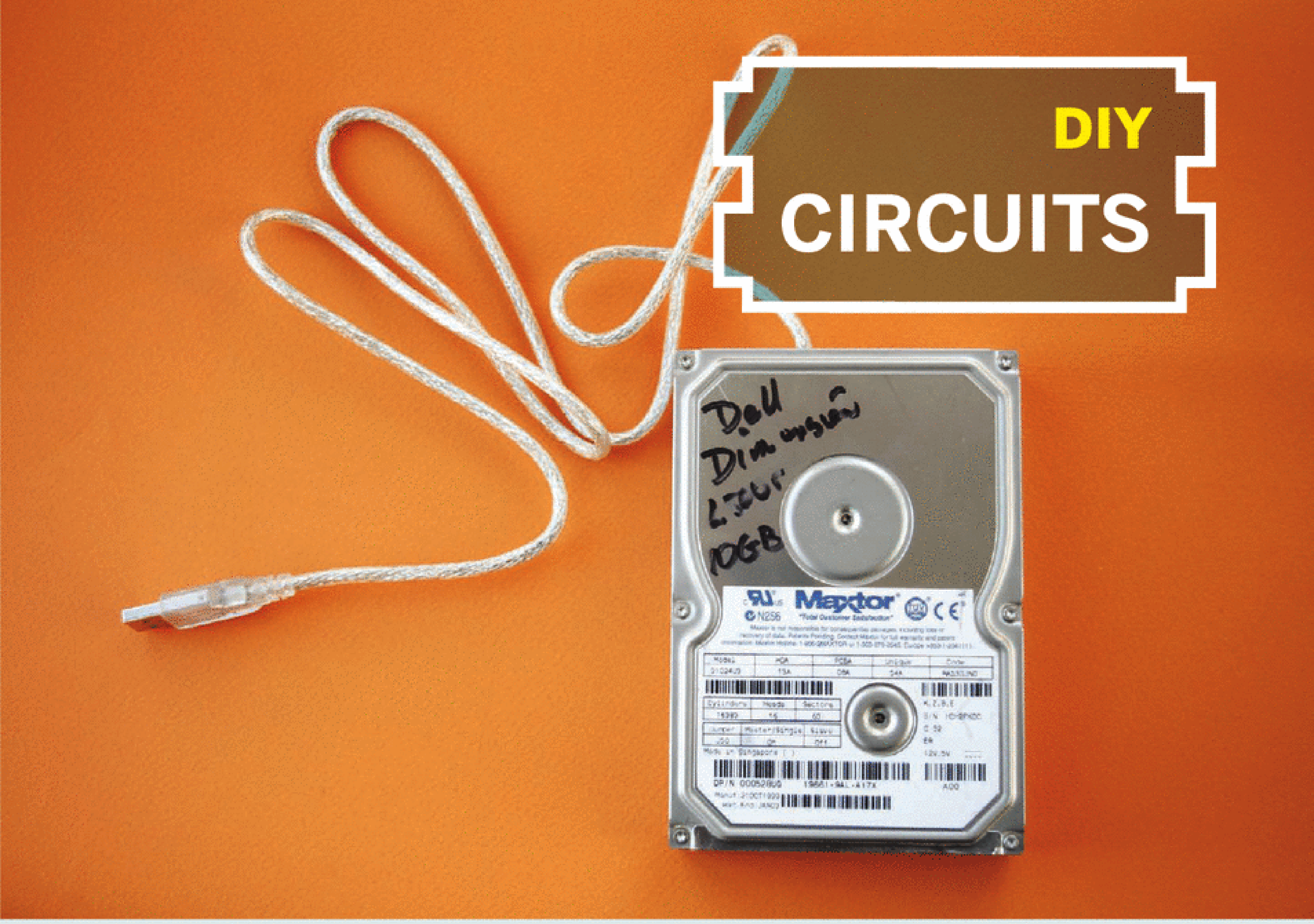
After our first night's success, I thought we might just keep getting the same cat. But the diversity of animals we've captured on video has been amazing.

In our first month, we shot 9 species: raccoons, cats, 1 robin, 1 wren, 1 catbird, 1 sparrow, 1 squirrel, 1 rabbit, and 1 human — our neighbor's son passing through our yard early one morning. And we've had possums come so regularly that we started putting out decorative backdrops for a laugh (Figure C).

The entertainment payback for this easy and inexpensive project has been terrific. Setup takes just a few minutes each day, and an animal appears most nights. Some animals have given us quite a laugh, like a possum that walks slowly in reverse each time the light turns on, a young rabbit that appears to panic and run toward — instead of away from — the house, and a squirrel who's learned to evade the motion sensor with a commando-style crawl.

Bob Goldstein is a dad who enjoys making stuff. His son wants to be an inventor when he grows up. Their videos can be seen at animaldetector.blogspot.com.

Illustrations by Alison Kendall



DIY CIRCUITS

FLASH MEMORY HARD DISK

This fake hard drive stores more data and raises eyebrows. By Brian Nadel

I love mixing technologies to create an amalgam that looks like one thing but is actually something different. A case in point is the old hard drive that I stuffed full of flash memory. It looks like an internal drive, but it's actually a solid-state memory peripheral that plugs in via USB. This makes it an instant conversation starter for anyone who ventures into my office.

1. Gut the hard drive.

The original drive stored 10GB, and by filling it with three 4GB memory sticks, I actually increased its capacity. To start the conversion, I attacked the 3½", 2-platter hard disk drive. Using a T9 Torx screwdriver, I unscrewed about a dozen screws from the case. Then I tore out the guts and cleared out space to make room for the flash drives and their cables.

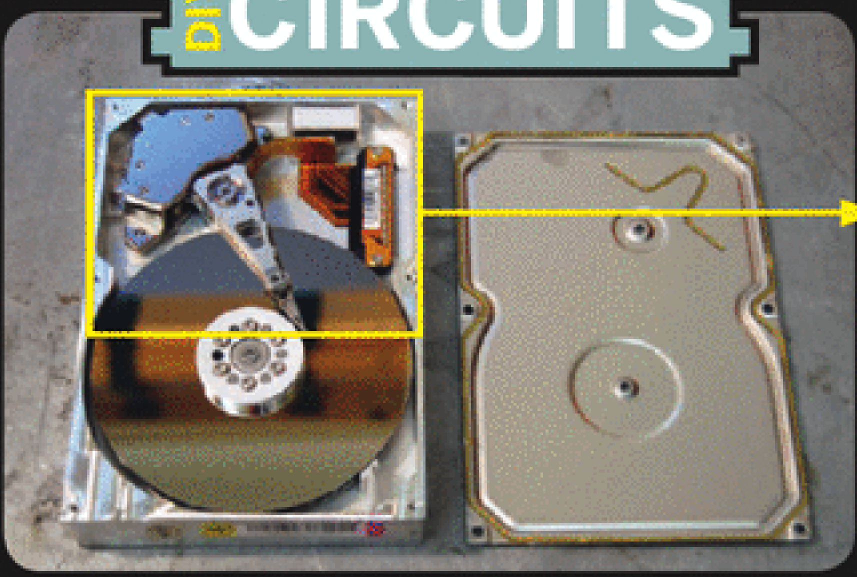
Photograph by Sam Murphy

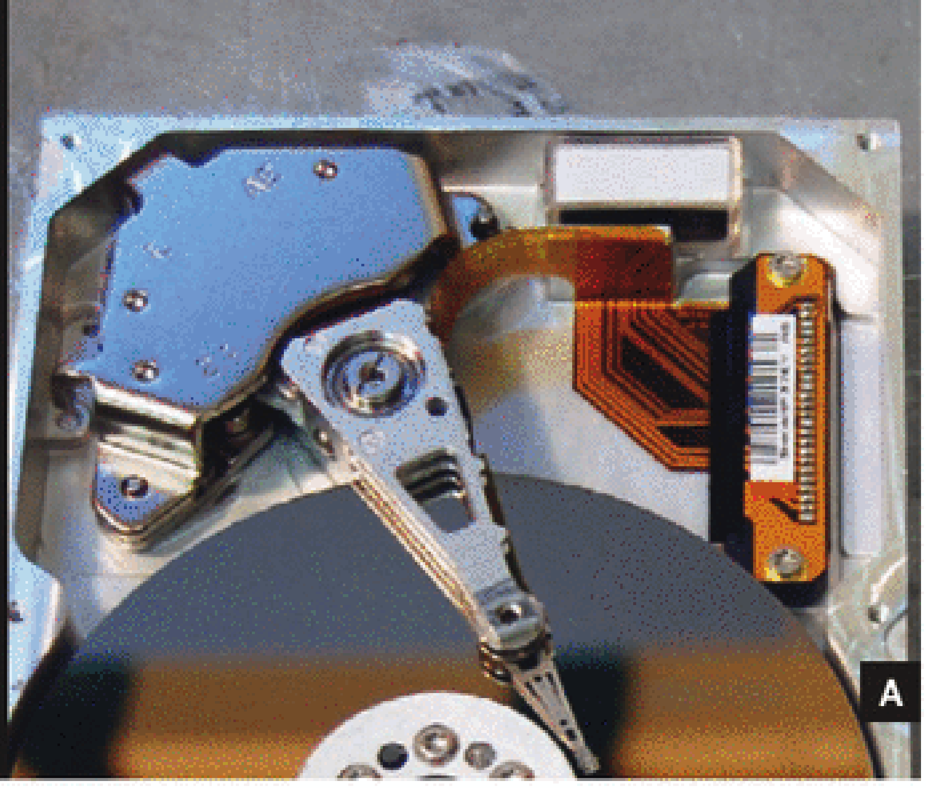
MATERIALS

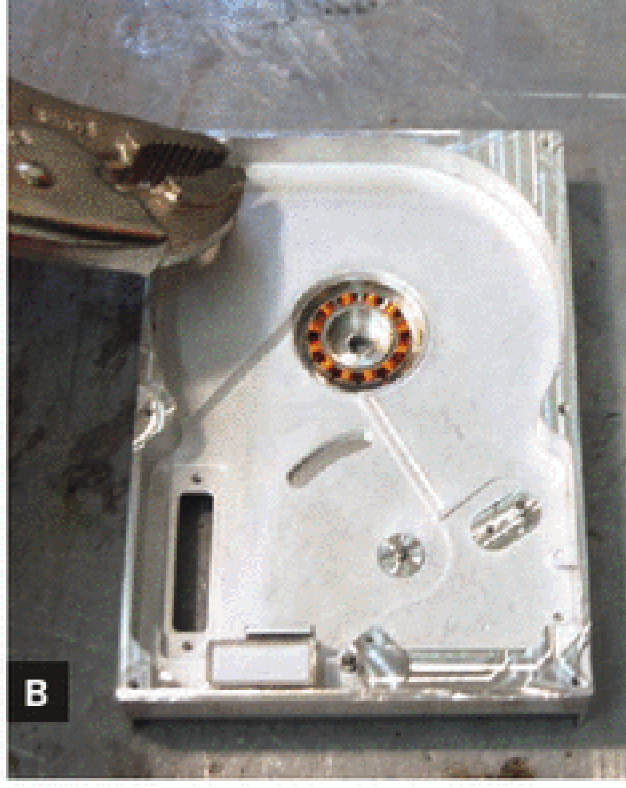
- **Old hard disk drive** does not need to work
- **Small USB hub**
- **USB flash drives (3–4)** as many as the USB hub will take; I used 3.
- **USB cables (3–4)** Get 2–3 short ones, to let the memory sticks pack close together, and another one of any length for the external cable.
- **Insulating tape**

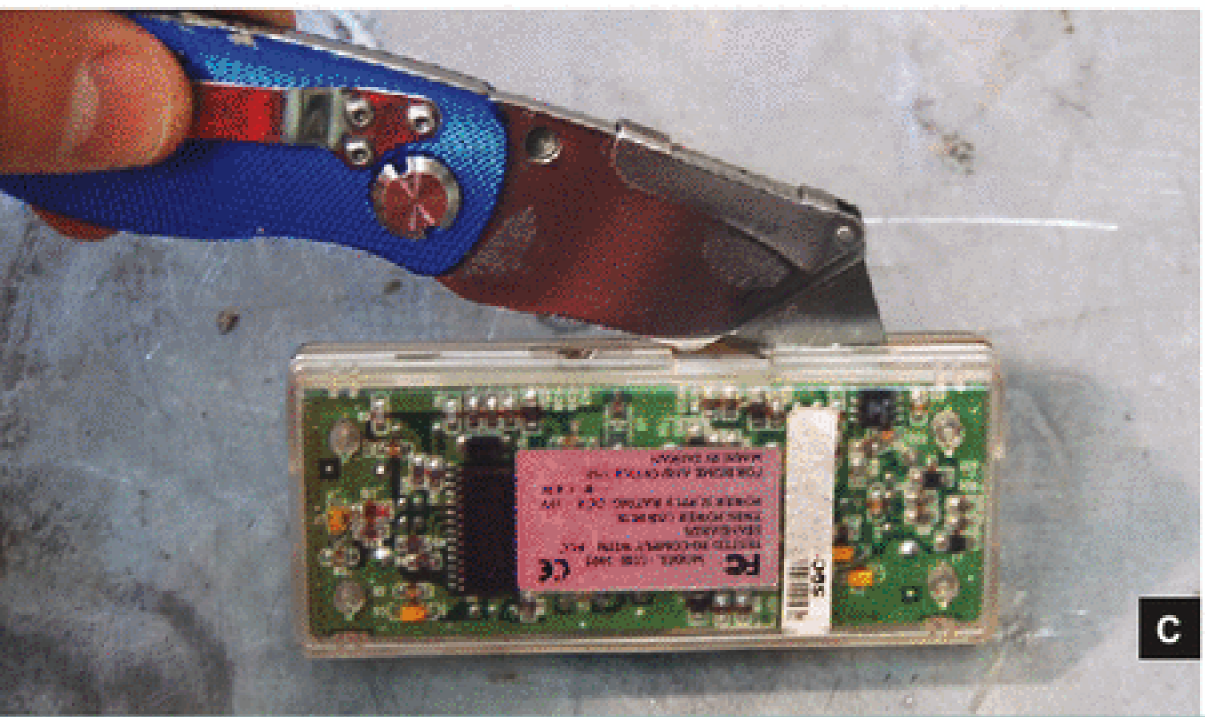
TOOLS

- **Torx screwdriver** My drive's screws needed a T9.
- **Large slotted screwdriver or equivalent** for prying
- **Pliers**
- **Dremel with abrasive wheel bit**
- **Drill and drill bits**
- **X-Acto knife**









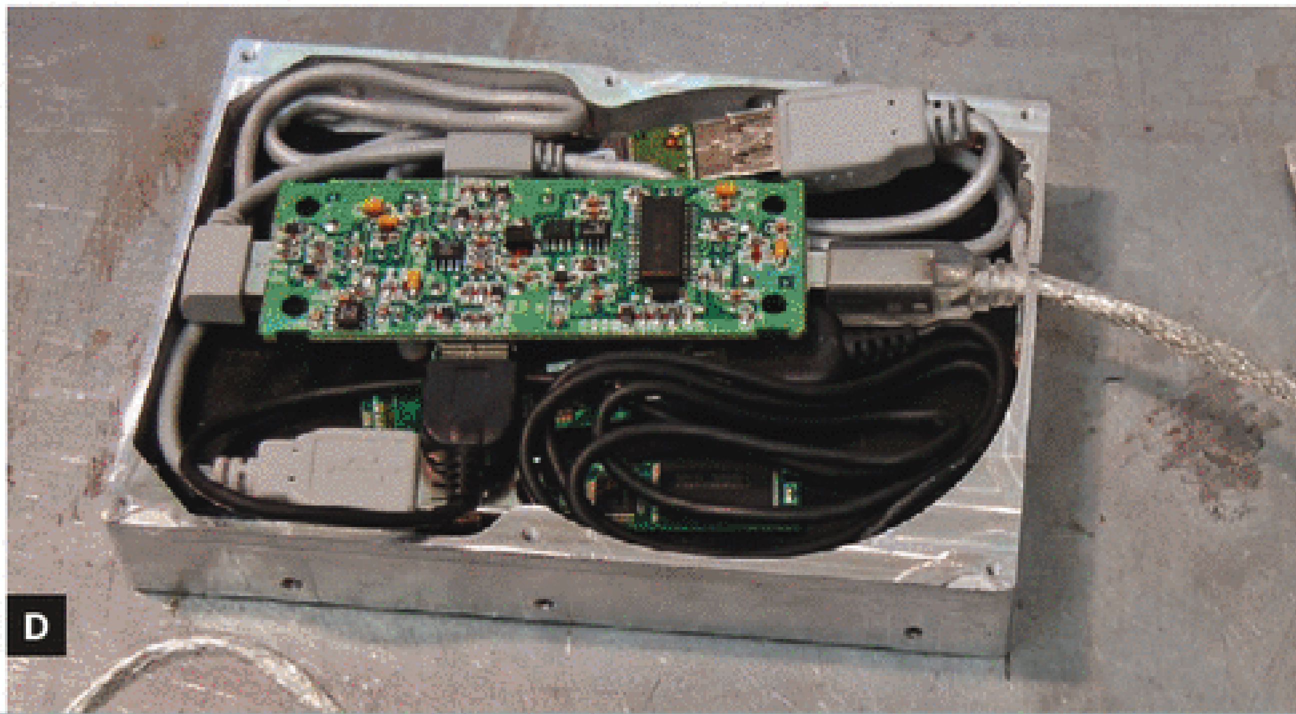


Fig. A: Hard disk drive with case opened. The neodymium magnet, upper right, is strong enough to require prying. Fig. B: Clear space inside the case by removing internal posts.

Fig. C: Pry apart the USB hub case and remove its board. Fig. D: Memory sticks, cables, and USB hub packed into the hard drive case. The external USB cable exits a hole drilled in one end.

You can use a large screwdriver to pry loose the magnets (Figure A, at top left). Any molded nubs or mounting studs inside you can break off with pliers (Figure B) and grind flat with a Dremel and an abrasive wheel.

2. Mount the USB hub board.

With the drive's case empty, I lined it all around with insulating tape, to prevent shorts. Next, I pried the USB hub's case apart (Figure C) and found a way to fit its board inside the drive case. I then drilled a hole in one end of the case, at the edge next to the lid, making it just big enough to tuck the external USB cable down into.

3. Stuff it all in.

Finally, it was time for the main event. I removed the flash drives from their cases, used USB cables to connect them to the hub, and packed everything into the hard drive case (Figure D). It was a tight fit, but there was enough room.

I then threaded the external cable out through its hole, screwed the hard drive's lid back down, and plugged the cable into a computer to make sure that my handiwork actually worked.

4. Configure 3 drives as 1.

All 3 drives responded, so there was one more thing to do. Rather than having to deal with 3 separate drive letters, I navigated Windows to combine them into a single letter. To accomplish this, start at the Disk Management page, and convert each drive into a "Dynamic Disk." This isn't hard, but it's tedious and confusing.

Now the 3 drives act like a single disk that gives me a place to stash my most precious digital possessions. I took an old disk drive, and in a flash I converted it into a solid-state "drive" that holds more data and runs faster than the original. You *can* teach an old drive new tricks!

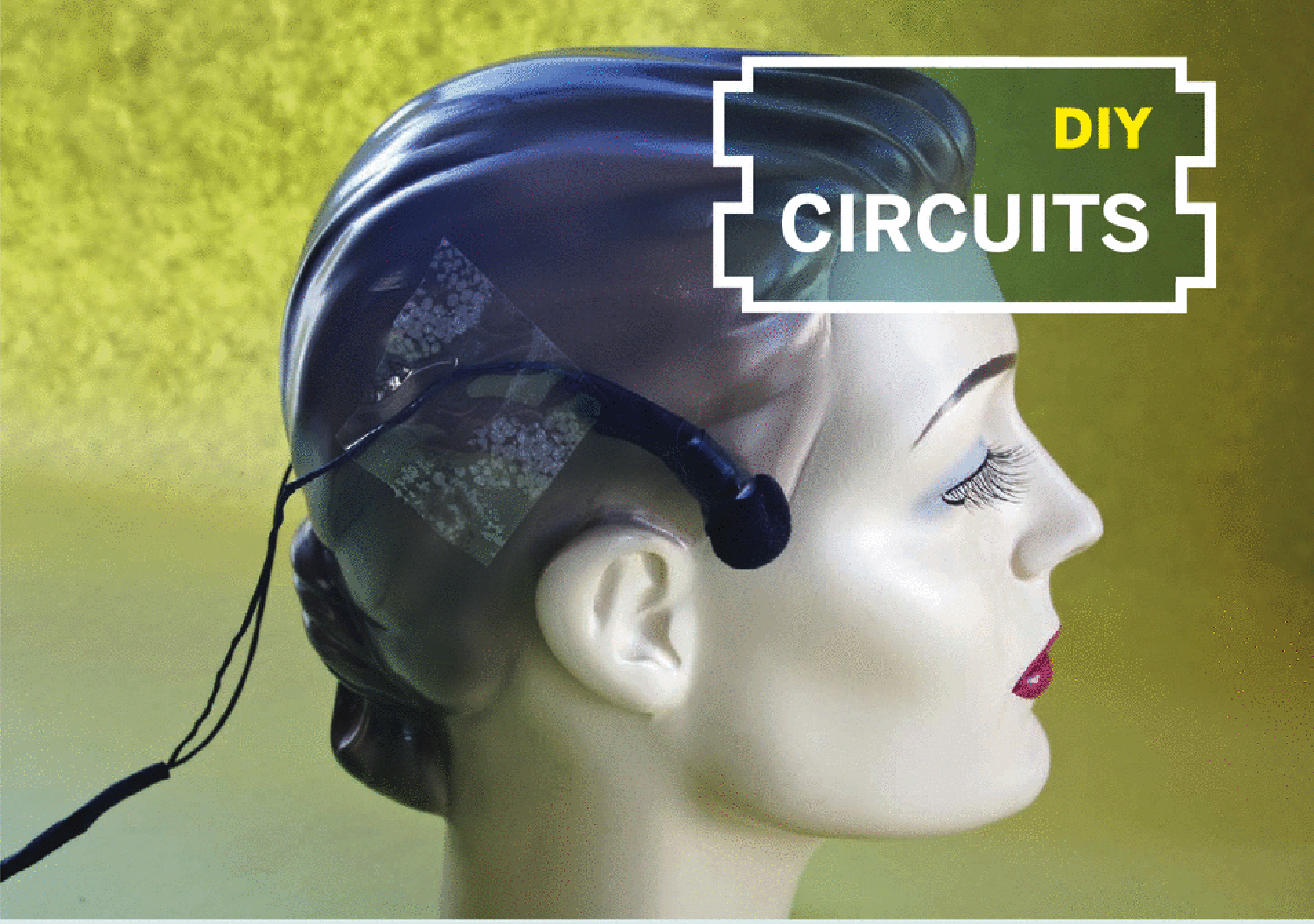
Brian Nadel is a New York-based writer and the former editor-in-chief of *Mobile Computing & Communications*. A 25-year veteran of technology journalism, he's worked for *Popular Science*, *PC Magazine*, and *Business Tokyo*.

Make: TIPS!

Salad Tong Finger Saver
A cut-down pair of plastic salad tongs keeps me from having cut-down fingers when cutting small items on a band saw.
—*Frank Ford*, frets.com/homeshoptech

Find more tools-n-tips at makezine.com/tnt.

Photography by Brian Nadel



THE STEALTH MIC

Disguise an inexpensive binaural microphone as ordinary earbuds. By Bill Byrne

Photograph by Sam Murphy

A binaural recording system re-creates the way a person actually hears by placing 2 microphones at a distance of about 7" (roughly the distance between your ears), usually mounted on a dummy head or worn on the human recorder's head. When played back on headphones, the binaural stereo effect is preserved and is often quite remarkable in its realism.

With some easy modifications, a pair of headphones can be turned into a binaural microphone with readily available materials and cheap parts. Better yet, I'll show you how to make your own binaural mic, disguised as earbuds.

In today's iPod-saturated urban environment, no one ever notices someone wearing headphones. This makes earbuds an ideal prop for covering a hidden mic that's plugged into a recording device, for various stealthy endeavors.

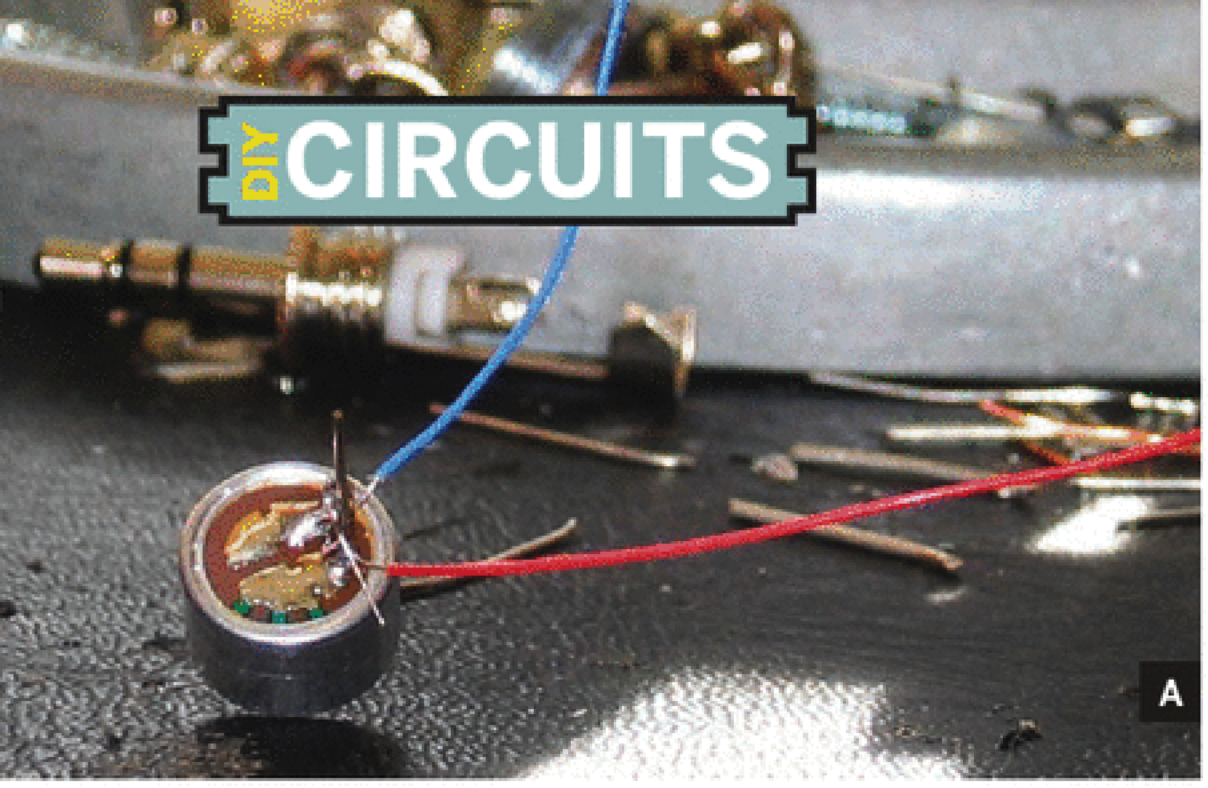
MATERIALS

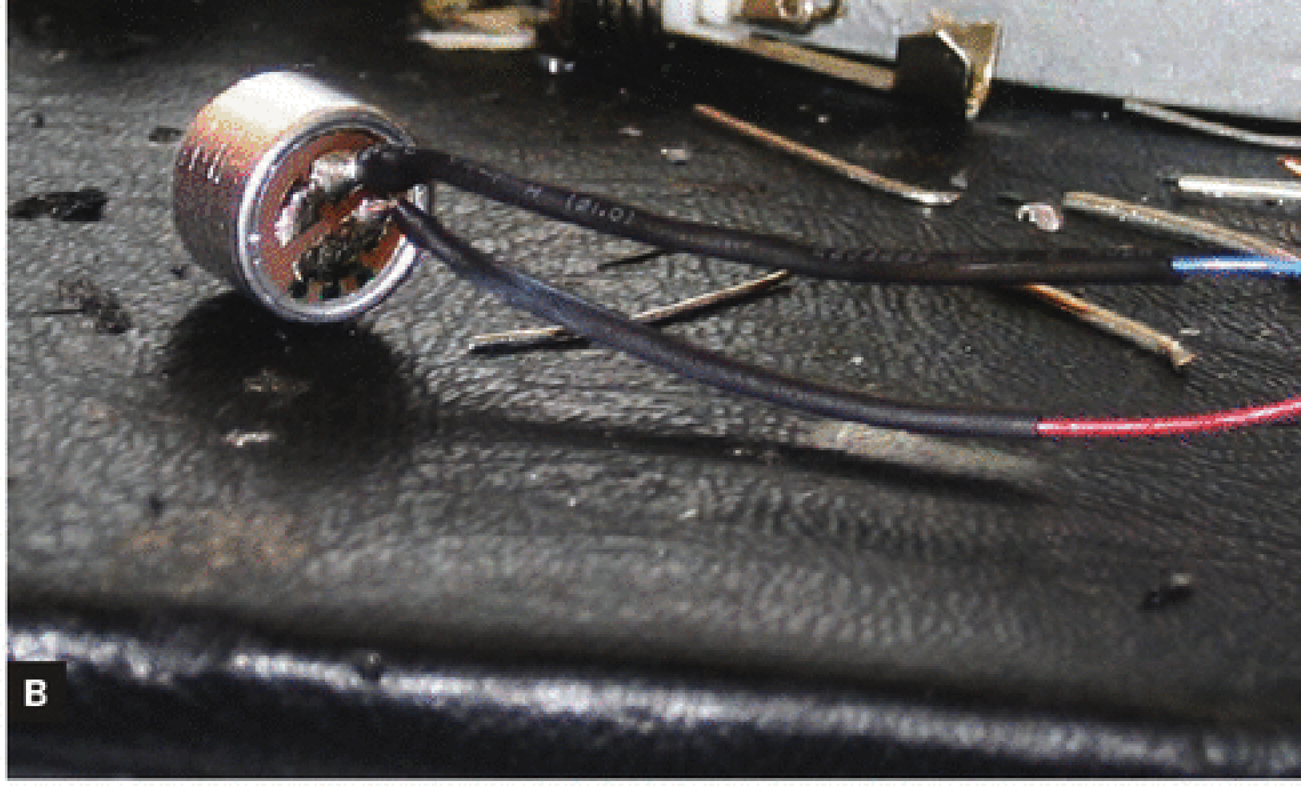
- Microphone condenser elements (2) RadioShack part #270-090
- Solid-core wrap wire, 30 gauge in 2 colors
- Soldering iron and solder
- ⅛" heat-shrink tubing
- Lighter
- ⅛" stereo plug
- Earbud cushions

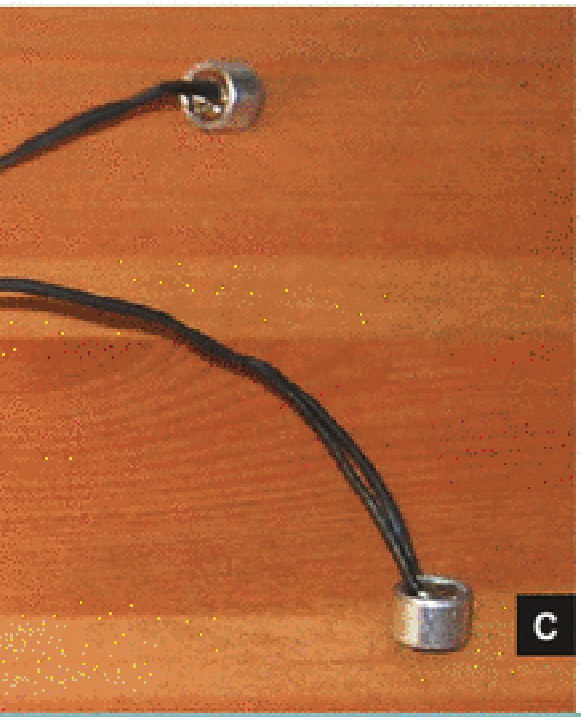
1. Wire the binaural mic elements.

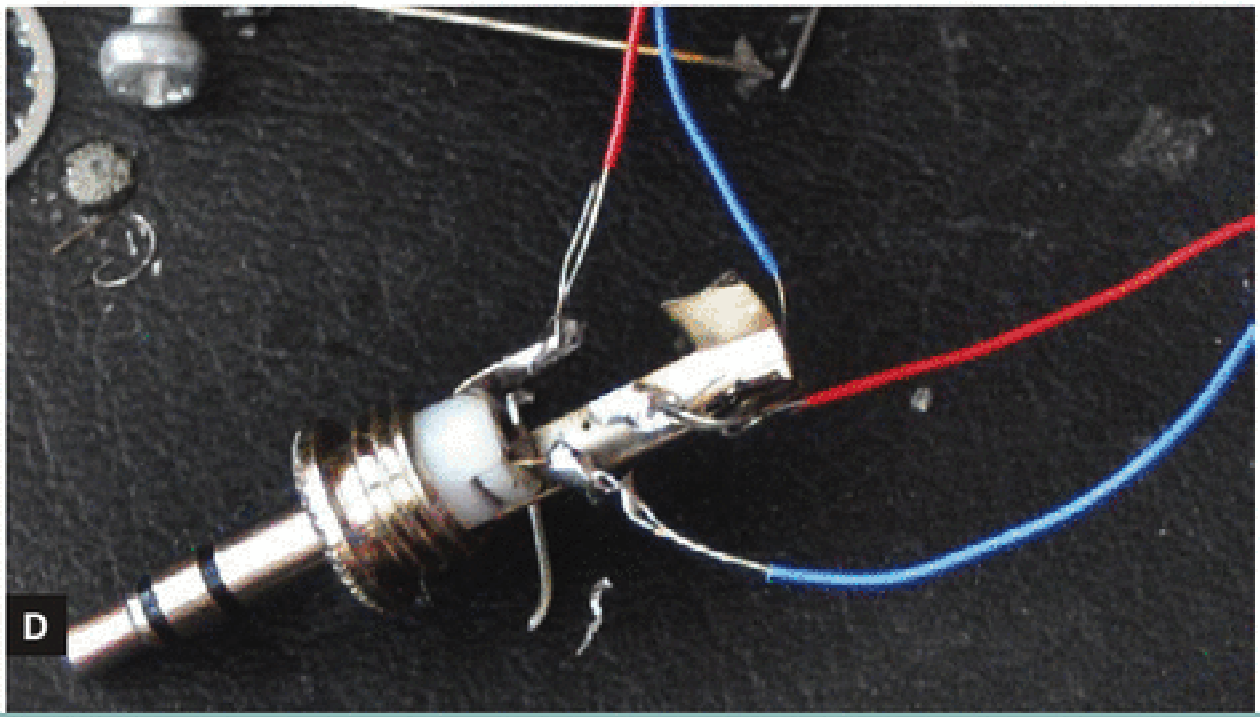
Normally I don't use wrap wire because it's so thin it can be frustrating to deal with, but in this case, for earbuds, we really need the wires to be thin and lightweight.

Cut two 3' lengths of wrap wire in each of 2 colors. Solder these to the first microphone element's 2 contacts (Figure A, next page). Slide a couple inches









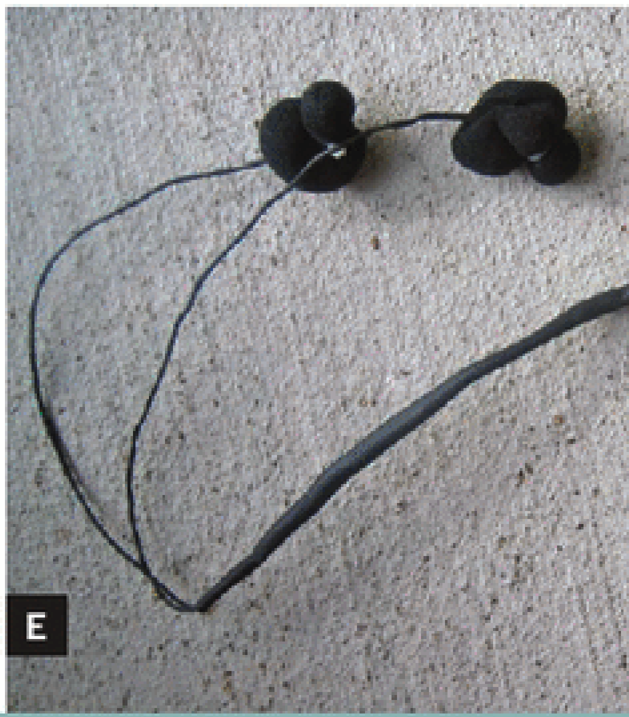


Fig. A: The microphone element soldered to 30-gauge wrap wire. Fig. B: Heat-shrink tubing reinforces connections to avoid introducing noise. Fig. C: Both elements wired and reinforced. Fig. D: Wire each element to the stereo plug in opposite directions, with ground (in back) connecting to blue on one, red on the other. Plug tip is the right channel, and sleeve (middle) is left. Fig. E: The finished microphone passes as earbuds.

of heat-shrink tubing over each connection, and heat it with a lighter. This will secure the connections (Figure B). We want them to be as stationary as possible, as movement of these wires will create noise on the line.

Twist the 2 wires together, but not too tightly. Slip on another piece of heat-shrink, this time over both wires. Slide it up to about 2" from the mic element, then shrink it.

Repeat the same process with the second mic element (Figure C).

About 10" from the mic elements, slip another piece of heat-shrink tube over to combine all 4 wires. Keep track of which pair goes to which mic.

2. Wire the stereo plug.

Open the stereo plug, and slide the cover over the 4 wires. Here's the trickiest part: in order to have the correct stereo image, the wires on 1 of the 2 mic elements should be reversed. So, for one mic element, the red goes to a plug terminal, and the blue to the plug's ground; on the other mic element, the blue goes to the second plug terminal and the red goes to the ground (Figure D).

Solder these connections, then screw the cover back on the plug.

3. Disguise the mics as earbuds.

Fasten the earbud cushions over the mic elements so that they're large enough to sit comfortably in your ears (Figure E). That's it, you're done.

4. Record.

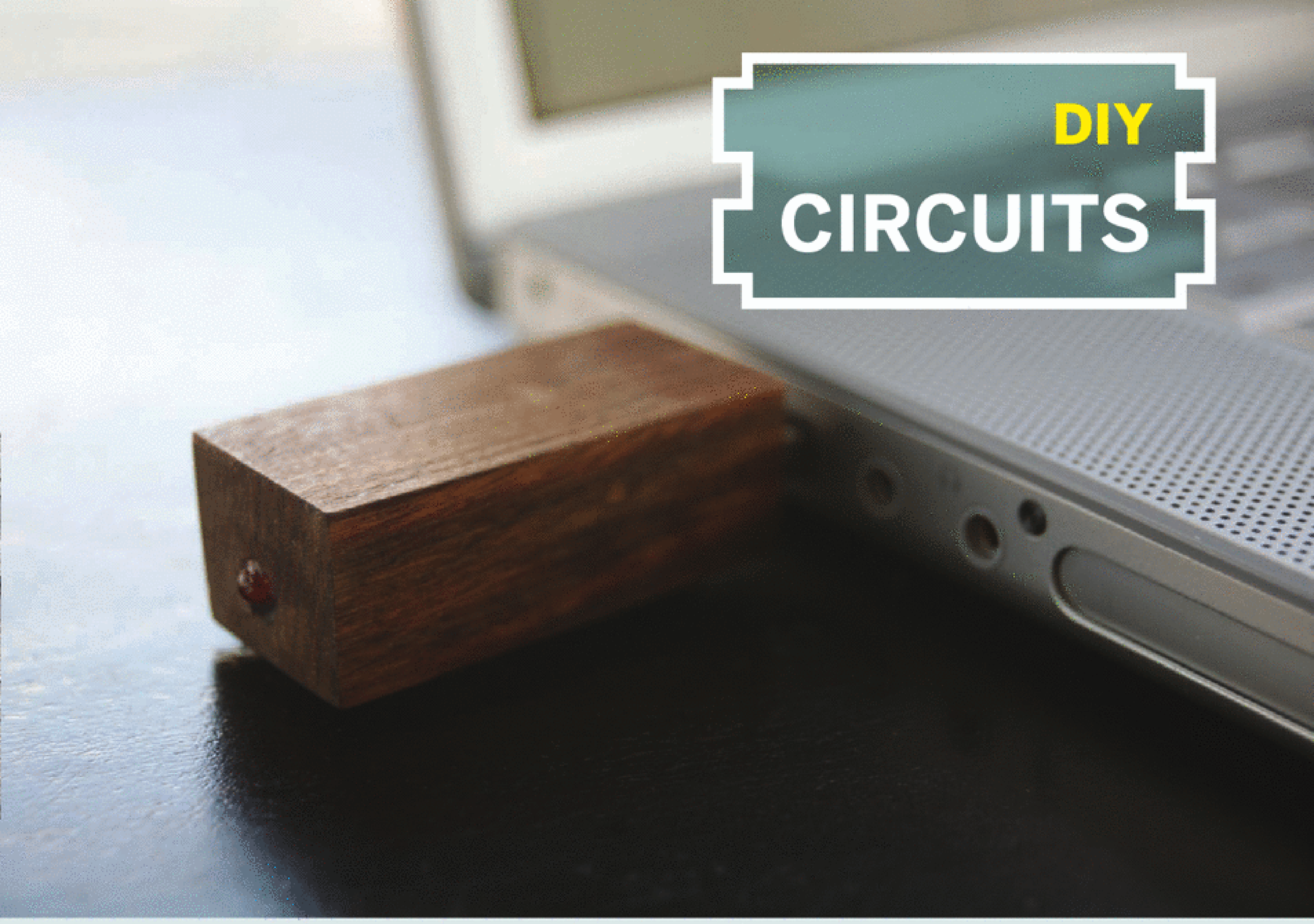
To hear exactly what's being recorded, some folks will actually use a mannequin's head to hold the binaural mic, and will hold the head in their hands while wearing a pair of normal headphones to monitor the sounds. Working this way creates the amazing effect of listening to a binaural recording as it happens, but keep in mind that if you walk around holding a dummy head out in front of you, you may attract attention (in fact, I think you'd get arrested in some places).

With these stealth binaural mic headphones, as long as you're in a situation in which it's socially acceptable to be wearing headphones, you can record away, knowing that what you hear will be very close to what you play back later.

+ For a schematic diagram and list of recordings, go to makezine.com/17/diycircuits_mic.

Bill Byrne is a multimedia artist, motion graphics designer, and educator. He wrote about Wii control in MAKE, Volume 14.

Photography by Bill Byrne



DIY CIRCUITS

USB KEY MAKEOVERS

These case-modded pocket drives move your files with style. By Brian Nadel

Memory sticks lack character. Even the nicest-looking ones are more functional than fun. But re-skinning a USB flash drive takes only an hour, max, and unlike a PC case mod, you'll carry your creation with you. They also make cute gifts ("Thanks for the memories!").

So far, I've done a finger puppet, a ChapStick, and 2 wood blocks, but these mini-mods are limited only by your imagination. Small toys, wine corks, or even a rabbit's foot are all fair game.

The hardest part is removing the case without damaging the circuit board. Most USB keys can be pried apart, but some require cutting (Figure A, next page). Then you just need to find the right cover.

Finger Puppet

A child's finger puppet is one of the easiest flash drive mods. If the circuit board fits, you just need

Photograph by Sam Murphy

MATERIALS

USB flash drive 1GB drives are as cheap as $5 now. Shop around and you can find them free or very close to it after a rebate.
Plastic wrap
Silicone glue or epoxy
Something to make a new enclosure This can be anything you want. I used a plastic finger puppet, a ChapStick container, and small blocks of wood.
Wood finish if you make the wood block enclosure. I used linseed oil.

TOOLS

X-Acto knife
Needlenose pliers for the ChapStick enclosure
Woodworking tools for the wood block enclosure. I used a saw, vise, drill press, clamp, belt sander, sandpaper, and lathe.

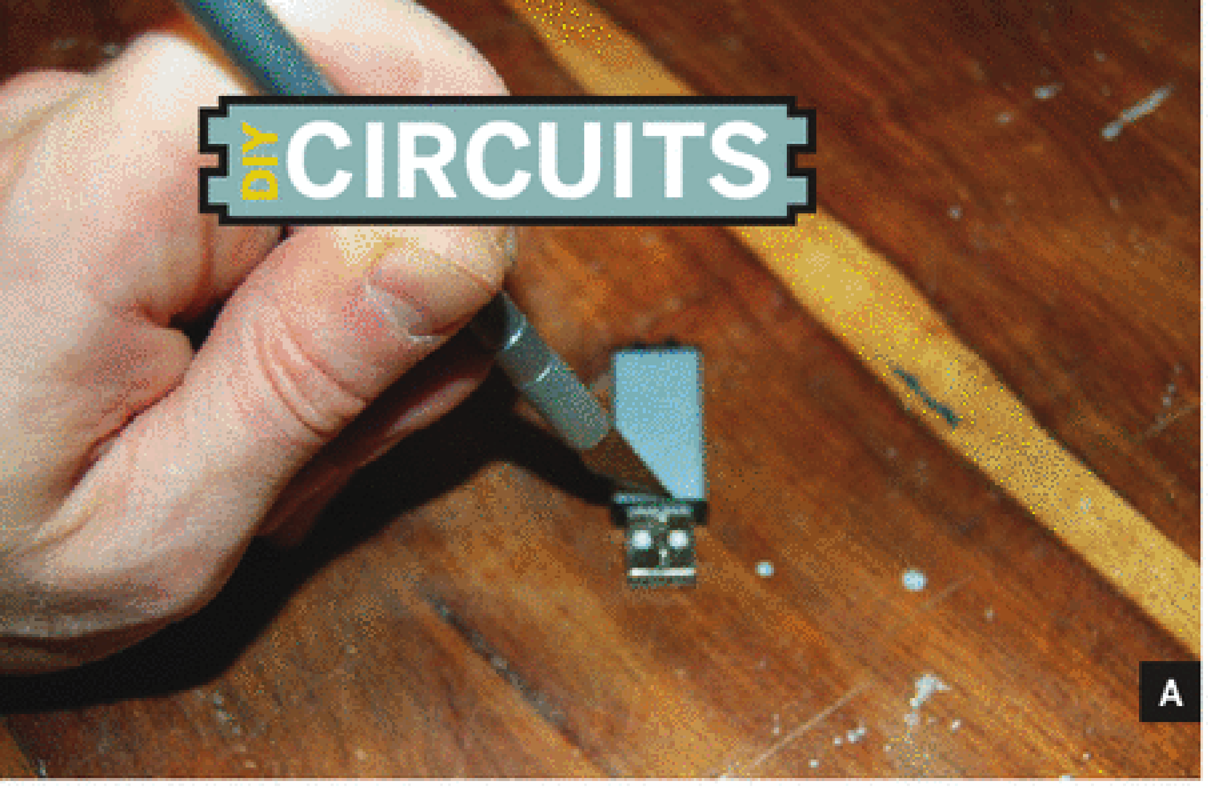


Fig. A: If you can't pry open the memory stick, be prepared to do X-Acto surgery. Fig. B: Cover your stick with plastic wrap to protect it from the silicone glue. Fig. C: Silicone sealant secures the drive in its new ChapStick tube. Fig. D: To make room for the drive, drill the block to ⅛" from the bottom. Fig. E: Finished block, ChapStick, and pirate puppet memory sticks.

to glue it into place. I used a pirate puppet from my son's birthday a few years ago. Its plastic is translucent, so the pirate's head glows eerily when the drive's LED indicator shows data moving in and out.

After shelling the drive, I covered its circuit board in plastic wrap so the glue wouldn't cause problems (Figure B). I slipped the board into place, making sure the USB connector had enough clearance; ⅝" is generally enough. With the board in position, I squirted in enough silicone to seal it in place. An hour later, it was ready to save a few naughty sea shanties.

ChapStick

Hiding a flash drive in a ChapStick (or other lip balm) case takes a little more effort. I started by cutting and peeling off the label, to make it a plain white tube. You can glue on your own label, but I left it bare.

Twist the knob to remove all the product and its carrier, then yank out the central screw with needle-nose pliers. Finally, as before, simply cover the board with plastic wrap and glue it into place (Figure C).

Wood Blocks

Some time ago, my wife bought me a box of hardwood samples, most of which I'd never heard of. To house a USB key drive, I picked a piece of African tamboti wood for its dark brown color and even grain. A small pine cone or knot would also work.

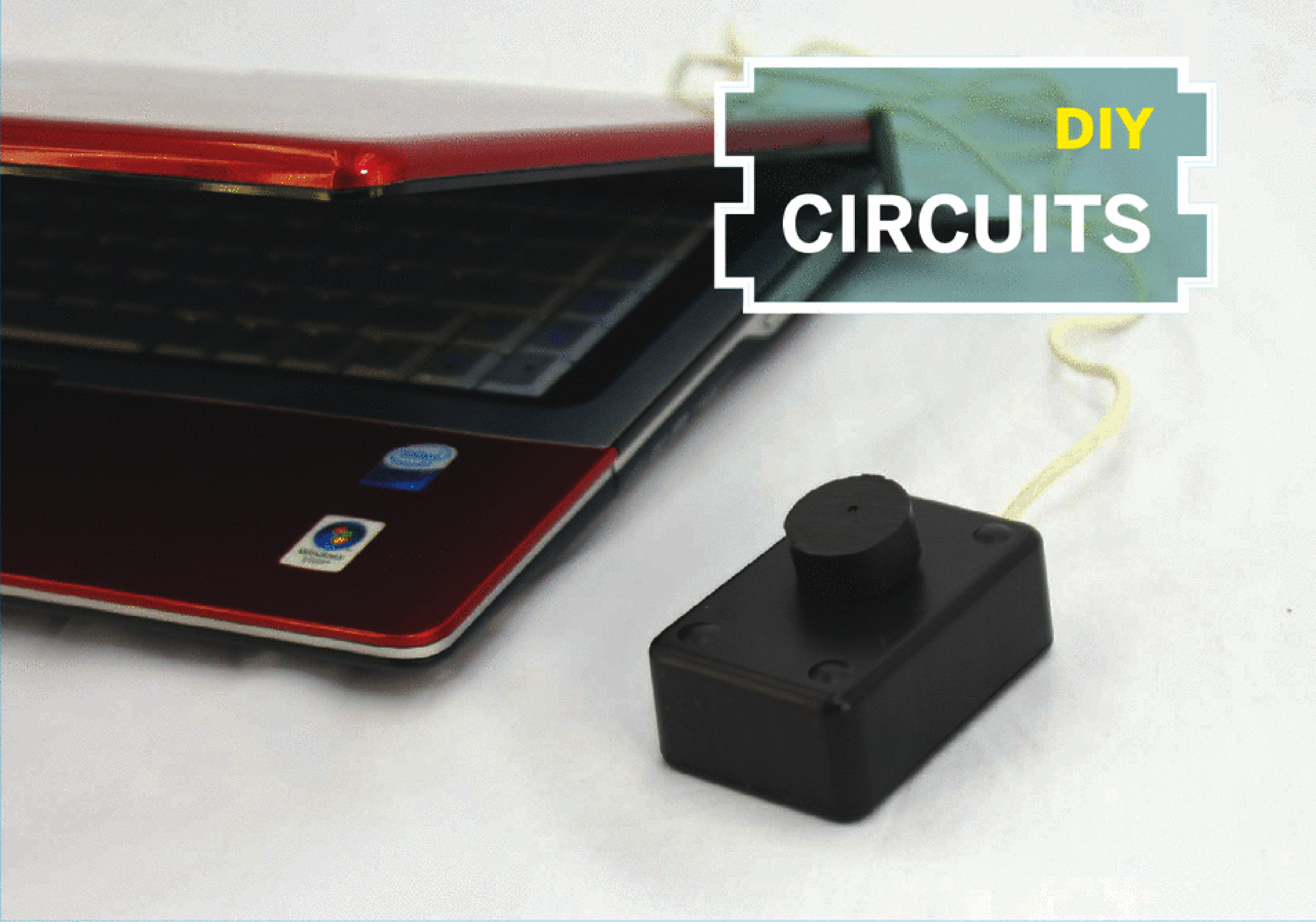
First, I cut the block to roughly the right size. To drill out room for the circuit board, I used a small drill press with its stop set about ⅛" from the bottom (Figure D). Then I drilled another hole just big enough to fit the activity indicator LED. This doesn't need to be precise, because you can bend the LED's wires to the position needed.

Then I shaped the outer surface with a belt sander. To avoid leaving ugly lines, I used 220-grit sandpaper and worked with the grain. For the final polish, I hand-sanded using 400-grit paper. Then I rough-fit the drive board, wrapped it in plastic, and glued it up.

I also did a memory stick makeover using a cylinder of the same wood, which I turned on my wood lathe; a pre-made dowel would work just as well. After turning the block round and drilling holes for the board and a lanyard, I finished both with a light coating of linseed oil for a hand-rubbed luster.

My modded memory sticks move files with style, but here's a word of warning: they tend to disappear. In fact, 3 of the 4 I've made have since been taken by family members, leaving just the pirate for me. In other words, as soon as friends and family see your homemade memory sticks, they'll want one.

Photography by Brian Nadel and Sam Murphy (E)



THE POWERFAKE

Make an inexpensive desktop scroll wheel and volume control. By Daniel Walker

The Griffin PowerMate (griffintechnology.com/products/powermate) is an assignable USB knob controller that you can set up for many purposes, such as browsing Google Earth, scrolling web pages, controlling volume, and so on.

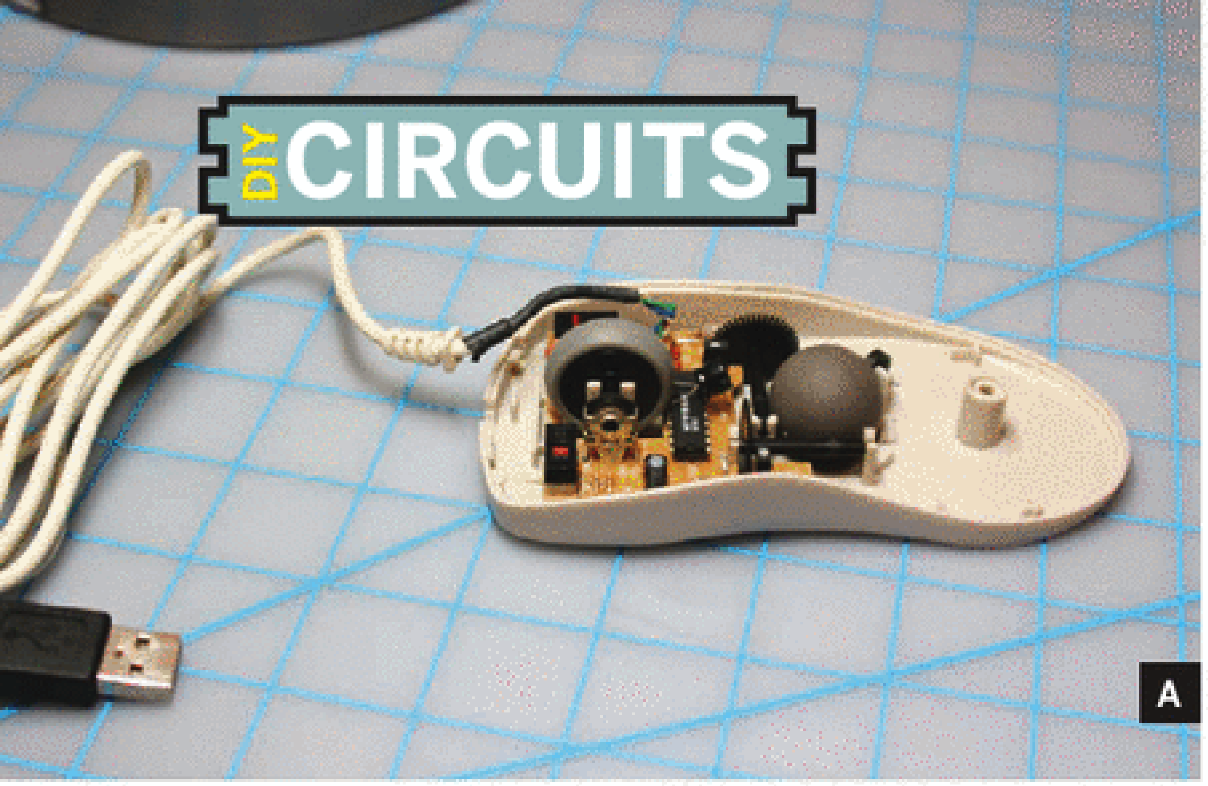
I took a look at some YouTube videos of it in use and thought it was literally a scroll mouse on its side with a fancy knob and some software. A few Googles later, and I found a post on the bit-tech.net forums about a guy who made his own from a VCR spindle and an old mouse. I fancied a bit of that, so away I went, and this is what I came up with.

I call it the PowerFake. It's made from an old PS/2 mouse, a project box, and an old R/C car wheel. The basic idea is to liberate the mouse's scroll wheel encoder from its circuit board, reconnect it using wires, and set it up to run off of the knob of your choice.

Photography by Ed Troxell

MATERIALS

- **PS/2 or USB mouse with scroll wheel** You need a rotary encoder for the scroll wheel, not an IR transmitter/detector. A ball mouse is more likely to use a rotary encoder than an optical one.
- **R/C car wheel and tire** or other circular object you can use for rotating that fits in your hand easily
- **Project box**
- **Thin metal rod** of suitable length to go through your R/C car wheel, project box side, and the rotary encoder. It could be a thin nail or a piece from a large paper clip.
- **Soldering iron and solder**
- **Solder wick or desoldering pump**
- **Tape or glue** to mount the encoder. I used double-sided foam tape.
- **Super glue**
- **Drill**
- **Screwdriver**
- **Small piece of stripboard, aka perfboard (optional)**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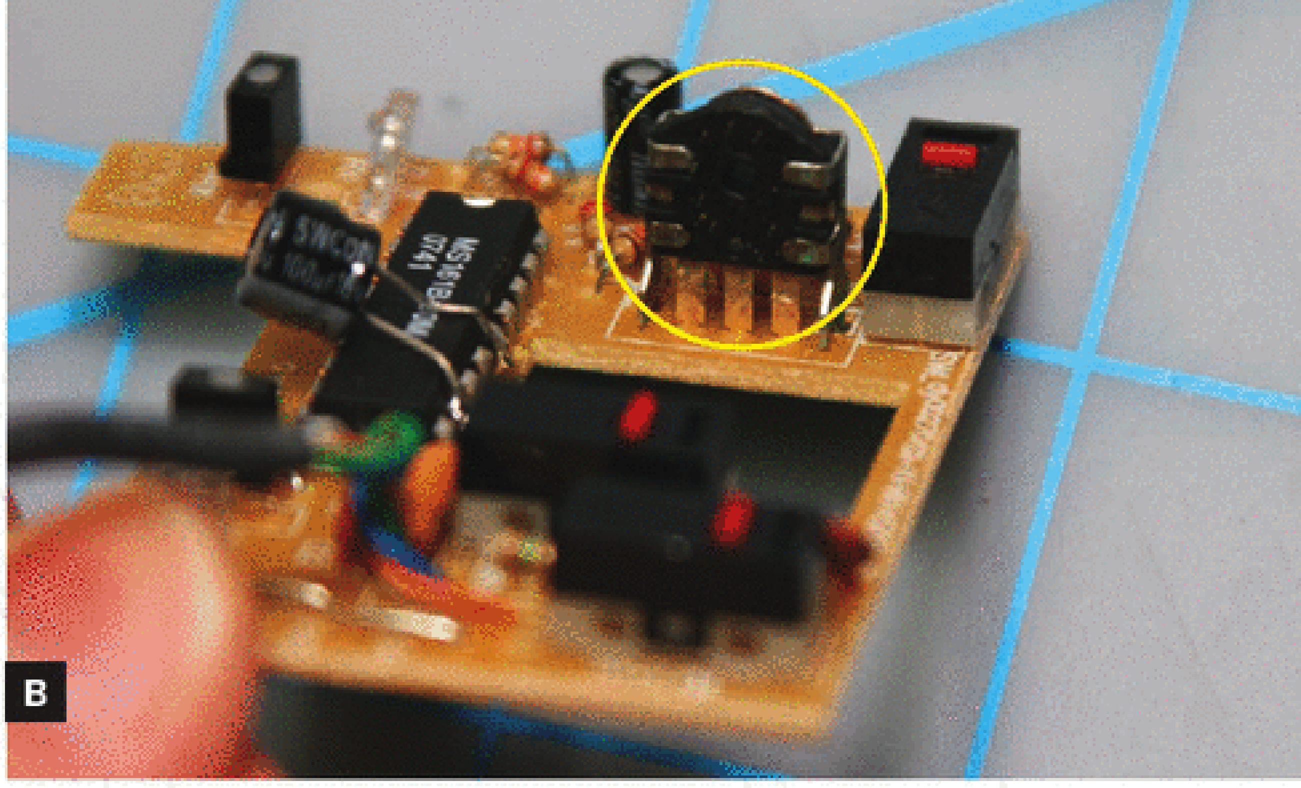
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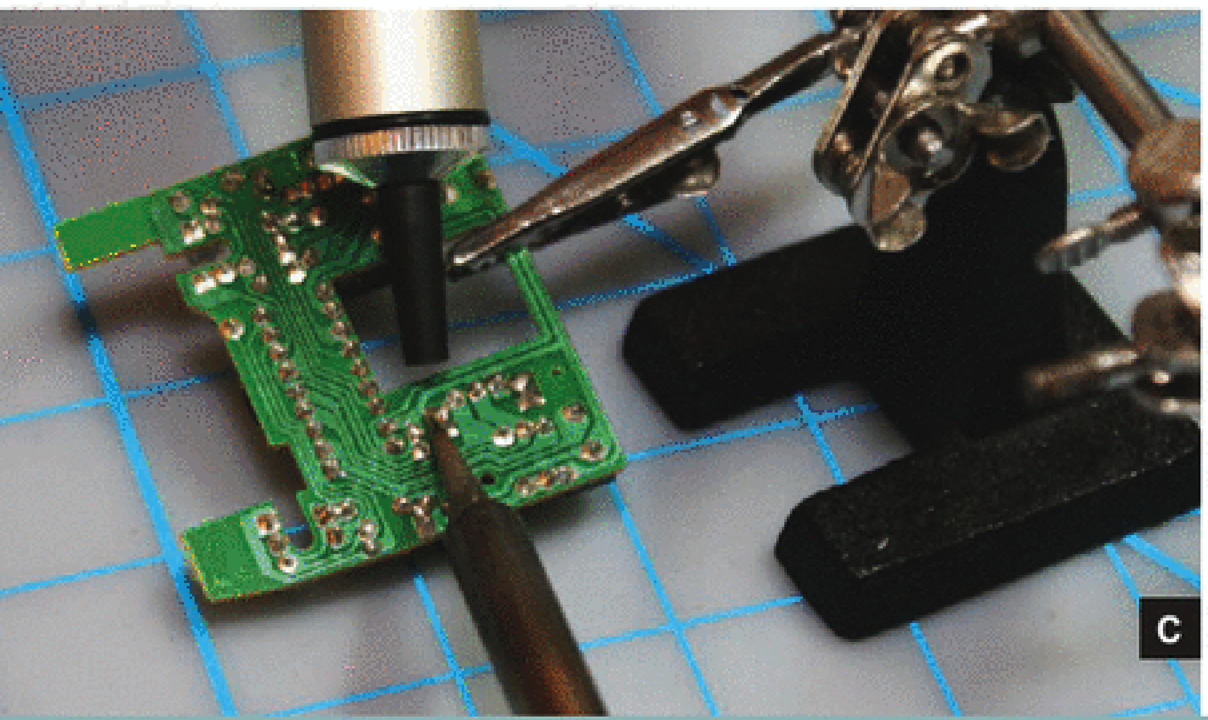
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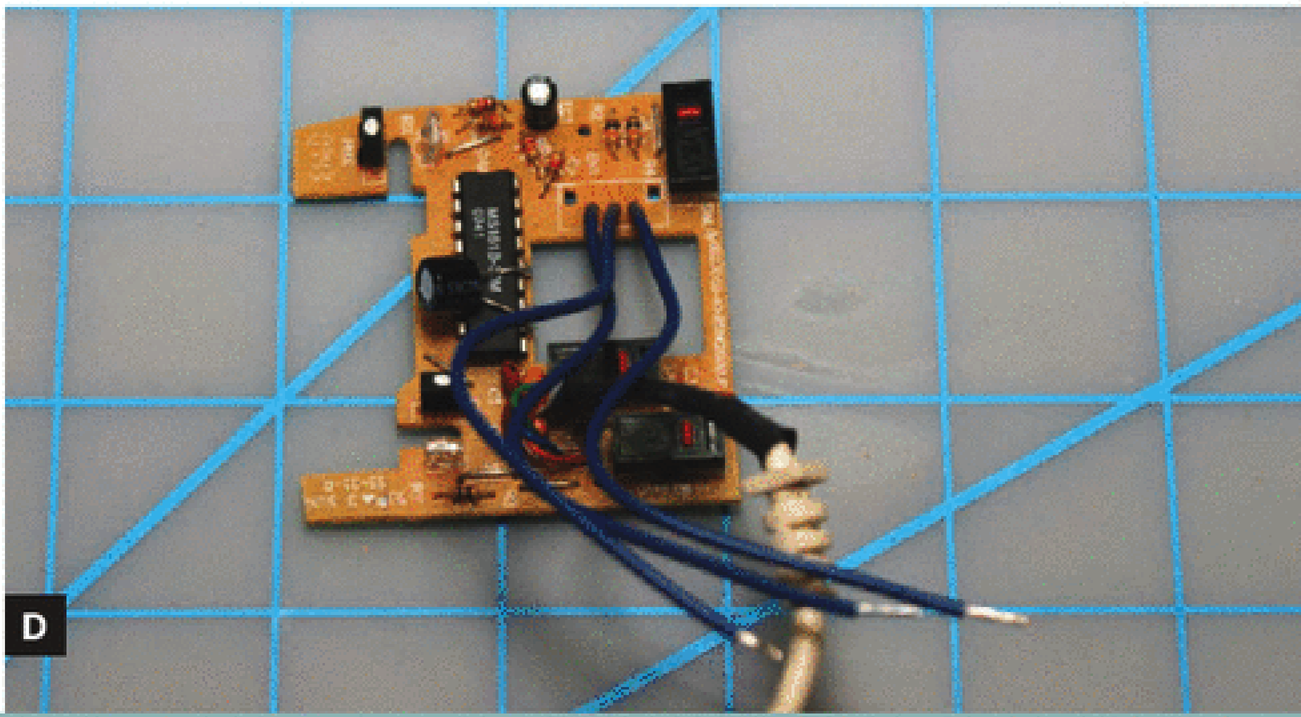

D

Fig. A: The mouse with the top of its case removed.
Fig. B: The scroll wheel removed from the circuit board, showing the rotary encoder (circled) next to the wheel slot.
Fig. C: Desoldering the rotary encoder's 3 contacts.
Fig. D: Wires soldered in to let the rotary encoder run offboard.

1. Gut the mouse.

Time to rip apart your beloved mouse (Figure A). Usually these just come apart with one screw, but maybe your manufacturer has decided to be a bit sneaky and put screws under stickers as a way of telling if the warranty has been voided.

Here's where you'll find out if you have a rotary encoder or an IR transmitter as a scroller. A rotary encoder holds the scroll wheel's axle and has 3 contacts below, whereas with an IR transmitter, the input probably comes from some type of sensors that the ball feeds.

If you have a rotary encoder, well done and carry on. If you have an IR transmitter (as is the case with cheapo mice) then it's no good for this. Try a different mouse.

Pull out the mouse's scroll wheel from the hole that it sits in and throw it away (Figure B).

2. Remove and rewire the encoder.

Flip over the board and find the holes where the rotary encoder is soldered in (there should be 3 in a row). Note which way the encoder points, or you'll solder it backward and it won't work properly. Heat the solder points with your iron and use either solder wick or a desoldering pump to pull off the solder from the board, releasing the encoder (Figure C).

Solder wires into the 3 encoder pin holes on the circuit board. These will need to be about 3"–6" long depending on your project box size (Figure D). You can either solder the other ends of the wires directly onto the corresponding pins of the encoder, or you can use a piece of stripboard to connect the pins to the wires, as I did; this is a bit more durable.

To get the encoder to fit neatly along the edge of my stripboard so that the new axle could face upward, I bent apart the 2 metal tabs that secured each end of the package to the original board.

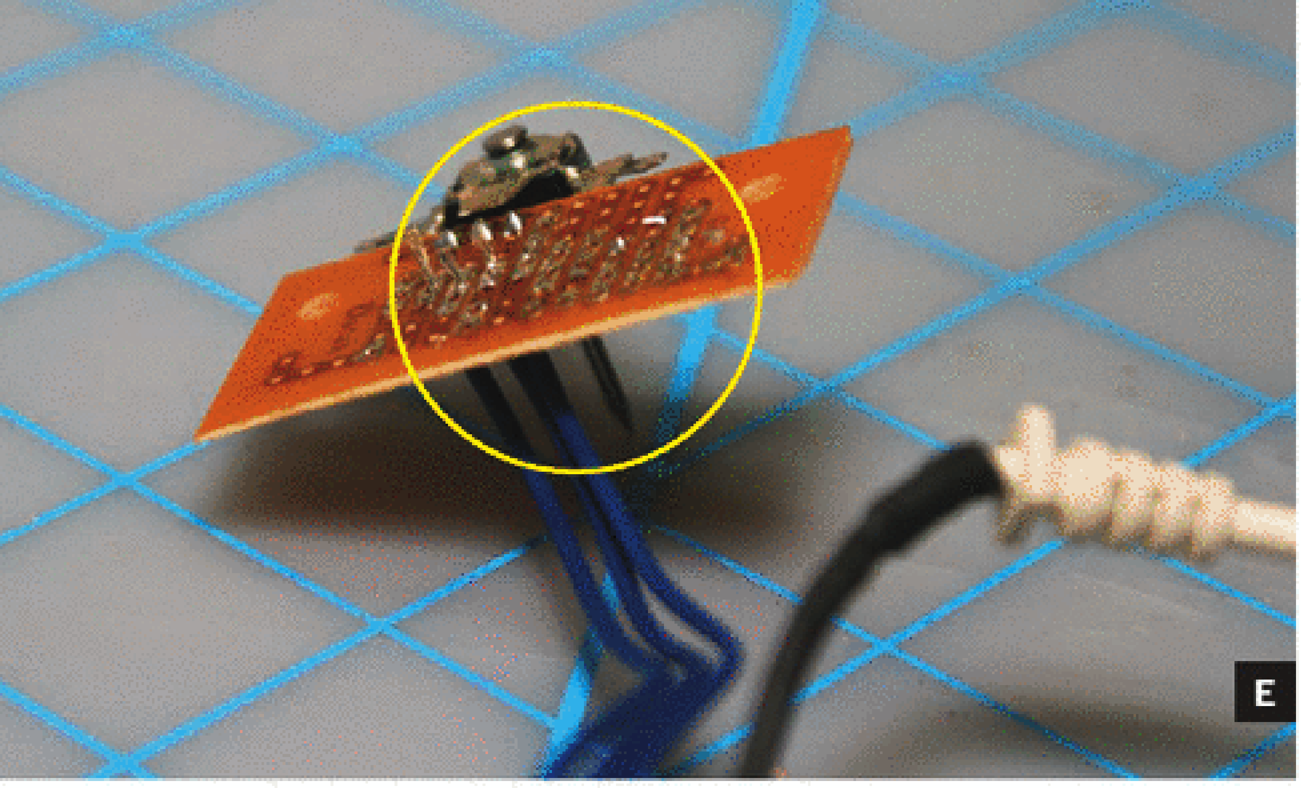
3. Glue the rod in.

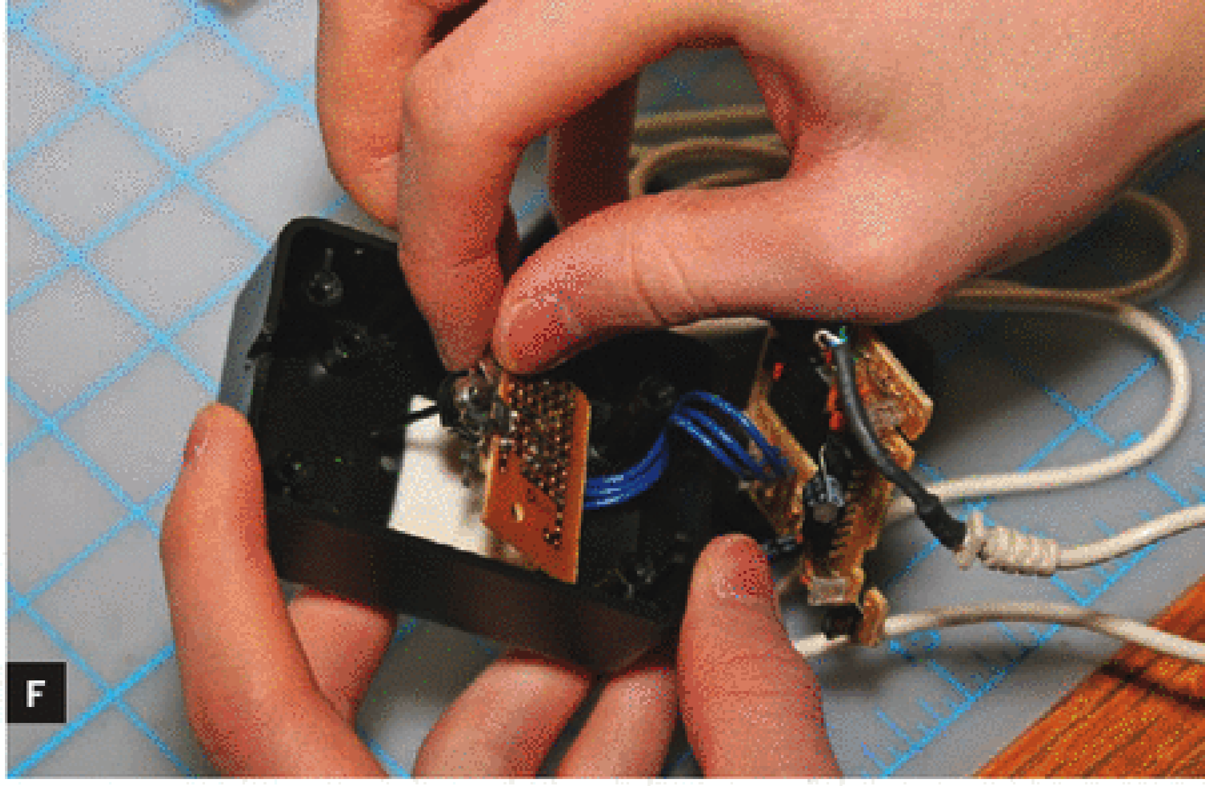
Find a metal rod that fits through the center of your encoder. such as a thin nail or a large paperclip.

Cut your rod to about 3". It needs to be long enough to fit through the encoder, through one side of the project box, and a good way into the car wheel. Put a small dab of super glue onto the rod and slide it into the rotary encoder's center hole (Figure E).

4. Mount the encoder.

Drill a hole in your project box that's the same diameter as your metal rod, and stick your rod through it. Now mount your encoder to the inside of your





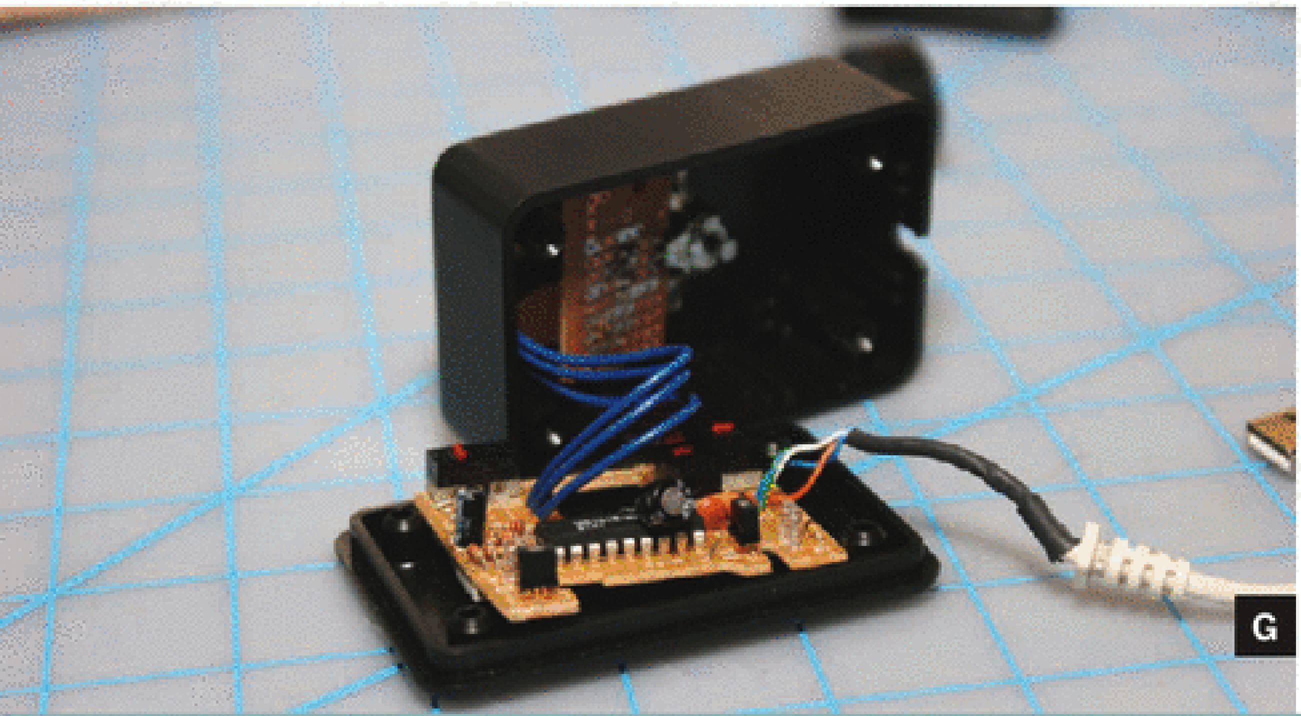


Fig. E: The rotary encoder mounted to the stripboard, with the nail axle (circled) glued in. Fig. F: Tape the stripboard to the inside of the project box with the axle sticking out of the drilled hole.

Fig. G: Both boards taped into position. Fig. H: The case closed, and the wheel mounted.

project box. I stuck it down with double-sided tape, then went over it with regular tape (Figure F).

5. Mount the wheel and the board.

Time to rip the wheel from your R/C car. If it comes with a gear in it, as mine did, try leaving it in to act as a spacer for your wheel. I simply used super glue to mount my wheel. If your wheel's hole is wider than the rod (Figure H), roll up some paper to pad out the hole, or gum it up with Blu-Tack poster putty.

Tape the circuit board to the bottom of the project box and drill a hole in the side of the case for the cable to escape through (Figure G). Then clip and/or screw the 2 halves of the box together and test it!

6. Test it.

Plug your new scroll wheel into your computer and give it a whirl. I use a USB mouse with my PC, so the PS/2 port was free. If you used a PS/2 mouse like I did, you'll have to reboot your PC after plugging it in for the BIOS to recognize it.

Fire up something scrollable, be it your Winamp library, your browser, or a massive e-book, and give it a test. If you find it's too sensitive or not sensitive enough, then go into your Control Panel and adjust your mouse properties, specifically, how many lines you scroll with 1 turn of the wheel.

As an added bonus, see if your wheel has enough momentum to scroll under its own weight with a flick of the wrist, like mine does.

7. Take it a step further.

I wanted to emulate the PowerMate as much as possible. A little Googling turned up an awesome piece of software called Volumouse (nirsoft.net/utils/volumouse.html). It lets you adjust your PC's volume by holding a keyboard button and scrolling up or down. It will also resize windows and change brightness, all according to the conditions you give it.

See a video of the PowerFake controlling Volumouse at makezine.com/go/diyscrollwheel.

(Originally published on instructables.com.)

Daniel Walker (diydaniel@gmail.com) is your average 16-year-old who loves to make stuff, sometimes to save money, but mostly for fun. A regular on instructables.com, he loves simple solutions to complex problems.

Cool beats, aged brass, an analog synth kit, and a guide to surviving the apocalypse (steampunk style).

TOOLBOX

Dr. Frankenstein's Nursery

Young Mad Scientist's First Alphabet Blocks

$40 xylocopa.com

Nineteenth-century iconography meets 21st-century craftsmanship in these awesome baby blocks from the husband-and-wife team known as Xylocopa Design. Artist Michele Lanan does these adorable and clever designs for the 26 letters of the alphabet, and Andrew Waser laser-etches them into a set of five 1⅜" American maple wood blocks. The results are truly wonderful, with finely detailed, precisely cut images that exude whimsy and a snarky sense of humor.

C is for Caffeine, and shows a mad scientist's brewing rig not unlike the Florence Siphon found in this issue (page 63). D is for Dirigible. H is for Henchmen, showing a mad scientist, test tube in hand, and his Igor — the pair show up again in Z is for Zombie, where they've obviously succumbed to some experiment gone horribly wrong. O is for Organs,P is for Peasants with Pitchforks, and U is for Underground Lair, depicting an extremely detailed cross-section of a Dr. Evil-esque compound. One can only image what one's little monsters would grow up to be if this was the symbolic vocabulary on which they cut their fangs.

—Gareth Branwyn

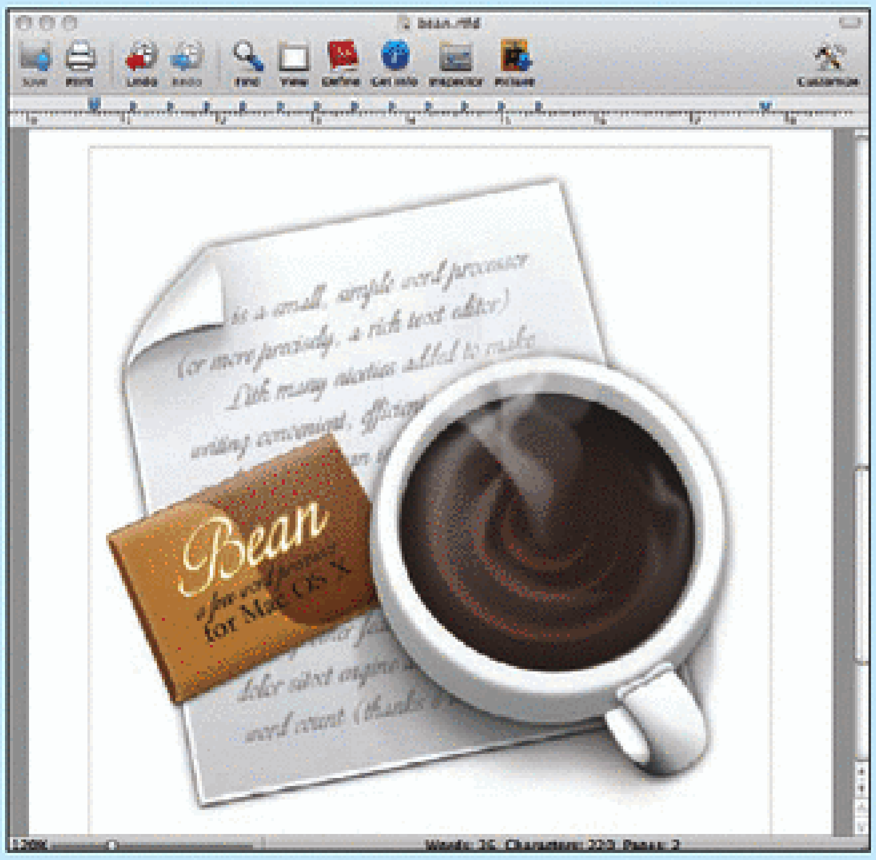
Want more? Check out our searchable online database of tips and tools at makezine.com/tnt.
Have a tool worth keeping in your toolbox? Let us know at toolbox@makezine.com.

Torch Carrier

BernzOmatic Trigger-Start Propane Torch
$40 bernzomatic.com

A propane torch is a useful tool for brazing, low-temperature welding, soldering, and just plain burning. Mostly, I use mine for starting the pellet stove. I finally gave up on my manual-light torch head when I tried to close the valve and a flame shot out from it, melting the knob.

To replace it, I bought a BernzOmatic TS4000T. It's just point-and-click: turn the safety to the on position, pull the trigger, and out shoots the flame. For long jobs, the trigger can be locked on. (The torch head is a bit top-heavy, but since it's so easy to ignite, I never set it down while lit.) It's rated for both propane and MAPP gas, and the brass tip is replaceable. With a street price of about $40, the TS4000T costs about triple what an ordinary pencil-flame torch costs, but it's built well and the convenience is worth it. —*Tom Owad*



Cool Beans

Bean Word Processor Software
Free bean-osx.com

As a writer, I'm persnickety about word processing programs. Maybe it's because I was spoiled by Microsoft's hallowed Word 5.1 for Mac, released in 1992. I clung to it for a decade, but the updated versions were bloated and buggy and just plain ugly, and that goes for OpenOffice, too.

Enter Bean, a freeware word processor for Mac OS X. Created by James Hoove, Bean is svelte (it starts almost instantly), clean (no overstuffed toolbars or dumb templates), and it doesn't get in your way. It does what you need it to do without making a fuss. In fact, you basically forget you're using it. It's just you and your words. Now that's refreshing.

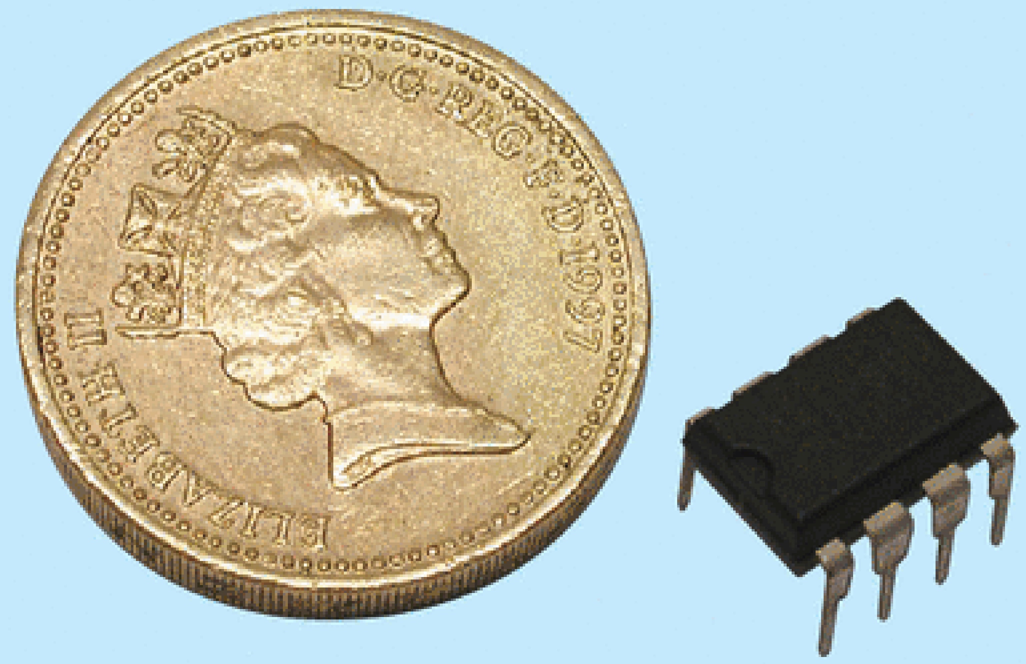
Bean can do the important stuff like spell check, simple formatting, and RTF, but it's not for heavy lifting like footnotes and desktop publishing. But, hey, you've always got OpenOffice there if you need it. —*Jeremy Jackson*

Picaxe 08M Microcontroller

$4 picaxe.co.uk

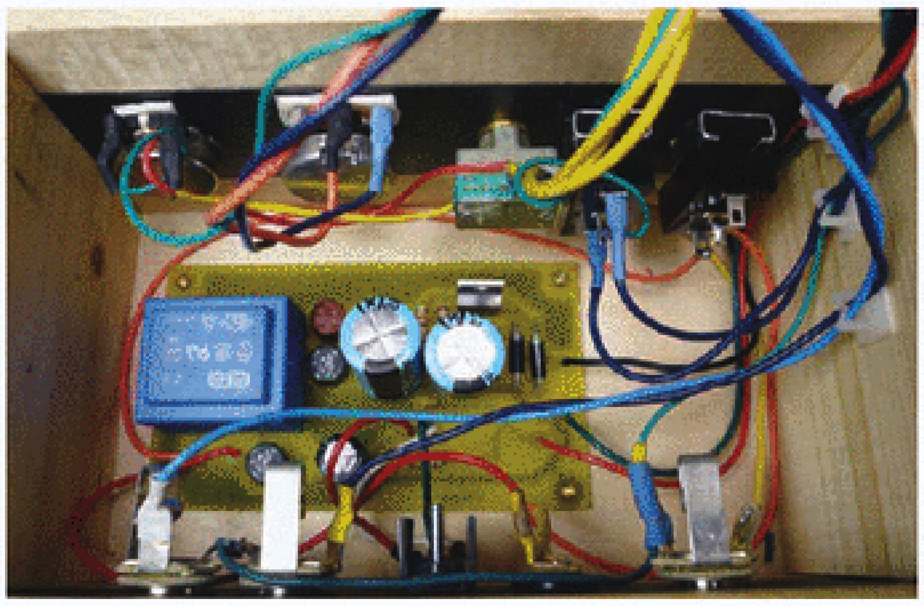
Some of MAKE's microcontroller projects can be overwhelming to the beginner. The Picaxe 08M chip is a great way to begin. Picaxe offers their programming IDE and compiler for free, and they even give details on how to build the programming cable. All you really need to get started is the chip, some spare parts that most of us already have in our junk bins, and 5 volts. The 08M chip has three I/O pins and one dedicated input pin, and can be programmed with up to 80 lines.

I first used the Picaxe 08M to make LEDs blink with simple code. When it's time to move on to more advanced projects, the Picaxe has larger ICs with more program memory. Projects like digital clocks, security systems, automatic plant watering, and data logging are all within reach. I started with Picaxe, and now I'm ready to make. —*Robbie Pitts*



Ye Olde Oscillator

Phantastron Synthesizer Kit
$195 electricwestern.com



In some alternate version of the Old West, folks played electronic synthesizers, and they likely called 'em Phantastrons. Those searching for the new and unusual in DIY synths will find a welcome change in this very analog device.

The kit incorporates two vintage vacuum tubes, rolled steel panels, and a hot-iron branded wooden crate enclosure ripe for customization. Though a basic power supply comes mostly assembled, the kit's core forgoes fancy-pants printed circuits for a 1930s-era "turret board" soldering experience — a refreshing challenge for seasoned kit builders.

Don't expect the standard volt-per-octave functionality here; this beast of an oscillator can be steered via amplified audio or basic control-voltage signals, reacting with a thick and often rebellious voice. The output's pitch response can be tamed or tweaked via onboard controls, and a rotary selector offers three different waveforms.

On the Electric Western website, kit maker Lorin Edwin Parker demonstrates the Phantastron using a homebrew ribbon controller appropriately built from bone and wood — though foil and a length of videotape would probably yield similar results.

Simply plugging my dual-humbucker electric straight into the sync/audio jack proved to be very fun. My guitar's familiar thumpy twangs were translated into staunch square/saw-wave plateaus offset by wiry bends and shifts. As an effects box, the device produced a variety of sub-octave tones along the lines of Devo meets Rage Against the Machine. Though it would be a more-than-welcome addition to my own "guitarsenal," I foresee the Phantastron being best used as the core of some original and unusual instrument. Hmm ... time for some brainstorming. *—Collin Cunningham*

House Bound

Free awdio.com

One of the things I miss the most about living in Chicago is Smart Bar's legendary House music sets. And now, thanks to Awdio, I can listen to live-streaming sets from Smart Bar and an extensive list of other nightclubs worldwide, for free.

Awdio is the first network to broadcast from a multitude of clubs in real time. Their amazingly clear sound quality comes from their trademark AwdioBox, a professional, 19"-rack IP audio component lent to the source clubs, which converts analog audio into digital MP3 signals and transmits to Awdio's servers.

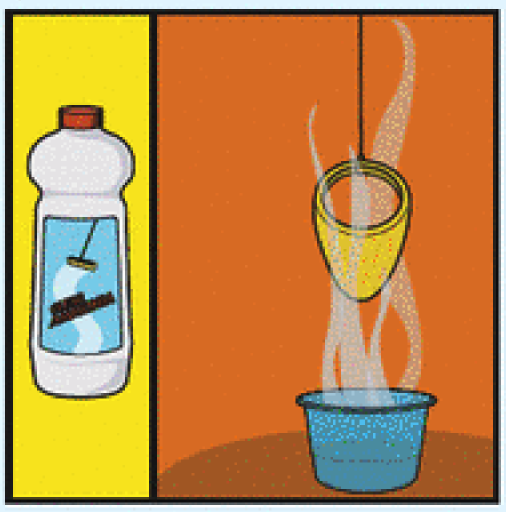
Awdio's sponsors enable them to offer their live music service for free. They host more than 100 clubs on five continents, and aim to triple that number in 2009. Their user interface is clean and easy to navigate, and each club listing gives a sneak peek into that part of the globe. These peeps are passionate about music and it shows.

Next time DJ Heather is turning up the heat in Chitown, I can clear out the furniture and turn up the bass right here in the redwoods. The best part is that in a world full of time zones, it's always time to boogie somewhere. —*Goli Mohammadi*

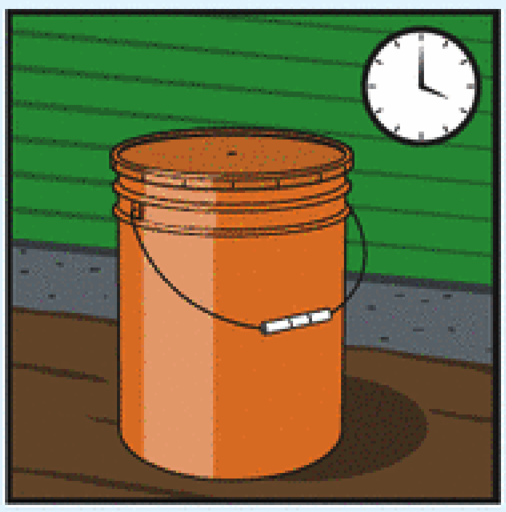
Tricks of the Trade By Tim Lillis

You can age gracefully.

Searching for an aged brass look for your next steampunk project? Use this trick, shared by Richard Nagy of datamancer.net.



Inside a sealable container, suspend your piece of brass a few inches over a small cup of ammonia.



Fume it anywhere from a few hours to a day until the desired effect is achieved. Add more ammonia if it completely evaporates.

For a burnished effect, fume the brass darker than you want it, then polish it afterward for a rich, dark, shiny, bronzed look.

Have a trick of the trade?
Send it to tricks@makezine.com.

Take precautions when using ammonia. Only use outdoors with proper ventilation and wear rubber gloves and eye protection.

« Dreams in the Dark

The Invention of Hugo Cabret **by Brian Selznick**
$23 Scholastic Press

There are precious few times when you experience media and feel that it's truly fresh, unique — something that actually imparts magic.

Such is the mojo of *The Invention of Hugo Cabret*. The book is a young adult title, but should appeal to anyone who hasn't forgotten how to dream. Something of a format-buster, it's filled with hundreds of meticulously drawn pencil sketches, although it's not really a graphic novel. And, with its flipbook-like interruptions of dozens of images between brief passages of text, it's not really a novel, either. It owes as much to the world of silent film as to that of the book.

And it's as much artifact as work of fiction: a beautiful 526-page piece of book art that *is* what it's about. It's about clocks and time, clockwork automata, the birth of cinema, and the nature of dreams.

It's also something of a fictionalized biography of silent filmmaker Georges Méliès. And, without giving *too* much away, the construction of the book itself works in ways similar to clockworks, silent films, and dream states. Heady stuff. Did I mention it's a kid's book? And it's one of the most engaging and affective things I read all year.

—GB

« Dorkbot of the 18th Century

The Lunar Men **by Jenny Uglow**
$22 Farrar, Straus and Giroux

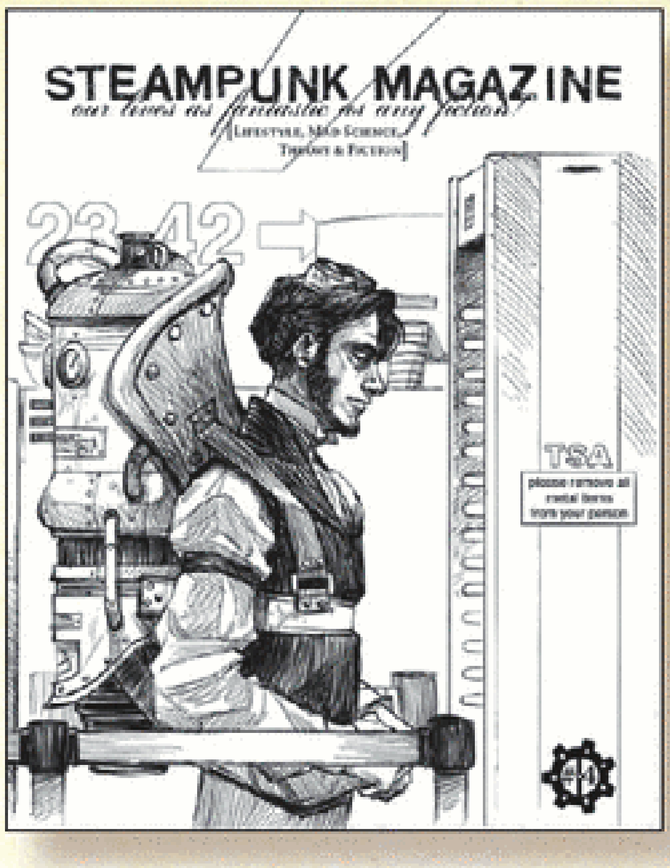
This remarkable biography paints a gorgeously rendered and revealing portrait of five 18th-century thinkers and tinkerers who basically rope-started the Industrial Revolution in Birmingham, England: toymaker Matthew Boulton, inventor of the steam engine James Watt, potter Josiah Wedgwood, discoverer of oxygen Joseph Priestley, and physician and evolutionary theorist Erasmus Darwin (Charles' grandfather). Being involved in the Dorkbot of today, I couldn't help but see comparisons (however modest) to these men's Lunar Society.

This was a group of deeply curious amateur scientists, technologists, and artists who liked to get together (on the full moon, so there was light to walk home) to exchange ideas and debate the deeper concerns of the day.

In the process, they made significant discoveries in science and naturalism; were in the vanguard of many new technologies, such as hydrogen balloons; and created entire industries, like industrialized pottery production. There was even some robot hacking going on, as Darwin drew up plans for a flying clockwork bird powered by compressed air, and a mechanical spider driven by hidden magnets.

The sheer quantity of ideas and ingenuity that poured from this handful of humans is staggering. It's hard to read this book and not want to get out your notebook, your magnifying glass, and your "beginner's mind," and set off in search of some Nobel discoveries of your own.

—GB



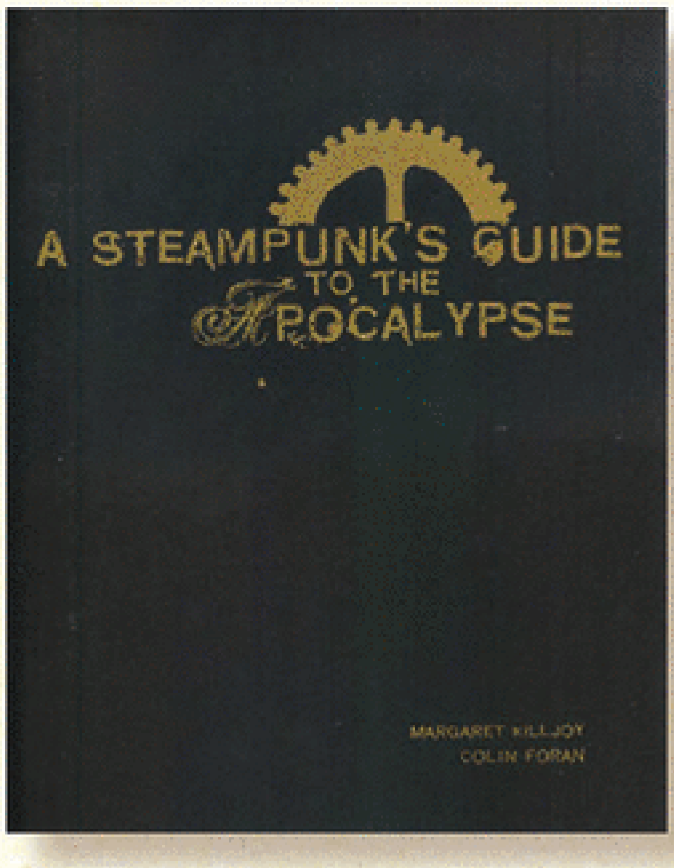
« Putting the Punk Back

SteamPunk Magazine
$3.50/issue, free PDFs steampunkmagazine.com

Every time a pop movement gets "punk" tagged onto it, people eventually start asking where the "punk" went, as said movement heads toward the mainstream, the mall, and finally, the waste bin of used-up (or thoroughly absorbed) cultural movements. If there is truly a punk arm of steampunk, it resides in the collective of writers, artists, musicians, and makers that creates *SteamPunk Magazine*.

First off: it's a zine. On paper! Who does that anymore? And it's dedicated to the kinds of anarchist, environmental, and feminist issues that punks are "supposed" to be all about.

So, what does this have to do with the naïve scientific romanticism, retro-tech gadgetry, and Victorian cosplay usually associated with steampunk? Every world needs ne'er-do-wells, rabble-rousers, street urchins, and artful dodgers. These guys have fashioned themselves up as the chaoticians of the steampunk world. And since their magazine has become something of a house organ for the movement, their punk is heard far and wide. *—GB*



« End of the World As We Know It

***A SteamPunk's Guide to the Apocalypse* by Margaret Killjoy and Colin Foran**
$5 or free PDF steampunkmagazine.com

With the success of imagined meltdown futures like *The Zombie Survival Guide* and *How to Survive a Robot Uprising*, one might understand the whimsical appeal of *A SteamPunk's Guide to the Apocalypse*. With the real meltdown of the global economy and a climate crisis, this book might be more practical than even its authors intended.

This 56-page guide has info on everything from building satellite dish solar cookers, to stripping a car for survival parts, to sanitation and self-defense, all done while looking dandy in steampunk street couture. Tongue-in-cheek sci-fi silliness? Anarchist wish fulfillment? Real-world survival guide? I don't know, but I'm stashing a copy in the emergency preparedness kit just in case. *—GB*

« Deluxe Pocketbook Disruptors

***Doctor Grordbort's Contrapulatronic Dingus Directory* by Greg Broadmore**
$13 wetanz.com/holics/raygun-directory.php

From the loony imagination of artist and prop designer Greg Broadmore comes this catalog from an alternative retro-future where arrogant aristocrats maraud the planets, wielding ray weapons with names like "The Unnatural Selector" and "The Man Melter," hunting alien big game, and warring with bug-eyed moon men. The steamy adventures may be fake, but the rayguns are really for sale, available as stunning, high-priced fantasy collectibles. *—GB*

Unleash Your Creativity

$300 epson.com

Even with the help of digital imaging software, my graphically oriented work would never be confused with that produced by even a fledgling artist. At least, that's what I thought until I tried the Epson Artisan 800.

The stylish Artisan 800 is a high-definition photo inkjet multifunction device that can print, scan, copy, and fax. The focal point is its intuitive 7.8" articulating color touch panel that allows users to send a fax, change preferences, or view and edit photo previews.

With a maximum 4,800dpi optical resolution, the Artisan 800 can scan up to legal-sized documents via its Automatic Document Feeder (ADF) built into its 8.5"×11.7" flatbed surface. Other image processing includes onboard memory card support, stand-alone photo editing and restoration, and the ability to save to PDF format. I was even able to easily turn family images into personalized coloring book pages — perfect for birthdays or the holidays.

In addition to its integrated CD/DVD media tray, the Artisan 800 also includes a multiuse paper tray. It also supports direct connection to both PC and Mac as well as Ethernet and wi-fi connectivity.

—Joseph Pasquini

The Humble Bootjack

$9 makezine.com/go/bootjack

Every winter morning when I go out to feed my horses, I slip off my indoor shoes and step into my muck boots. When I come back, I don't get my hands dirty pulling off muddy boots. I simply set one heel into my bootjack, and step on the jack with the other foot. With a quick pull, the boot is levered off my foot in a trice — hands free.

Alas, the bootjack is now largely the province of the horseman, despite its wonderful utility for anyone who wears boots. Its decline is not recent. An account from "an old timer" published in the New York *Evening Telegram* from 1890 laments:

"I can easily recall, as I presume nearly all old men can, the time when the boot-jack was supreme in every household. ... All labor was by hand; the tailor, the cobbler, the candle-maker, and all the rest had their assured places in the community. But the time was fast approaching when, with the increasing enterprise of the time, the boot-jack was to be dethroned. ... Boots were found to be clumsy, stiff, uncomfortable, and heaven knows what besides. Shoes came into favor on every side."

I, for one, have not forgotten. The bootjack is an elegantly designed tool, applying simple principles of leverage to near-miraculous effect. Anyone who wears boots should own one.

—Tim O'Reilly

Gareth Branwyn is a contributing editor for MAKE.

Collin Cunningham blogs for makezine.com.

Jeremy Jackson is a novelist and food writer from the faraway land of Iowa.

Tim Lillis is a frequently contributing illustrator for MAKE.

Goli Mohammadi is the associate managing editor for MAKE and CRAFT.

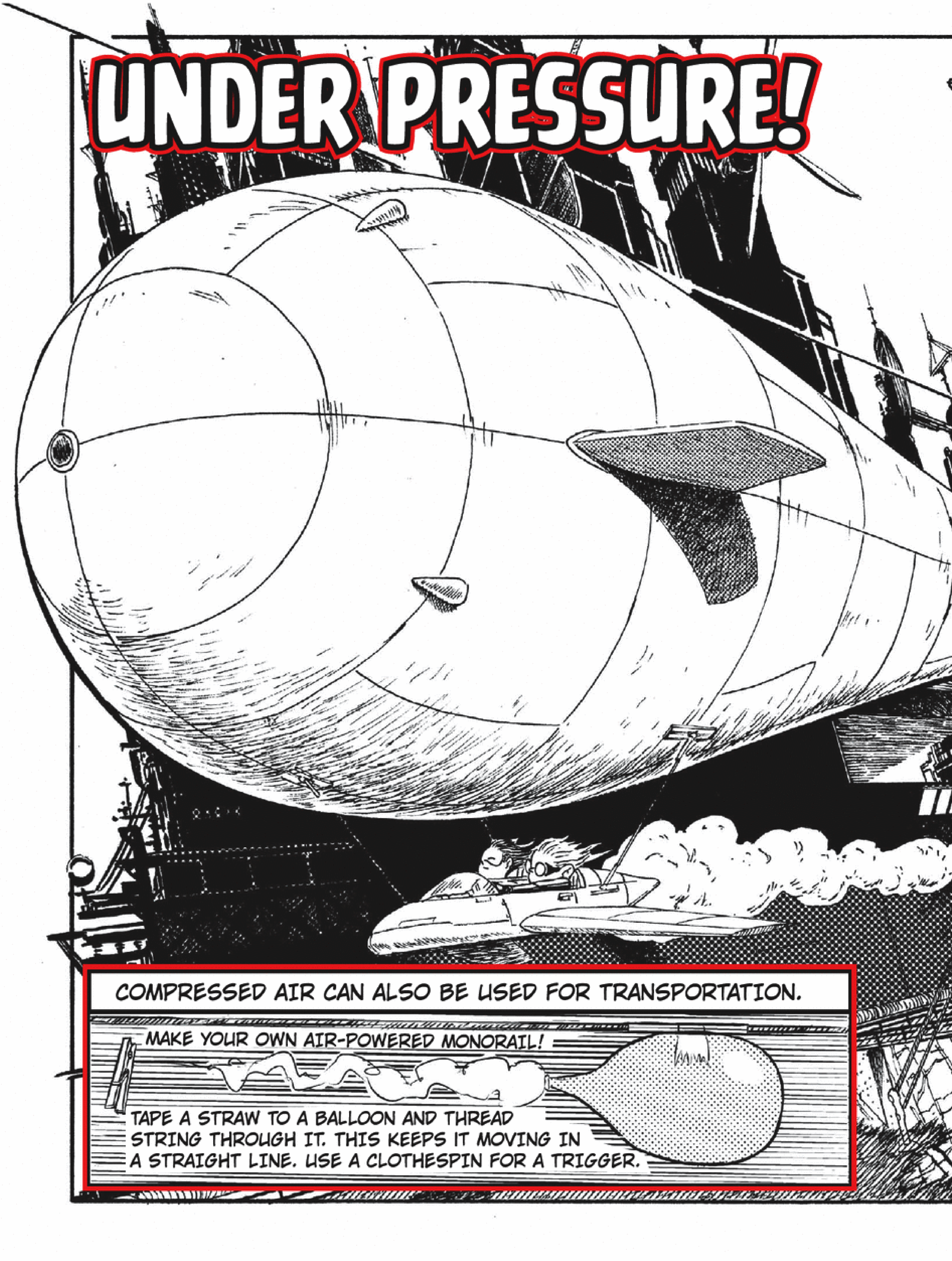
Tom Owad is a Macintosh consultant and editor of Applefritter (applefritter.com). He's the author of *Apple I Replica Creation*.

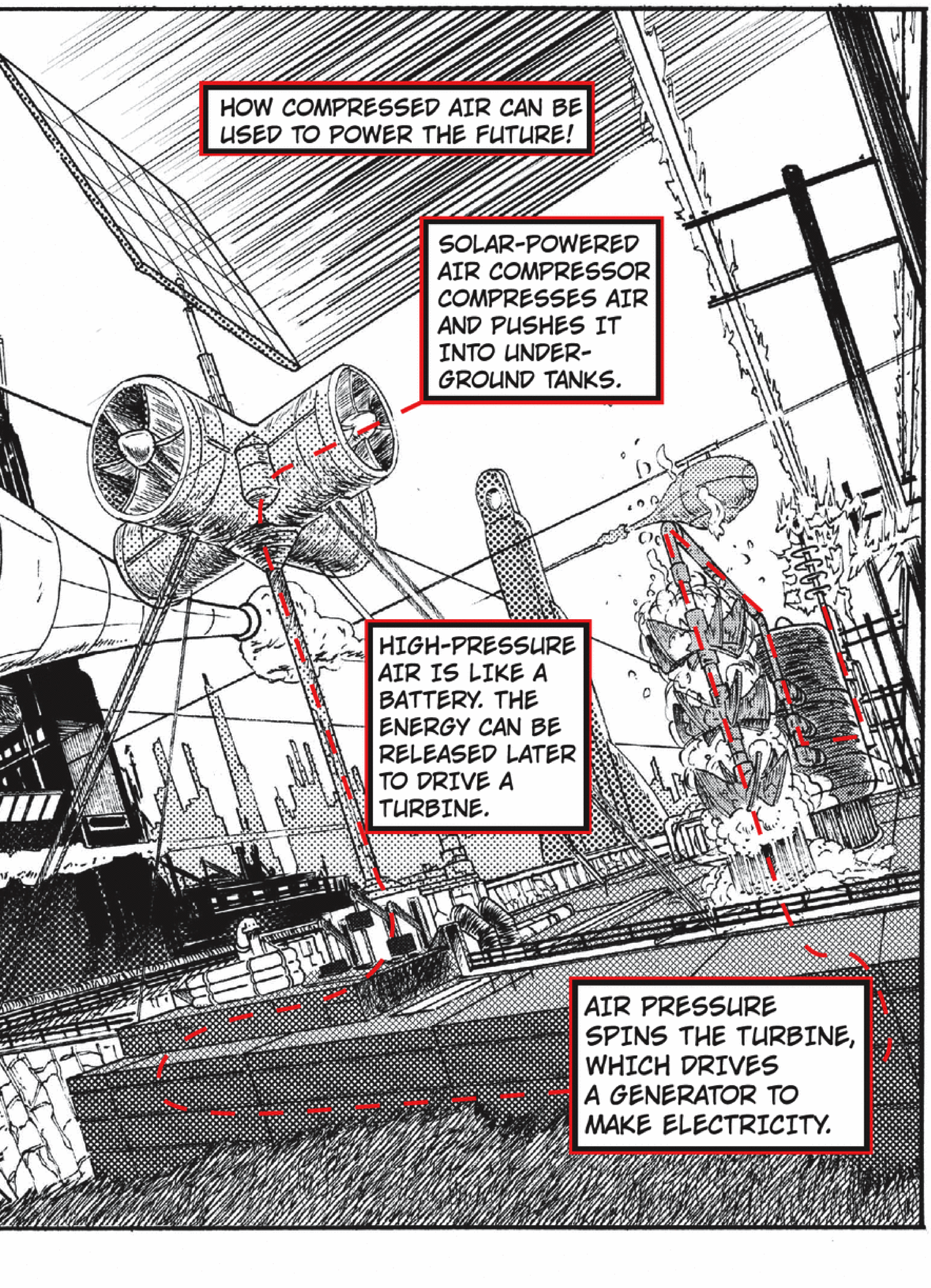
Tim O'Reilly is the founder and CEO of O'Reilly Media.

Joseph Pasquini is an avid amateur radio operator and shortwave listener.

Robbie Pitts is an electronics hobbyist and tinkerer from Georgia.

Have you used something worth keeping in your toolbox? Let us know at toolbox@makezine.com.


UNDER PRESSURE!
COMPRESSED AIR CAN ALSO BE USED FOR TRANSPORTATION.
MAKE YOUR OWN AIR-POWERED MONORAIL!
TAPE A STRAW TO A BALLOON AND THREAD STRING THROUGH IT. THIS KEEPS IT MOVING IN A STRAIGHT LINE. USE A CLOTHESPIN FOR A TRIGGER.


HOW COMPRESSED AIR CAN BE USED TO POWER THE FUTURE!
SOLAR-POWERED AIR COMPRESSOR COMPRESSES AIR AND PUSHES IT INTO UNDER-GROUND TANKS.
HIGH-PRESSURE AIR IS LIKE A BATTERY. THE ENERGY CAN BE RELEASED LATER TO DRIVE A TURBINE.
AIR PRESSURE SPINS THE TURBINE, WHICH DRIVES A GENERATOR TO MAKE ELECTRICITY.

HEIRLOOM TECHNOLOGY
By Tim Anderson

Island Tricks

I came across some handy techniques on a recent visit to Maui. Here are just some of the island tricks you should know about.

Old Tires Boat Rack

These are the Wailea Canoe Club's 6-person racing canoes (Figure A). The canoe never touches the ground. The paddlers pick it up in the water, carry it onto land, and set it on tires.

Canoe Dolly with Golf Cart Wheels

The Wailea Canoe Club has this slick homemade dolly for putting boats in and out of the water. Purpose-made beach wheels are expensive. Wheels from junk golf carts are free (Figure B).

Homemade Wind Speed Flags

As seen on Kite Beach, the flags are different lengths and possibly different weights (Figure C). If a flag is flying straight out, it's easy to read the number. That's the wind speed. If a flag is hanging and wagging around, there's not that much wind.

Lazy Man's Cherry Picker

Johnny V, the surfboard guru, has a Surinam cherry tree in his yard in Haiku (Figure D). Here's how you harvest them: put some sheets under the tree and let it dump cherries on them. He says, "If I don't rake them up every day it's like walking through a pile of mush. And you can't kill these things. Want some saplings?" He points to a forest of Surinam cherry tree shoots sprouting under the tree.

Drink a Coconut

Even very young green coconuts are full of "coconut water," or coconut juice. Before I knew anything I'd try to open them with a hammer, a hatchet, or by banging them on the ground. By the time I got them open, all the juice had leaked out.

Here's how to drink a coconut with a knife:

1. Take your shirt off. Coconut juice and sap will stain your shirt yellowish brown.
2. Stab the side of the coconut. This is easier than it sounds, especially if it's a young coconut. Probably a little bit of juice will squirt out, since the coconut is under pressure.
3. Make two more stabs to make a triangular hole. Rock the knife to connect the cuts and pry the plug out.
4. Drink it. If you have a straw, use that. Otherwise arch your back and drink it like you're in a commercial (Figure E).

Digression: Coconut juice has all the electrolytes you need in the tropical places where coconuts grow. It's also sterile if it's from a picked coconut. They used it in World War II as IV fluid for wounded soldiers or soldiers sick from the wet kind of tropical diseases. A coconut on the ground is probably sterile also, but some of them crack and go sour after they hit the ground.

Prickly Pears

It's the fruit of the prickly pear cactus. The rest of the cactus is edible, too, just so you know. The green pads are a great vegetable served raw or cooked. They taste kind of like a cucumber-tomato cross. The pears sit on top for a long time. The darker the color of the pear, the sweeter it is (Figure F).

These delicious things are covered with tiny hairy thorns called glochids. You'll get them all over yourself the first time because they're hard to see and you won't believe any of the following.

Real picking method: Pick them using leather gloves or tongs. Put them in a bucket. What I did: Pick with bare hands and put them in my shirt pocket. I got so many thorns in my chest that I had a hairy chest for the first time in my life. Remove all the thorns!

Real cleaning method: Rub them with dirt or gravel, or put them in a chicken-plucking machine with a thousand pencil erasers. Wash them with cold water. Skin them while wearing gloves. What

I did: Rub them on my pants so I got thorns in my leg. Peel them barehanded so I got thorns in my hands. Eat them so that I got thorns all around my mouth.

Stationary Van Air Conditioner

The aloha spirit means people get to do what they want if it doesn't hurt someone else. Here's a van with a regular house air conditioner in the back window (Figure G). I assume the owners were living in the van in a hot part of the island and had access to an extension cord, so they came up with this improvised source of cool.

Pandanus Key Paintbrushes

The pandanus tree has many uses. Hawaiians made sails and sleeping mats by braiding the leaves. The fruit is a big thing that looks sort of like a giant pineapple. It comes apart into sections called keys. Chew on the orange part and suck the juice. Or pound them and wring out the juice to dry into a sort of fruit leather. It tastes like mango/cantaloupe.

The old fruits make good paintbrushes. I especially like them for epoxy glue. I feel bad about throwing away a commercial brush every time I glue something. I picked up a bunch of old keys under a tree in Lahaina. Rub them on a wire brush to soften up the bristles and dislodge any loose ones. The best paintbrushes come from keys that get beaten by the surf and then wash up. Watch out for sand that comes out of the inner part of the key.

Surfboard Shaper Art

Here's a nifty chair made from an old windsurfing board and boom (Figure H). Seen outside the Ding King surfboard factory in Kahului, it was probably made by Mark "Euroman" Raaphorst.

Flower Pot From an Old Tire

Cut the sidewall off a tire in a zigzag pattern. Turn the tire inside out. You'll get a graceful vase shape (Figure I). If you leave the tire mounted on the rim, the rim becomes a pedestal for the vase. That makes the vase even more graceful, and the cut-off chunk of sidewall adds to the ornate base.

+ More island tricks: makezine.com/17/heirloom

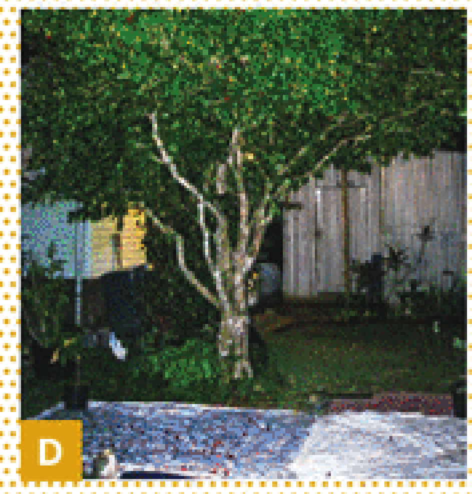
Tim Anderson (mit.edu/robot) is the founder of Z Corp. See a hundred more of his projects at instructables.com.

Photography by Tim Anderson and Star Simpson


A


B


C


D


E


F


G


H


I

Jan	Feb	Mar
Apr	May	Jun
July	Aug	Sept
Oct	Nov	Dec

MAKER'S CALENDAR

Compiled by William Gurstelle

Our favorite events from around the world.

100 Hours of Astronomy

April 2–5, worldwide

100 Hours of Astronomy is a United Nations-sponsored event consisting of a series of live webcasts and astronomical observing events. It coincides with the 400th anniversary of Galileo's first astronomical observations with a telescope. 100hoursofastronomy.org

Levin Stargazers public star party, New Zealand.

›› MARCH

RobotChallenge

March 21, Vienna, Austria

It's one of the biggest competitions in Europe for autonomous and mobile robots. Challenges include line following, bipedal motion, robot sumo, and free-style robot creations. robotchallenge.at/en

Discovery Week

March 23–April 3, San Diego, Calif.

San Diego's first-ever science festival. Scientists will visit local schools; companies and universities will open their labs for tours and exhibits; and the Science Expo will take place in Balboa Park. sdsciencefestival.com

›› APRIL

Catapults of Château des Baux-de-Provence

April 1–Sept. 30, Arles, France

Three full-scale replicas of medieval siege warfare machines demonstrate power and grace, certain to inspire mechanically minded makers to conceive their own hurling projects. makezine.com/go/chateau

Lunar Reconnaissance Orbiter Launch

April 24, Cape Canaveral, Fla.

This launch is the first mission in the U.S. Vision of Space Exploration program, which aims to return astronauts to the moon, build a lunar outpost, and press on to Mars. nasa.gov/missions/highlights/schedule.html

Boston Cyberarts Festival

April 24–May 10, Boston, Mass.

One of the largest collaborations of electronic and computer-based artists in North America. Techno/artistic events encompass the visual arts, electronic music, dance, and more. bostoncyberarts.org

›› MAY

40th Annual Kinetic Grand Championship Race

May 24–26, Arcata, Calif.

This "triathlon of the art world" takes place when human-powered kinetic racers tackle a 30-plus-mile course of pavement, mud, sand, and water. These vehicles are also elaborate works of art. kineticuniverse.com

Maker Faire

May 30–31, San Mateo, Calif.

Our very own Maker Faire is a family-friendly event for creative, resourceful people of all ages and backgrounds who like to tinker and love to make things. In other words, it's for people like you. makerfaire.com

IMPORTANT: All times, dates, locations, and events are subject to change. Verify all information before making plans to attend.

Know an event that should be included? Send it to events@makezine.com. Sorry, it's not possible to list all submitted events in the magazine, but they will be listed online.

If you attend one of these events, please tell us about it at forums.makezine.com.

Photograph by Paul Moss, astronomy.net.nz (top)

MAKE MONEY

Chess Set By Tom Parker

Sometimes it costs more to buy it than to make it from the money itself.

$4.99

Cardboard and plastic chess set from toy store

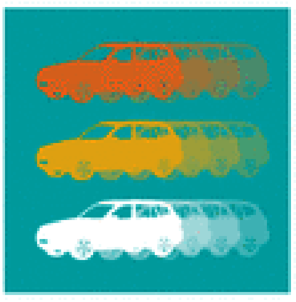
⬆ $3.52

Exchange value of coins used as chessmen plus $2 for wood and paint

Photography by Tom Parker

CHANGE YOU CAN CHECKMATE:

A: 1960s Japan 5 yen (8)
B: 1943 Malaya 1 cent (2)
C: 1991 Myanmar 25 pyas (2)
D: 1984 Tanzania 10 senti (2)
E: 1917 Great Britain 1 penny (1)
F: 1967 Great Britain 1 penny (1)
G: 1965 Fiji 1 penny (8)
H: 1994 Aruba 50 cents (2)
I: 1988 India 20 paise (2)
J: 1970 Rwanda 2 francs (2)
K: 1939 Great Britain half crown (1)
L: 1889 Great Britian Victorian double florin (1)



RETROSPECT
By George Dyson

Theory of Self-Reproducing Automata

I parked my car at the airport in Seattle, Wash., and rented a car in Oakland, Calif., after a two-hour flight. It cost more to park my old car than to rent a new one. Have machines finally become less expensive than the space they fill?

» Because airport parking is always scarce and cars are rented below cost on weekends, this is not a fair comparison. But the decline in the relative cost of machines versus the costs of space and people is real. Machines are being manufactured less and less by people, and more and more by other machines.

The current economic crisis, like a minus tide during a December full moon, is exposing human misunderstanding and misbehavior that normal water levels have concealed. And there is now no concealing that something new is going on in the world of machines. We are facing the first economic downturn to include free cellphones, more automobiles than we have room for, and computers that cost less than a dinner at a good restaurant yet run at billions of cycles per second for years.

One reason things look so bad is that we measure our economy in money, not in things. In an era of increasingly self-reproducing goods, we can suffer a declining economy while still producing more stuff than people can consume. There is a growing imbalance between the cost of people and the cost of machines. What prices are rising the fastest? Health care — the cost of maintaining human beings. What prices are dropping fastest? Computing — exponentially driving down the cost of information that increasingly governs the cost of new machines.

The 5 kilobytes of random-access Williams tube memory that spawned the digital universe (*see MAKE, Volume 10, page 178*) cost roughly $100,000 in 1947 dollars. Today, the equivalent costs one-hundredth of 1 cent — and it cycles at 1,000 times the speed. Similar cost reductions have occurred across the technological landscape, from operating systems to search engines to numerically controlled machine tools. Like rental cars at airports on weekends, products are being sold at nominal cost simply to make room for the new products that are about to appear.

"Why may we not say that all Automata (Engines that move themselves by springs and wheeles as doth a watch) have an artificiall life?" asked Thomas Hobbes on the first page of *Leviathan* in 1651. Hobbes believed that the human commonwealth, given collective substance by the power of its institutions and the ingenuity of its machines, would coalesce to form that Leviathan described in the Old Testament, when the Lord, speaking to Job out of the whirlwind, had warned, "Upon earth there is not his like, who is made without fear."

Leviathan suggested that an artificial intelligence would come to occupy the vacuum between the supreme intelligence of God and the earthly intelligence of humankind; Hobbes avoided being condemned to death for heresy only through his friendship with King Charles II, who awarded him a small pension and protection against his enemies, describing him as "a bear, against whom the Church played their young dogs, in order to exercise them."

The era of digital computation that Hobbes predicted is now upon us, yet there is still an element of heresy to saying that Nature might grant life or intelligence to machines. Computers will only do what people program them to do! And machines do not self-reproduce! Only heretics disagree.

"Surely if a machine is able to reproduce another machine systematically, we may say that it has a reproductive system," wrote Samuel Butler, author of the 1863 essay "Darwin Among the Machines."

"And how few of the machines are there which have not been produced systematically by other machines? Each one of ourselves has sprung from minute animalcules whose entity was entirely distinct from our own, and which acted after their kind with no thought or heed of what we might think about it. These little creatures are part of our own

In an era of increasingly self-reproducing goods, we can suffer a declining economy while still producing more stuff than people can consume.

reproductive system; then why not we part of that of the machines?"

Butler's essay was written by candlelight in a remote sheep station at the headwaters of the Rangitata River in southern New Zealand, where he had emigrated in 1859, as far from his disapproving father as he could get. Though taken by some as a spoof on Darwin's *Origin of Species*, Butler's argument was not *against* Darwin, but *beyond* Darwin.

"As the vegetable kingdom was slowly developed from the mineral, and as in like manner the animal supervened upon the vegetable, so now in these last few ages an entirely new kingdom has sprung up, of which we as yet have only seen what will one day be considered the antediluvian prototypes of the race," argued Butler. "As some of the lowest of the vertebrata attained a far greater size than has descended to their more highly organized living representatives, so a diminution in the size of machines has often attended their development and progress. ... It appears to us that we are ourselves creating our own successors ... giving them greater power and supplying by all sorts of ingenious contrivance that self-regulating, self-acting power which will be to them what intellect has been to the human race."

Eighty-eight years later, John von Neumann and Stanislaw Ulam began collaborating on an ambitious *Theory of Self-Reproducing Automata* that would encompass living, nonliving, and about-to-become-living machines. "An *organism* (any reason to be afraid of this term yet?) is a universal automaton which produces other automata like it in space which is inert or only 'randomly activated' around it," explained Ulam, reporting on a conversation with von Neumann that took place on a bench in Central Park in early November 1952.

Fifty-six years after that, the unbounded digital universe that Ulam and von Neumann had imagined

NO EARTHLY POWER CAN COMPARE: Frontispiece of *Leviathan, or The Matter, Forme, and Power of A Commonwealth Ecclesiasticall and Civill*, by Thomas Hobbes, London, 1651.

as a mathematical abstraction actually exists. We are surrounded by codes (some Turing-universal) that make copies of themselves, and by physical machines that spawn virtual machines that in turn spawn demand for more physical machines. Some of these digital sequences code for spreadsheets, for music, for operating systems, or for sprawling, metazoan search engines. Other digital sequences code for proteins, or for a helical gear that is itself part of a numerically controlled gear-cutting machine.

Steam engines have gone extinct, microprocessors roam the Earth, and technology is now translating freely, in both directions, between strings of digital code and strings of DNA. Were Butler alive today, he might ask: Are we using digital computers to sequence, store, and better replicate our own genetic code, or are digital computers optimizing our genetic code so that we can do a better job of replicating *them*?

In an age of self-reproducing machines, why should people keep making things? Is it simply because with so many things to consume, there are no longer enough things to do? All those machines that are collectively becoming so skilled at making other machines, will one day, perhaps when we least expect it, learn to make human beings. We human beings need to remember how to make machines.

George Dyson, a kayak designer and historian of technology, is the author of *Baidarka*, *Project Orion*, and *Darwin Among the Machines: The Evolution of Global Intelligence*.

By Lee D. Zlotoff

Mountain Bike Rescue

The Scenario: You and your best friend, both experienced mountain bikers, take off on a day-long jaunt to explore a little-known and rocky canyon trail. The ride is challenging but spectacular until, as you finally decide to turn around and head back, your friend's bike hits a loose rock, skids out from under him, and they both topple off the edge of the trail down into the canyon. Smashing his knee in the fall, your friend manages to land on a thin, unstable ledge about 15 feet straight down from the trail, only able to keep himself from falling farther by grabbing onto a small but secure tree branch jutting out from the rock, while his bike cartwheels out of sight to the bottom of the canyon.

The Challenge: Your friend is clearly in a lot of pain and there's no telling how long the ledge he's on will hold, so riding the many miles out to the trailhead to call for outside help is not an option. And, as is always the case in these situations, your cellphone gets no signal out here. Bottom line, you need to figure out a way to get your friend, who weighs a good 30 pounds more than you, up off that ledge and back down the trail to your car before nightfall — which is maybe four or so hours off.

What You Have: In addition to your bike, you've got your daypack, which contains a canteen of water, some protein bars, a basic bicycle repair tool kit, an extra inner tube, your Swiss Army knife or Leatherman tool, a strong, flexible, 3-foot wire saw with split-ring finger-handles on both ends, some waterproof matches, and roughly 30 feet of strong nylon cord you use to tie your bikes onto the car. Since you know from experience that you can't predict the weather, you also have some waterproof nylon rain gear and a warm jacket.

There are some small trees on the upper side of the trail but none immediately adjacent to the ledge where your friend fell. Though he's conscious, it's best to assume he can do very little to assist you in getting him off the ledge below, and he certainly won't be able to walk if and when you do. However, he does have enough strength in his arms to hang onto the tree branch, at least for now. So what are you going to do?

Send a detailed description of your MakeShift solution with sketches and/or photos to makeshift@makezine.com by May 22, 2009. If duplicate solutions are submitted, the winner will be determined by the quality of the explanation and presentation. The most plausible and most creative solutions will each win a MAKE T-shirt and a *MAKE Pocket Ref*. Think positive and include your shirt size and contact information with your solution. Good luck! For readers' solutions to previous MakeShift challenges, visit makezine.com/makeshift.

And the next MakeShift challenge could be yours! That's right, we're throwing open the doors and offering you the chance to create your own MakeShift to challenge the world. Just submit an original scenario in the familiar format — the challenge, what you have, etc. — with some ideas of how you think it should be solved. The winning scenario will not only be published right here but also earn you a $50 gift certificate for the Maker Shed. The deadline is May 22, 2009, so get out there and start looking for trouble!

Lee David Zlotoff is a writer/producer/director among whose numerous credits is creator of *MacGyver*. He is also president of Custom Image Concepts (customimageconcepts.com).

Photograph by Jen Siska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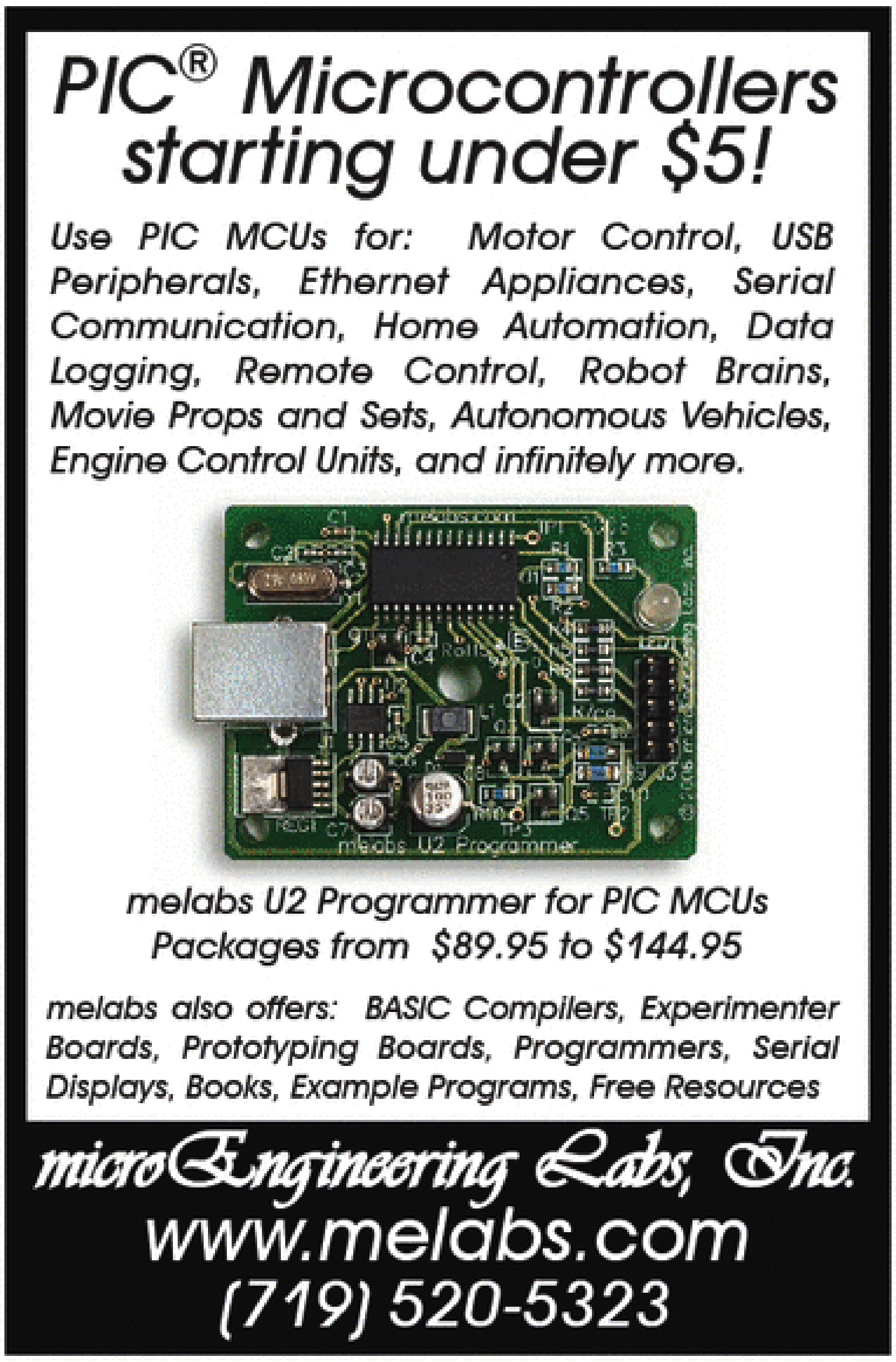
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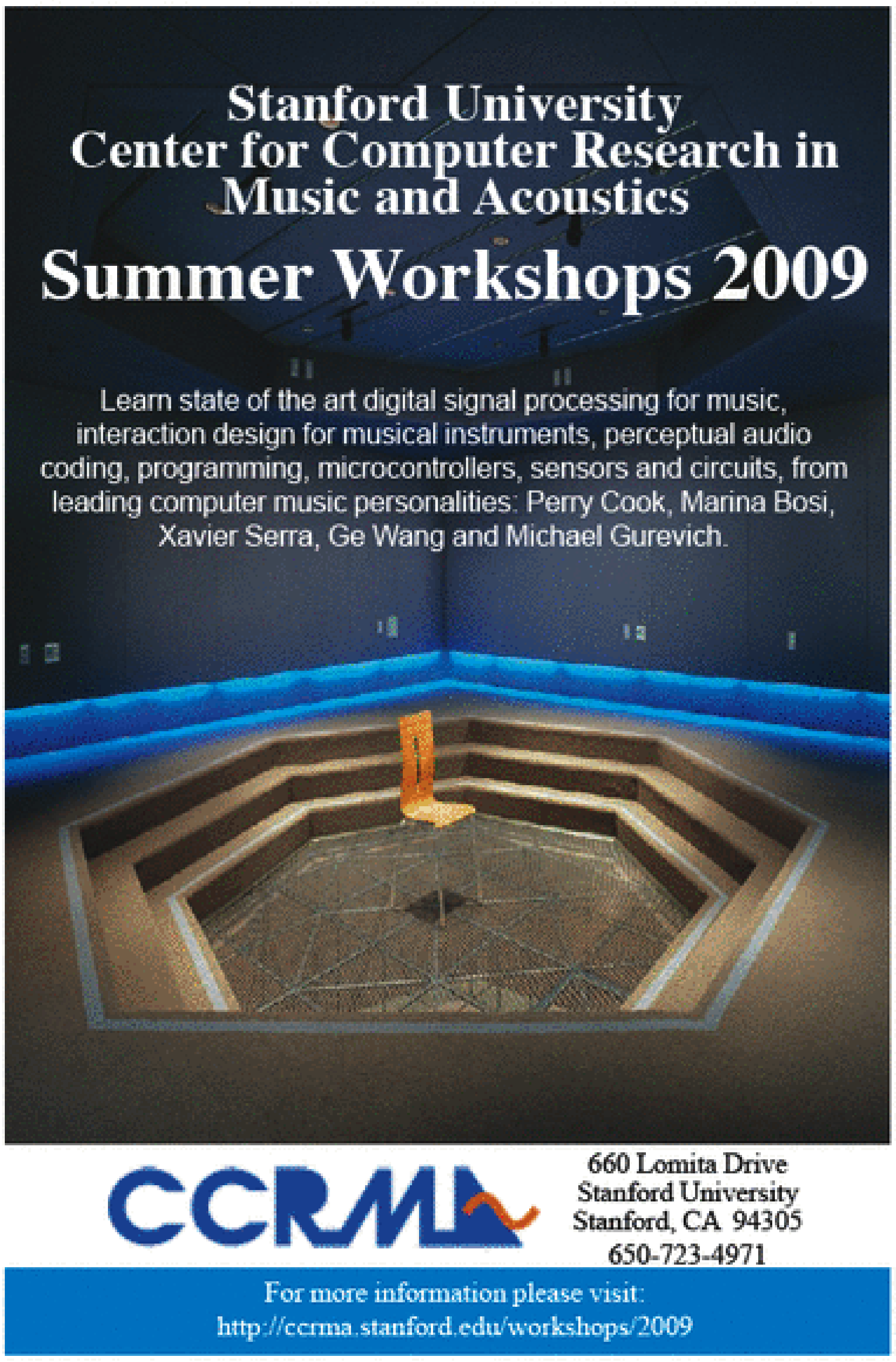
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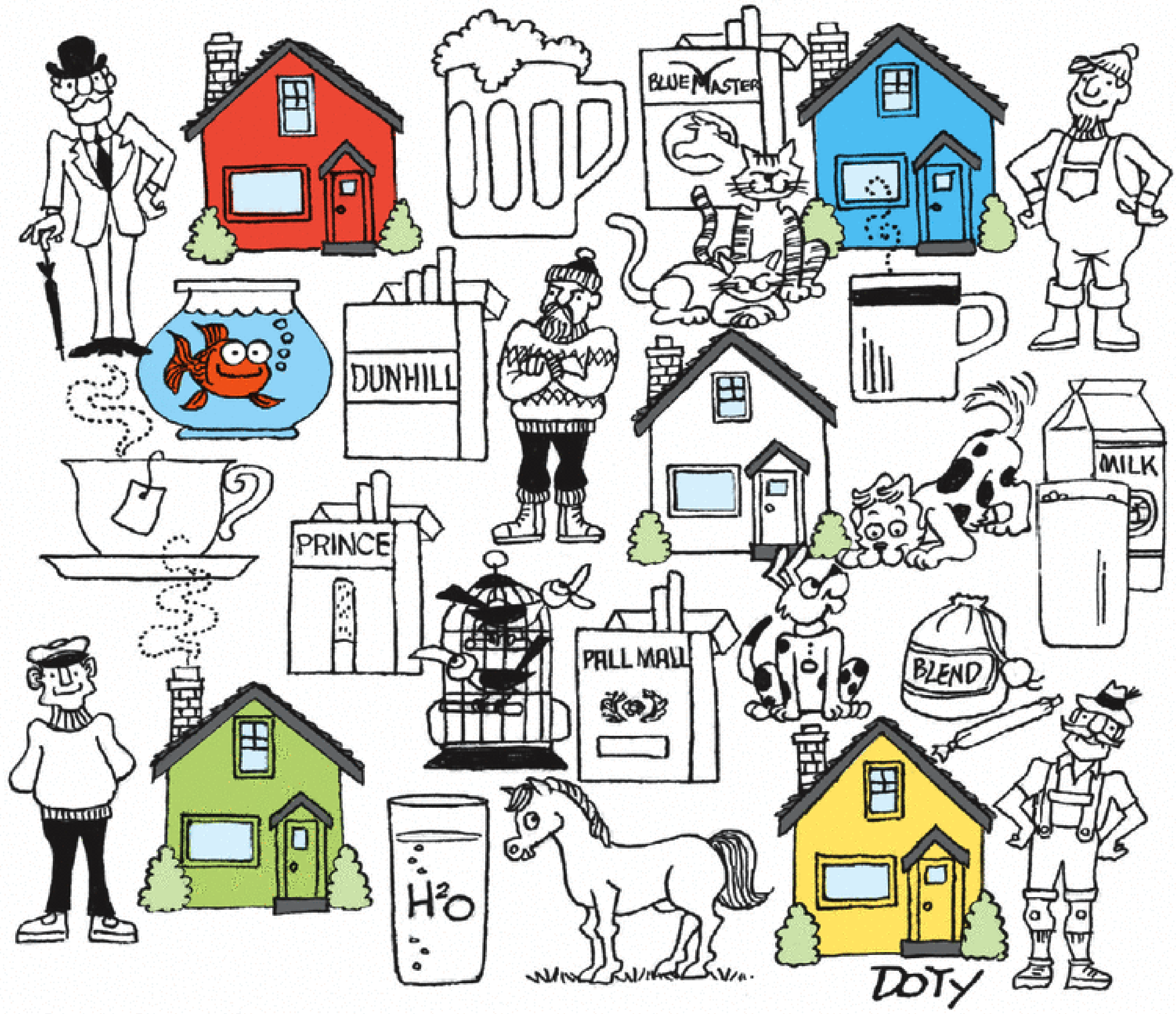
AHA! **Puzzle This** By Michael H. Pryor

MAKE's favorite puzzles. (When you're ready to check your answers, visit makezine.com/17/aha.)



"Einstein's Riddle"

It's rumored that Albert Einstein made up this logic puzzle and that he claimed that 98% of the population could not solve it. Are you among the 2%?

There are 5 houses, each of a different color. Each of their owners has a unique heritage, drinks a certain type of beverage, smokes a certain brand of cigarette, and keeps a certain variety of pet. None of the owners have the same variety of pet, smoke the same brand of cigarette, or drink the same beverage.

- The Brit lives in the red house.
- The Swede keeps dogs as pets.
- The Dane drinks tea.
- Looking from the front, the green house is just to the left of the white house.
- The green house's owner drinks coffee.
- The person who smokes Pall Malls raises birds.
- The owner of the yellow house smokes Dunhills.
- The owner of the center house drinks milk.
- The Norwegian lives in the leftmost house.
- The owner who smokes Blends lives next to the one who keeps cats.
- The owner who keeps a horse lives next to the one who smokes Dunhills.
- The owner who smokes Blue Masters also drinks beer.
- The German smokes Princes.
- The Norwegian lives next to the blue house.
- The owner who smokes Blends has a neighbor who drinks water.

Who owns the pet fish?

Illustration by Roy Doty

Michael Pryor is the co-founder and president of Fog Creek Software. He runs a technical interview site at techinterview.org.

HOMEBREW My Own Arduino Espresso Machine

By Timothy Hirzel

My espresso machine is customized for a quality coffee experience. Although not alone in the world of modified appliances, I think my Rancilio Silvia is unique. Her central nervous system is an Arduino microcontroller: all the switches that once flipped power to components now send requests to the Arduino. Through a set of relays, the Arduino performs the duties once assigned to the switches, making the machine entirely software-controlled. This intervention provides a platform ripe for change.

I added a precision temperature sensor and implemented a feedback algorithm to control boiler temperature. This is a scratch-built version of the popular PID mod for temperature stabilization (*see MAKE, Volume 04, page 121*). The Arduino's built-in USB connection can also send temperature data to a graph on my laptop. This helps greatly in tuning the feedback loop where three values must be artfully adjusted to achieve the best temperature stability.

Because I always forget to check the water level, I installed a capacitive sensor chip and attached it to a wire that runs into the water reservoir. But water isn't all I forget; just turning the machine on and off presents a challenge to me. As a remedy, I found a real-time clock board from SparkFun. Now Silvia starts to warm up every morning before I wake, and when I forget to shut her down before heading out to work, she goes to sleep after an hour of inactivity.

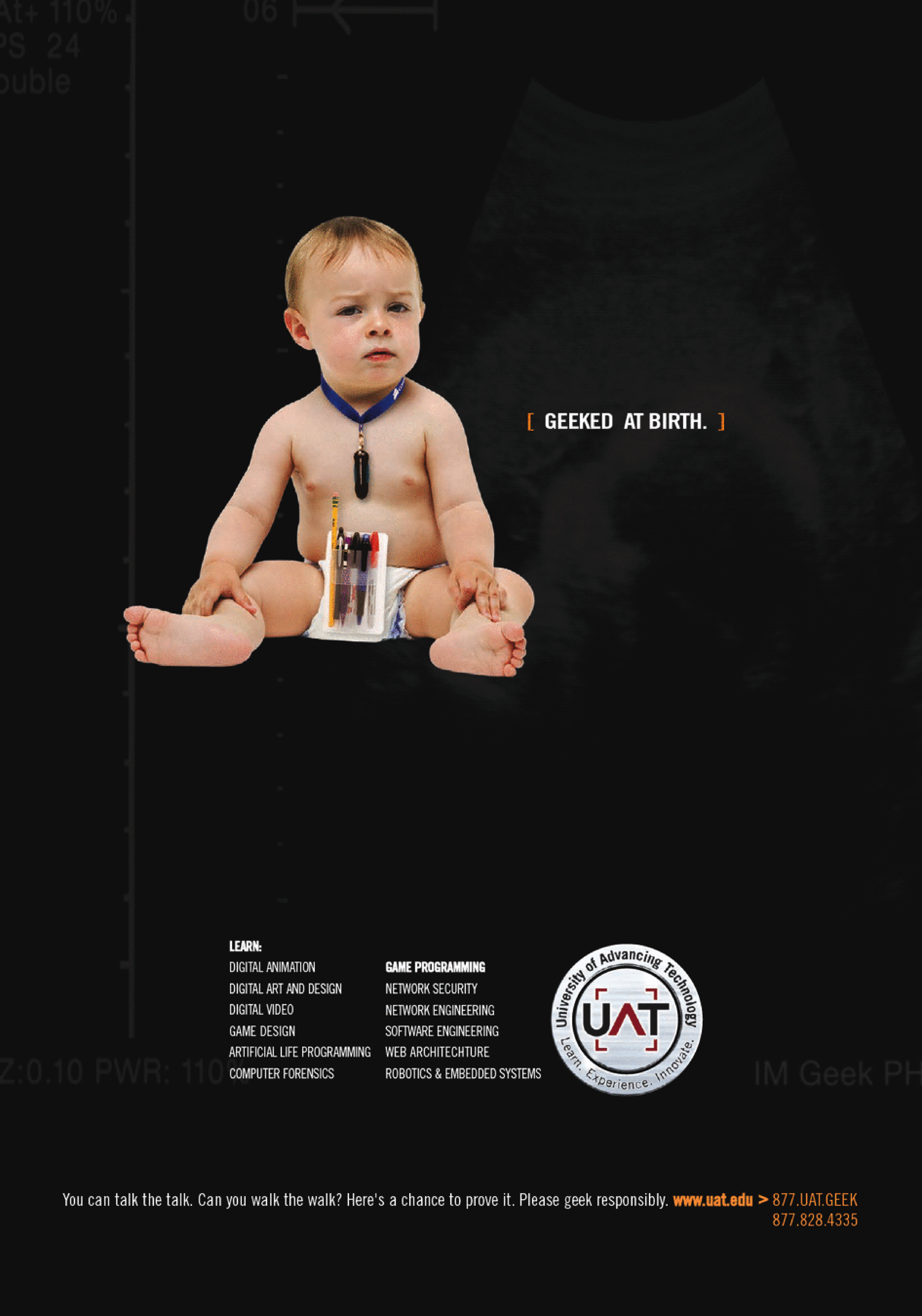
Needing some way to check all these new settings, I embedded an LCD display and attached a Wii Nunchuck game controller. I can now verify the machine's temperature, the duration of a shot, and the time of day as I prepare the daily beverages. The WiiChuck allows me to browse a simple menu system and adjust settings.

Each morning, I wake up bleary-eyed and stumble to the kitchen. There, Silvia and I produce coffee offerings that can range from heinous to delicious. These daily failures and successes inspire changes both to my own technique and to Silvia herself. In the evening, I can return to the kitchen to tinker and tweak — efforts to help her help me. Together, we evolve toward espresso betterment.

» More electronic coffee projects: arduino.cc/playground/Main/CoffeeTronics

Photograph by Timothy Hirzel

Timothy Hirzel lives in Ithaca, N.Y., where he writes software and tinkers with small boats, electronics, and coffee.



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