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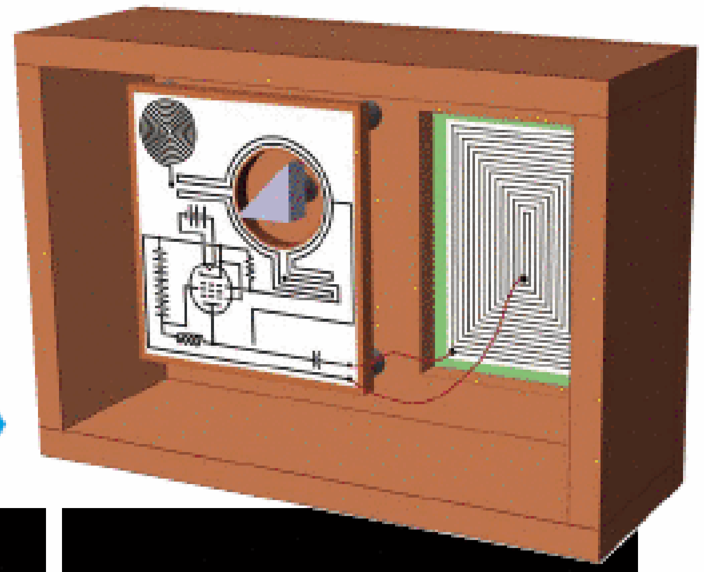
What is this strange device? See page 59 to build your own. »



Tales & Projects from the

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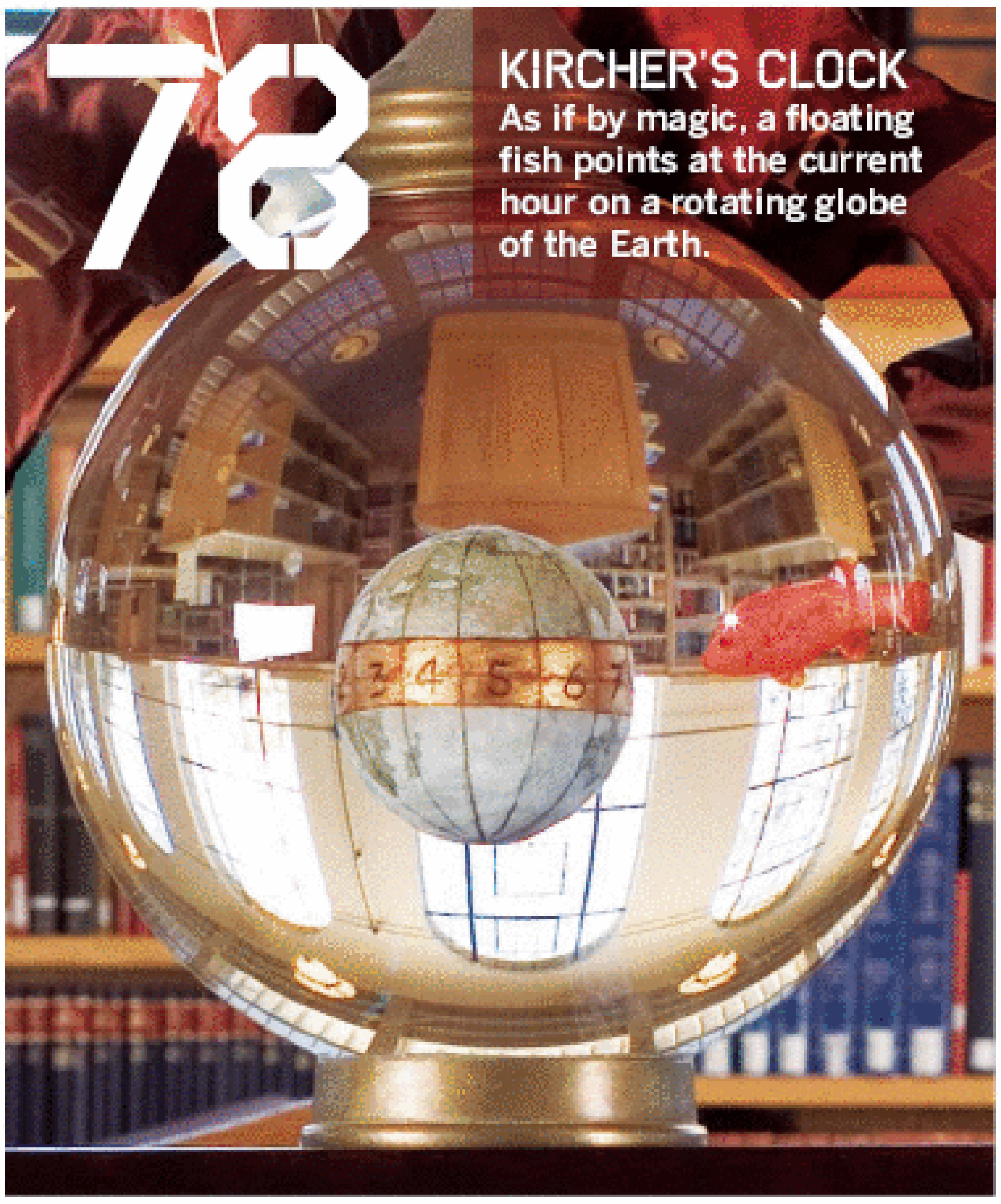
Special Fringe Section

Columns



ON THE COVER: Kirlian Photo of a Coin
Jasper Nance, who took the cover photo, writes that "the light you see during a Kirlian discharge comes from an electric field ionizing the air and parts of your Kirlian subject. The charged air gives off intense heat and ultraviolet radiation as well as visible light." *(See page 66.)*

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www.seaside5592.blogspot.com

Bill Young. Maker, boatbuilder, designer, programmer, craftsman, hacker and ShopBotter.

At Seaside Small Craft in the coastal town of Willis Wharf, Virginia, boatbuilder Bill Young's work consisted of "putting odd-shaped pieces of wood into odd-shaped holes in boats." That Was before he read about ShopBot's first CNC machine. That first tool was slow compared to today's high-performance ShopBots, but it allowed Bill to design and cut those odd-shaped pieces more quickly and with less error than if done by hand. It also allowed him to design new boats that were easy to make with CNC.





More than ten years later, Bill's still a boatbuilder, and a ShopBotter. Bill still cuts those odd-shaped pieces, but now his work also includes creating new CNC applications, like his stepped scarf method of designing, cutting and joining plywood parts - a method that has revolutionized kit boatbuilding. And, when Bill isn't using his ShopBot for "work," he's cutting projects for local schools. From boat parts to alphabet puzzle blocks to rubber band racers, Bill's creations are helping to build a love of thinking, designing and creating in a generation of future Makers.

See Bill's regular column, Bill's Corner, on the ShopBot website - www.shopbottools.com/bill's_corner.

ShopBot CNC Routers - What have you created today?

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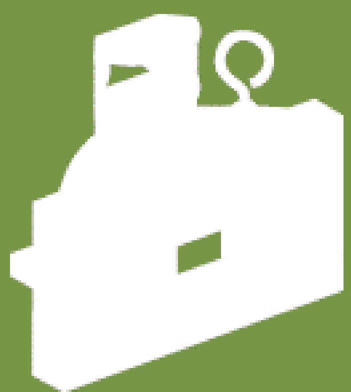

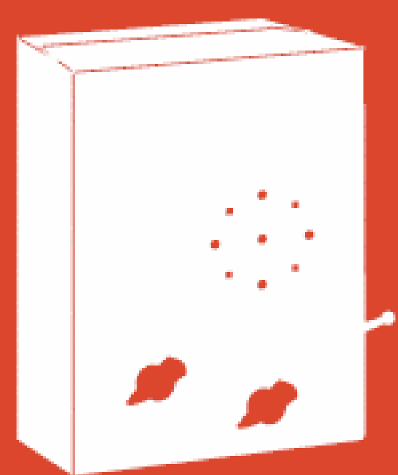

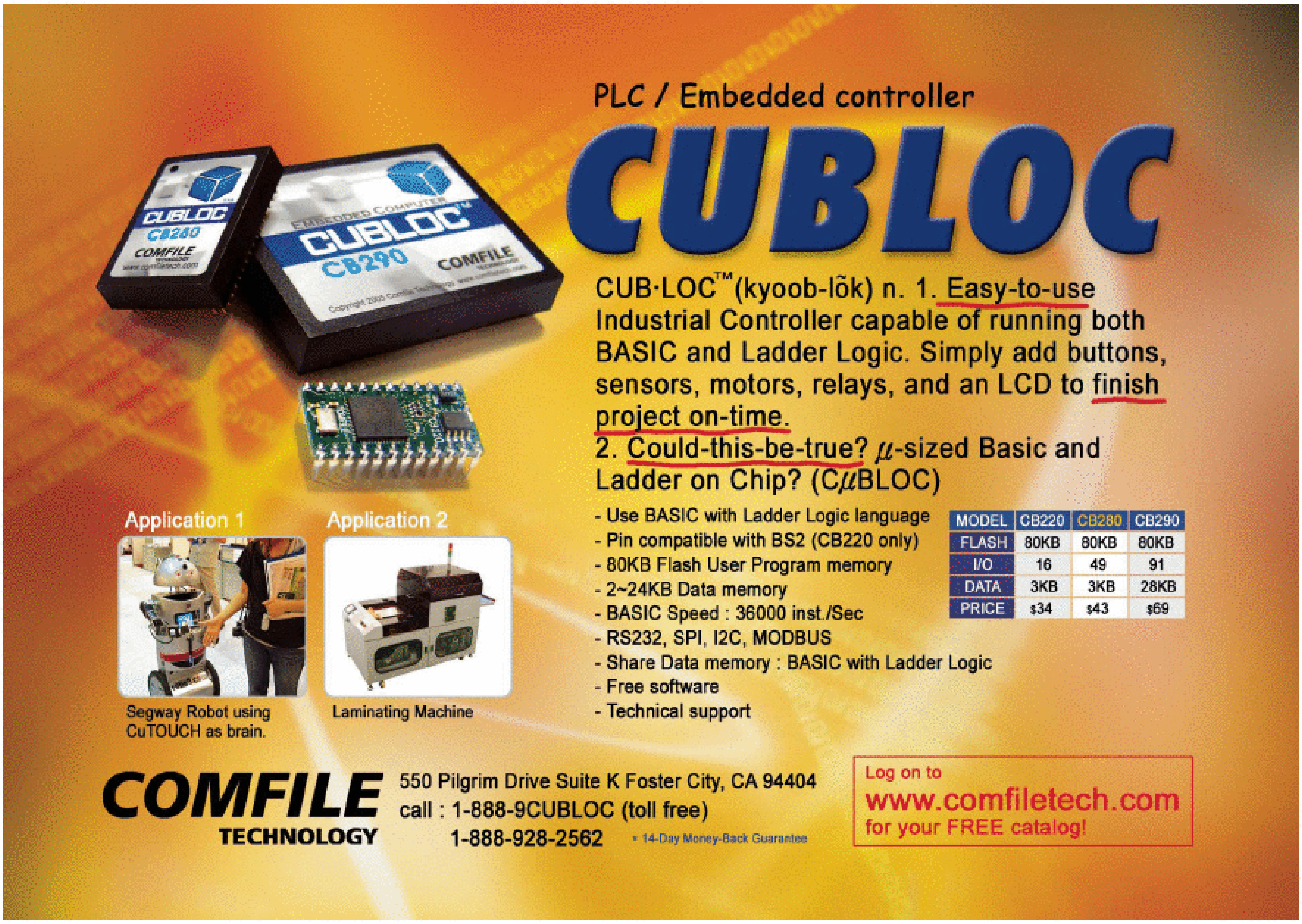
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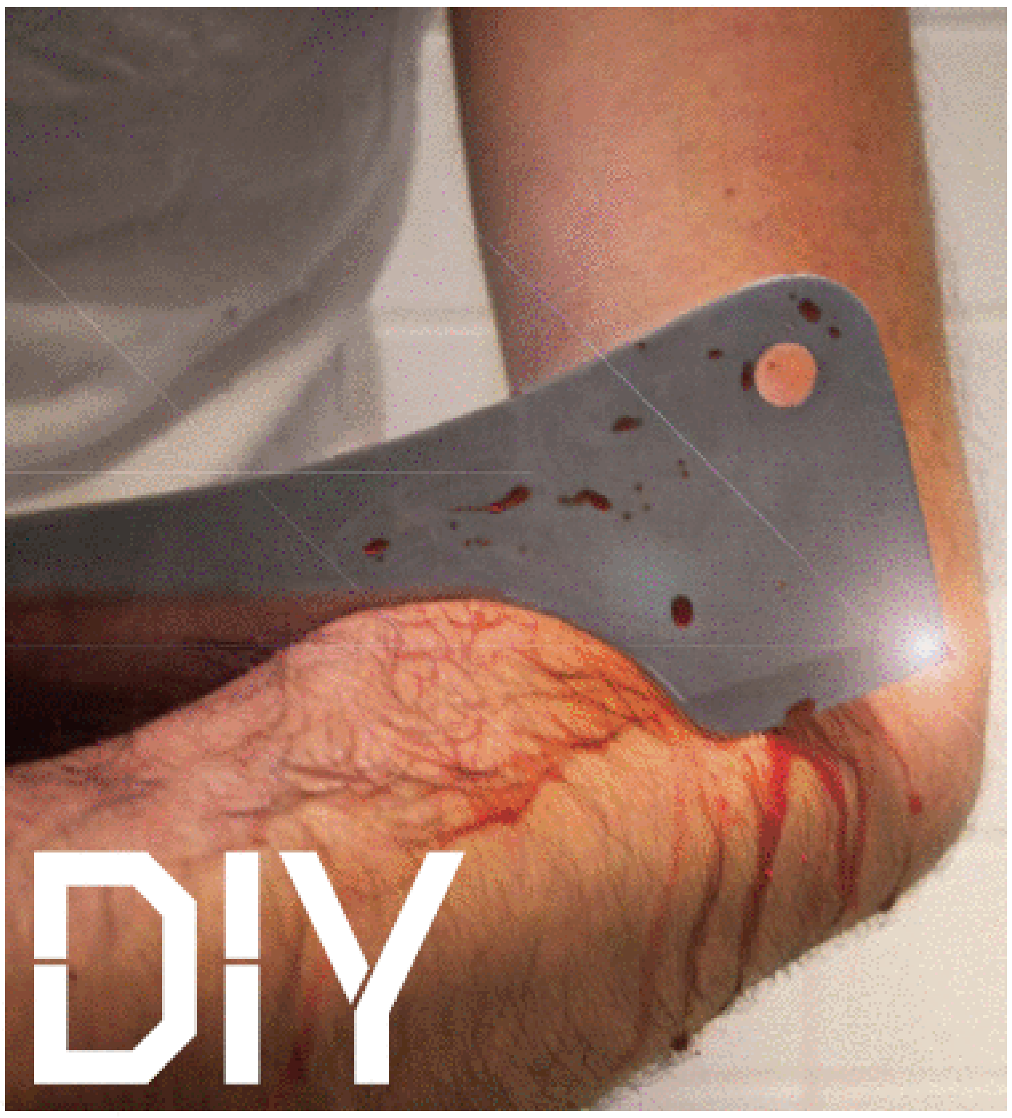

115


77" of your "thing" capacity
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You have "a thing." And no. It's not your "issues." Or your "stuff." It's the one thing you love doing. And maybe even being. Maybe you feel it when you're plugging in a guitar. Maybe you feel it when you're sitting in the middle of the ocean, alone. Waiting. Maybe you feel it when you're taking a load of Little Leaguers to Districts, two states away. Whatever it is, it's your thing. And it's always been your thing. Okay, sure. People may share the same thing. But deep deep, deep down, you know your thing is a little different. (Okay...a lot different.)
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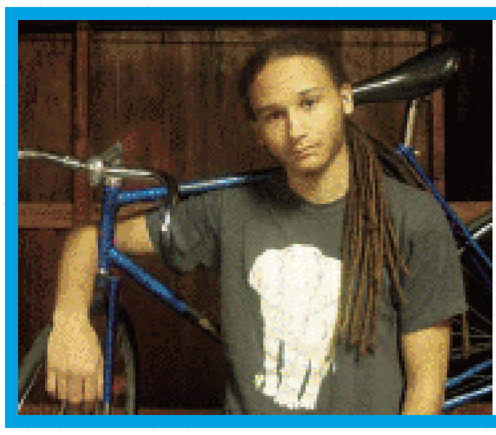
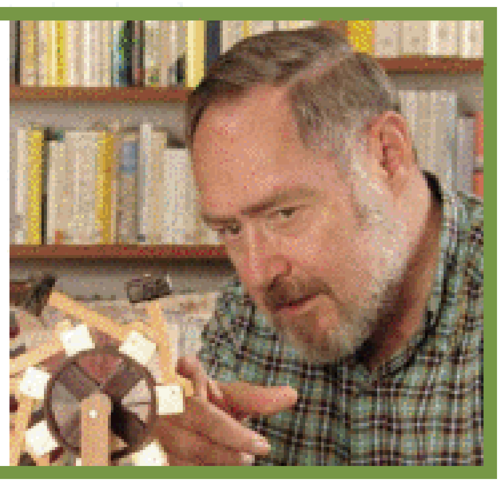


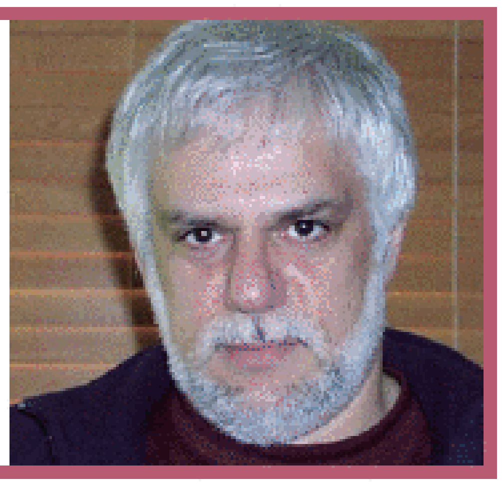
Jake MacKenzie (MAKE engineering intern) started taking stuff apart as soon as he discovered it was possible, and can get most of it back together. He enjoys bike riding, table tennis, video games, and foreign or classic films (boo Hollywood). An engineering student, he likes working on vintage amps, DIY radio gear, synths, and bikes. His current project is restoring a Tektronix oscilloscope from the 50s ("They don't make 'em like they used to — this thing is truly a boat anchor"). He will always eat udon, phô, pizza, or waffles.

Donald Simanek (*Reinventing the Square Wheel*) is a retired professor of physics with much experience dealing with things that don't work as they should. He has long been concerned with how students learn (and fail to learn) basic concepts of physics, and with the continuing failures of institutionalized education. The culmination of these concerns is his website (www.lhup.edu/~dsimanek/home.htm), which includes the occasionally acclaimed "Museum of Unworkable Devices." His other interests include the history of science, the science/pseudoscience boundary, photography, and classical music. He lives in Pennsylvania with his wife, Connie, a mathematician, a field where everything works, by definition.



Robyn Twomey (*Workshop* photographer) is "nonstop, curious, obsessive, resourceful with material things, and indulgent with expensive food." Her shoot with Kevin Binkert was a great success: "At first he was too humble to ham it up for the camera, but I couldn't get him to stop posing by the end of it." She is currently working on a photo essay about people with Tupac tattoos, but for fun she likes to "drink pinot noir, drive down the coast, read 'The Ethicist,' and go dumb." She lives in the Mission District of San Francisco, loves the idea that "30 is the new 20," and will always eat Delfina's flatiron steak and her mom's homegrown artichokes.

John Iovine (*Digital Kirlian Photography*), a tinker and science experimenter, is the author of many books, including *Kirlian Photography* and *Holography for Photographers*. He lives in Staten Island with his children, Anna Rose and James, his wife, (the "one and only") Ellen, dog Chansey, and "a number of neighborhood strays." What interesting projects is he working on now? "That could fill a book." He likes to read and write science fiction ("writing is hard, fiction is harder"), and explore the areas of science that "mainstream science doesn't want to look at." His favorite food is steak, barbecued.



Michael John Gorman (*Kircher's Clock limited edition booklet*) is the author of several books and various articles about the history of science and technology in journals including *Nature*, *Science*, and *Leonardo*. He is a founder of SEED (seedartscience.blogspot.com), a Dublin-based group dedicated to the dialogue between art and science. Michael John lived for some years in Rome, where he was cofounder and director of the Athanasius Kircher Correspondence Project, before returning (via Stanford) to his native Dublin, where he lives with his wife, Caroline Bouguereau, and their 2-year-old daughter Maia. He is currently director of the Science Gallery at Trinity College.

Sam Murphy (MAKE photo editor) lives in the Mission District of San Francisco with her cinematographer boyfriend, Mike, and their two kitties, Presley and Priscilla (who they did not name). Together, Mike and Sam make nonfiction films for nonprofits (cyclepathproductions.com), and annoy people with their photo/film-geek talk. Sam is a slightly angry, smart-ass, vegetarian bicyclist and bluegrass lover. When she is not watching a documentary film, she can be found playing soccer or drinking a soy chai. Her photographs can be seen in this issue opening each major project, and Mike is the star rocking out with the cracker box amp (and cracking the bullwhip).

FRINGE BENEFITS

By Mark Frauenfelder

STEWART BRAND, FOUNDER OF THE seminal *Whole Earth Review*, once famously said, "You've got to explore the edges to see where the middle is going." It's good advice because interesting changes often occur where cultures, ideas, and disciplines merge and mutate.

The special section in this volume of MAKE explores ideas on the edge. For example, Bob Parks' article on the Global Consciousness Project in Princeton, N.J., looks at the heretical notion that random number generators might be able to predict catastrophic events hours before they happen. We also show you how to take Kirlian photographs, which reveal the "auras" surrounding objects and living things. The principle behind Kirlian photography is well understood, and there's nothing supernatural about it, but the history of the process is interestingly laced with pseudoscientific speculation, and the resulting photographs are beautiful.

In this issue we also explore ideas that go way beyond the edge of traditionally accepted notions into the domain of the inexplicable, the unreasonable, and the impossible. Why should we be interested in this outer fringe? Is there anything of value being made there? More often than not, the answer is no. But that doesn't mean it's not worth making the occasional foray into the murky areas where it is difficult to distinguish between quackery and the genuine-but-inexplicable.

The most obvious reason for exploring the outer fringe is to discover the limits of the natural world. Take perpetual motion, for instance. To this day, a curious subculture of cockeyed optimists are tinkering away in self-funded laboratories, trying to make perpetual motion machines that defy the cardinal rules of physics (which say you can't get something for nothing). Occasionally, some of these inventors even get funding and public attention for their outlandish contraptions. The most recent free-energy company to shine under a surprisingly uncritical media spotlight is the Dublin-based Steorn, which claims to have developed a technology that uses magnetism to produce more energy than it consumes. If Steorn's claims prove true, it would mean the end of the energy crisis, and the potential to raise the standard of living of every person on the planet to the kind enjoyed by Halliburton's board of directors.

Anyone who thinks Steorn might be onto something would do well to read Donald Simanek's article on the history of perpetual motion machines in this volume (*page 70*). Simanek explains why making a perpetual motion machine is a worthwhile experience — not because it will work, but because you will gain firsthand knowledge learning why it does not work.

Rest assured, this issue contains plenty of projects that *do* work, like the amazing Hilsch vortex tube, which uses compressed air to push hot air out one side of the tube and cold air out the other side, and a pinhole camera that doesn't require your own darkroom to develop the photos. (We leave it up to you to come up with a way to take Kirlian photos with a pinhole camera.) Our nifty, easy-to-make Curie heat engine looks like something that could be found merrily swinging back and forth in the corner of a perpetual motionist's laboratory, but its operation depends on the energy of a candle to heat up a nickel-iron alloy wire so that it temporarily loses its attraction to a magnet. You might be able to use it as a metronome when you play your cigar box guitar (*from MAKE, Volume 04*) through the cracker box amplifier we'll show you how to make in this issue (*page 104*).

Finally, I'd like to remind you to mark your calendars for this year's Maker Faire, which will be held at the San Mateo County Fairgrounds in Northern California on the weekend of May 19–20, 2007. Last year over 20,000 people came to participate in demonstrations, projects, entertainment, and learning. If you're a maker and have something you'd like to show at the faire, visit makerfaire.com for information. I hope I see you there!

Mark Frauenfelder (markf@oreilly.com) is editor-in-chief of MAKE.

News From the Future

PERVASIVE PUBLISHING

By Tim O'Reilly

PETER BRANTLEY, OF THE CALIFORNIA Digital Library, has written a fascinating meditation on the future of publishing (xrl.us/brantley):

Books are artifacts — loved, endearing, effective in their form. They will endure. But they and other media will be consumed in a wide range of environments, more or less virtual, more or less complex, more or less multimedia. It is all of a degree.

It is not, therefore, whether the reading experience will be textual or richly media immersive. All the world will be a skein of media, linked and interacting, flowing and increasingly seamless. There will be text, but text embedded within other environments, available to and linking to a rich cornucopia of information, amusement, and education.

Brantley nominated Second Life as a candidate for both the platform, and the channel for media in the future. Much as I like SL, I'm not sure that's right. Second Life as currently constituted is a pale shadow of what is to come. What I took away from Peter's post was the idea of Second Life as a metaphor for pervasive publishing. We already live in Second Life; we just haven't recognized it yet.

As the poet Wallace Stevens said, "It is not in the premise that reality is a solid." Reality is always a dialogue between the world and the mind, what we see and what we make of it. Stored ideas and images are used to filter and enrich the stuff of everyday experience. A baby spends its first years building a map of the world; an active, thoughtful reader continues that process while a passive media recipient lets others do the mapping. Ideas and images are tools we think with. Mastery of these tools makes the difference between creativity and mere consumption.

Books (and in fact, all media, including commercial media like advertising) have always provided "a context in which other people can think," as Edwin Schlossberg famously said, but what is different today is the pervasiveness of that media.

Think back to the days before Google and Wikipedia, when a gap in your knowledge was not so easily filled, and now roll forward, to imagine a world where the ability to check facts, to add background, and to share the experience with others, is truly ubiquitous. We can look forward to a future in which information retrieval about the things we encounter in our daily lives, and contextual advertising to go with it, is not limited to text on a screen, but becomes a component of audio and video overlays on our perceptual field.

In the past, the dialogue between mind and matter was carried out in the imagination. But increasingly, it will happen as part of our daily experience, mediated by technology. We will need to find new ways of engaging, new ways of being active rather than passive, or our thinking will be done for us.

And that brings us back to Second Life. What is important about Second Life is not just its immersive quality. It's the fact that its members are active participants in creating it. They are makers, not consumers. That's what is also important about the World Wide Web, Wikipedia, YouTube, and Flickr.

Stevens talked about this idea, too. He wrote about reality as "the supreme fiction," and foresaw a future in which we sought not "truth" but rather aesthetic visions that would form a new shared reality.

The future of media is the future of thinking, the future of the shared imaginings that we call culture, and science, and religion. How we communicate, and what we communicate, are inseparable. What does not change is the imperative to engage, to imagine, and to remake what we are given into something new that we can share.

Check makezine.com/09/nff for links to related stories.

Tim O'Reilly (tim.oreilly.com) is founder and CEO of O'Reilly Media, Inc. See what's on the O'Reilly Radar at radar.oreilly.com.

MAKER'S CORNER

By Dan Woods, Associate Publisher

Advice and news for MAKE readers.

Maker Faire 2007: Save the Date!

One of the more popular emails we receive is, "Are you guys doing another Maker Faire this year?" Hell yes, we are! In fact we're planning two Maker Faires this year:

- SF Bay Area Maker Faire: May 19–20 at the San Mateo County Fairgrounds
- Austin, Texas Maker Faire: October 20–21 at the Travis County Fairgrounds

And yes, we are also actively exploring other potential Maker Faire venues across the planet. If you'd like to be alerted as to upcoming MAKE events, including future Maker Faires, visit makezine.com/faire and sign up for the MAKE newsletter.

So save the dates, be a good maker and spread the word, and sign up for the free MAKE newsletter (makezine.com/newsletter) for further details.

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MAKE: The Next Year Boxed Collector's Set Now Available

It's finally here: MAKE: The Next Year! The original boxed collector's set, MAKE: The First Year, proved so popular with our readers (three reprints!) that we decided to put together a special collector's edition of our entire second year. Hence, MAKE Volumes 05 through 08 are now packaged up in a sturdy (and handsome) collector's box. Our price: $60. That's the same price as buying the individual copies on the newsstand, plus we throw in the box. Hard to think of a better gift for a maker (or maybe yourself). Order yours today at store.makezine.com.

MAKE Has a Brand New Store

If you weren't among the record number of makers who visited the Maker Store (store.makezine.com) last December, you haven't yet seen our brand new storefront or our growing list of cool MAKE: It tools, project kits, books, apparel, and toys. Just a small sample of our new products:

- MAKE Warranty Voider tool
- Limor Fried's MintyBoost USB Charger Kit for your MP3 player, camera, cellphone, etc.
- MAKE Controller Kit
- MAKE Open Source MP3 Player Kit
- Andre Lamothe's XGameStation Pico Edition 2.0
- Building Small Form Factor PCs (downloadable book)

Stop by and check out the latest merch at store.makezine.com.

CRAFT, Volume 02 Is Out!

When the first box of CRAFT, Volume 02 arrived in the MAKE offices, it may have set a Maker Media record for vanishing acts. I stashed a copy for some perusing at home that night. No better way to say it than Frickin' Awesome! Check out the TOC and sample articles at craftzine.com/magazine. And if the spirit moves you, consider giving CRAFT as a gift for any and all occasions. (Maybe you forgot Valentine's Day?)

Dan Woods is associate publisher of MAKE and CRAFT magazines. When he's not working on circulation and marketing or finding cool new stuff for the Maker Store, he likes to hack and build barbecues, smokers, and outdoor grills.

I AGREE

IN ORDER TO "PROTECT INTELLECTUAL PROPERTY," THESE BANDITS ARE PERFECTLY WILLING TO TAKE AWAY YOUR RIGHTS TO YOUR PHYSICAL, PERSONAL PROPERTY.

By Cory Doctorow

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It's amazing how little it takes to form an "agreement" these days. I once heard an MPAA executive explain that you could "agree" to waive your fair use rights to record a TV show by changing the channel. My ThinkPad arrived from Lenovo with an eight-page "acquisition agreement" that explained all the things I'd just "agreed" to by sending them thousands of dollars. Amazon Unbox makes you agree to install spyware on your computer in order to download their videos. From the dry-cleaner's ticket to the hotel room to the small print on the back of your cellular bill, these gotcha-greements lurk everywhere, waiting to leap out and clobber you with abusive terms and services. Woe betide the fool who installs Vista (you "agree" not to solve your own problems without authorization) — and don't let's get started on all the things you "agree" to before you get on a plane.

Civilization begins with an agreement: the social contract. The idea that we can meet as relative equals and hammer out a compromise practically defines what it means to be human. Can you have a social contract if you reduce the idea of a contract to "By standing there, shaking your head, and screaming, 'No no no no no no! I don't agree,' you agree to let me come over to your house, wear your underwear, make some long distance phone calls, and clean out your fridge. Run away screaming to indicate your assent"?

These "agreements" set out the terms under which you can use your own property. They waive fair use, prohibit lending, resale, or reverse engineering — sometimes even swear you to secrecy!

If you're a maker, your vocation is voiding warranties and creating fire hazards. These "agreements" set out two classes of people: lordly manufacturers who own and control everything, and lowly tenant farmers who merely borrow their goods from the lord.

Being a maker is about owning and Owning — having access to the lowest-level guts of the machine, putting Tab A into any slot that takes your fancy. It's the right to break your stuff and fix it again. It's all about real, non-metaphorical property.

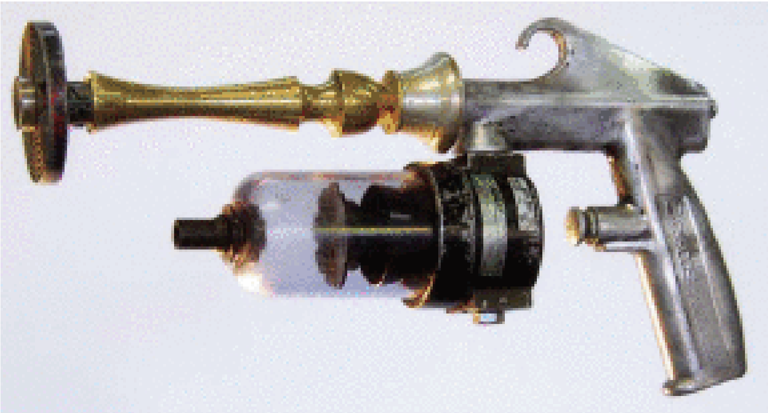
Start a count of the "agreements" in your life. How many times a day do you "agree," and what is it you "agree" to? Start pushing back. Don't take it lying down.

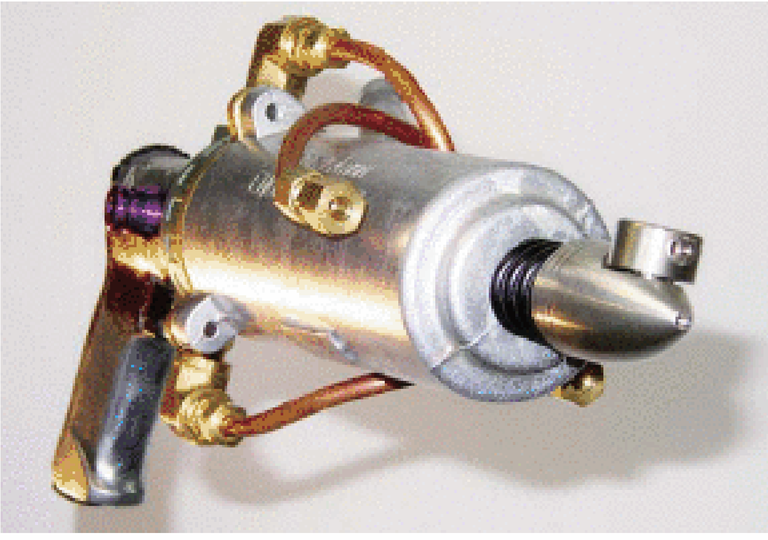
Be disagreeable.

Cory Doctorow (craphound.com) is a science fiction novelist, blogger, and technology activist. He is co-editor of the popular weblog Boing Boing (boingboing.net), and a contributor to *Wired*, *Popular Science*, and *The New York Times*.

MADEONEARTH

Report from the world of backyard technology





Raygun Reverie

Photography by Paul Loughridge; photograph far right by Cindy Loughridge

"You know, guys never really grow up," says **Paul Loughridge**. His hand-built, retro raygun models have the authentic menace of *Star Wars* and the wacky form factor of *Men in Black*. But their mid-century, all-metal look is straight out of his childhood favorites: *Flash Gordon*, *Amazing Stories*, *Lost in Space*.

Collectors think he's on to something. His work has a satisfying heft from a time before plastics and semiconductors ruled the Earth, when science fiction was built to last with rivets and bolts, copper flanges and chrome fins. Who wouldn't love to fry a Martian with the Aluminizer, the Shrink Ray, or the Double Barreled Intergalactic Self-Defense Mechanism?

Loughridge, 51, is a Silicon Valley graphic designer, trade-show director, and compulsive collector whose itch for vintage toys took him down the DIY path. Maybe it was his wife banishing his collection ("rayguns, rocketships, and robots ... all pre-*Star Wars*") to a storage unit. Maybe it was the raygun that got away.

"I'd just got back from a toy show," he recalls, "and must have seen some bitchin' raygun I couldn't afford. I decided to make my own out of metal. Used an old drill handle that had belonged to my dad." He Googled "raygun," and master maker Clayton Bailey became his inspiration. Dozens of rayguns followed.

In a garage outfitted with a drill press and grinder, Loughridge bolts together flea-market junk. Pistol grips come from old air tools and hacksaws. Barrels and muzzles might be a mean-looking orange juicer, BMX foot peg, or — just once — a perfectly good flower vase. ("Sorry, honey!") Finishing touches include cocktail shakers, brake hoses, and copper toilet floats.

"Rayguns are definitely a guy thing ... it's a Tim Allen grunt kinda thing. Boys want to touch them." But he's broadening his audience. "I made a couple robot dogs and female robots, and women are buying them."

Now when he's not tending his bonsai tree collection (he's got 70 in the backyard), you might find Loughridge in the garage, creating toy robots, rocketships, and rayguns. "I just love old retro stuff. It all has to do with being a kid." —*Keith Hammond*

» **Rayguns:** lockwasherdesign.com/index_4.htm
claytonbailey.com/galleryrayguns.htm

Illegal Soapbox Derby Races

There are no permits from City Hall, no advance promotions, no schedules, and only one ironclad rule: every car must have a beer can holder. Yet even that edict often falls by the wayside because no one knows who's in charge of enforcement. And besides, at the Bernal Heights Illegal Soapbox Derby races — held each autumn in San Francisco —the point isn't to follow the rules, or even to go fast.

Instead, it's about figuring out how to build a gravity-powered car out of whatever materials you can find, then taking your homebuilt wheels on a white-knuckle ride down a twisty mountain road that overlooks the sprawling city below.

"Some guys want to win more than others, but pretty much it's all just for fun," says **Scott Strebel**, 29, co-creator of a car unofficially known as the Keg Racer. Built over the course of a week by combining the front end of a Quarter Midget go-cart, a few wheels purchased at Orchard Supply, and three old beer kegs he found lying around his garage, Strebel's vehicle looks like a Homer Simpson-inspired cross between Luke Skywalker's Landspeeder and Anakin Skywalker's Pod Racer — though he insists the similarity is purely coincidental.

"We just arranged all the materials on the floor, then figured out what we could build with them," he says. Other cars on the hill in 2006 included a bullet-shaped streamliner with a fully enclosed cockpit, a four-wheeled surfboard, an unmodified 1960s pedal-car called the Dude Wagon, and a rolling coffin emblazoned with Dale Earnhardt's signature "3" logo.

Soapbox derby races have been taking place atop Bernal Hill since the 1970s, but it's not entirely clear what makes the event illegal — some say the outlaw tag refers to the unauthorized appropriation of a normally serene city park, while others claim the race is a defiant antidote to the more uptight (read: rulebook) American Soap Box Derby.

Of course, the AASBD doesn't require each car to have a beer can holder. But then again, at the Bernal Heights Illegal Soapbox Derby Races, no one really does either. *—Todd Lappin*

Photograph by Telstar Logistics

Photograph courtesy of San Francisco Maritime National Historic Park

History Junkies

As an undergrad, **John C. Muir** came across 19th century photos of Chinese junks sailing the San Francisco Bay. Curious about what these foreign vessels were doing in California, Muir dove into maritime research and was soon building a replica himself.

Muir learned that several immigrant Chinese shrimping communities settled in the San Francisco and San Pablo Bays between 1860 and 1910. Little remains of these villages, but the well-preserved remains of two redwood junks were discovered during low tide in the mudflats of China Camp State Park in Marin County.

Muir, now a curator of small craft at San Francisco Maritime National Historical Park, decided to recreate a traditional California-Chinese shrimp junk from the ground up. With Park Service approval he snowshoed through the mud to take photos and measurements, and enlisted the help of third-generation China Camp resident **Frank Quan** and a crew of mostly amateur boat-builders, who called themselves "Junkies."

To build the 42-foot replica, they used traditional techniques Muir learned from trips to boatyards in the Guangdong province of China. The Junkies bent the redwood of the keel and planks over a fire, shaping them around a fulcrum while clamping or weighing the ends down with buckets of rocks, and constantly spraying the lumber with water, to prevent burning.

"At first fire-bending seemed counterintuitive," says Junkie **Inka Petersen**, "but it works instantaneously. Plus we got to have a bonfire on the beach every day."

When it was time to piece the vessel together, volunteer blacksmiths taught the Junkies to forge headless iron nails based on samples Muir brought from China. Headless nails are integral to the art of edge-nailing, which joins the planks to each other as well as to the main structure.

Six months later the junk was christened the *Grace Quan* after Frank's mother. The crew raised the hand-sewn and tanbark-dyed cotton canvas sail, perhaps the vessel's most stunning feature, and the *Grace Quan* set sail on San Francisco Bay.

—Audra Wolfmann

>> **Shrimp Junk Project:** nps.gov/archive/safr/junk.html

Purrfect Relaxation

Feeling stressed? You need a visit to the studio of **Duncan Laurie**, a three-story structure perched on a gorgeous spit of land that overlooks Rhode Island's Narragansett Bay. Laurie built the structure from mostly salvaged parts, and if the salt air and crashing waves outside don't ease your mind, the studio's Purr Generator surely will.

The Purr Generator is based on Radionics, an alternative technology founded by Dr. Albert Abrams in the early 1900s, on the observation that all matter emits radiation. Radionics surmises that a healthy person attains energetic equilibrium, while unhealthy people are essentially out of tune. The Purr Generator aims to restore balance with healing frequencies that neutralize energy blockage.

The Purr Generator attempts to replicate and amplify the sense of relaxation people experience while holding a purring cat. The device produces its main signal wave at a happy-feline frequency of approximately 25Hz, and directs it into the user as sound, physical vibrations, and "radionic intent," bathing the body in good vibes. A second channel generates a signal that's close to the first but offset by a user-adjustable +/- 2Hz, which adds a dramatic spatial effect and a throbbing beat frequency.

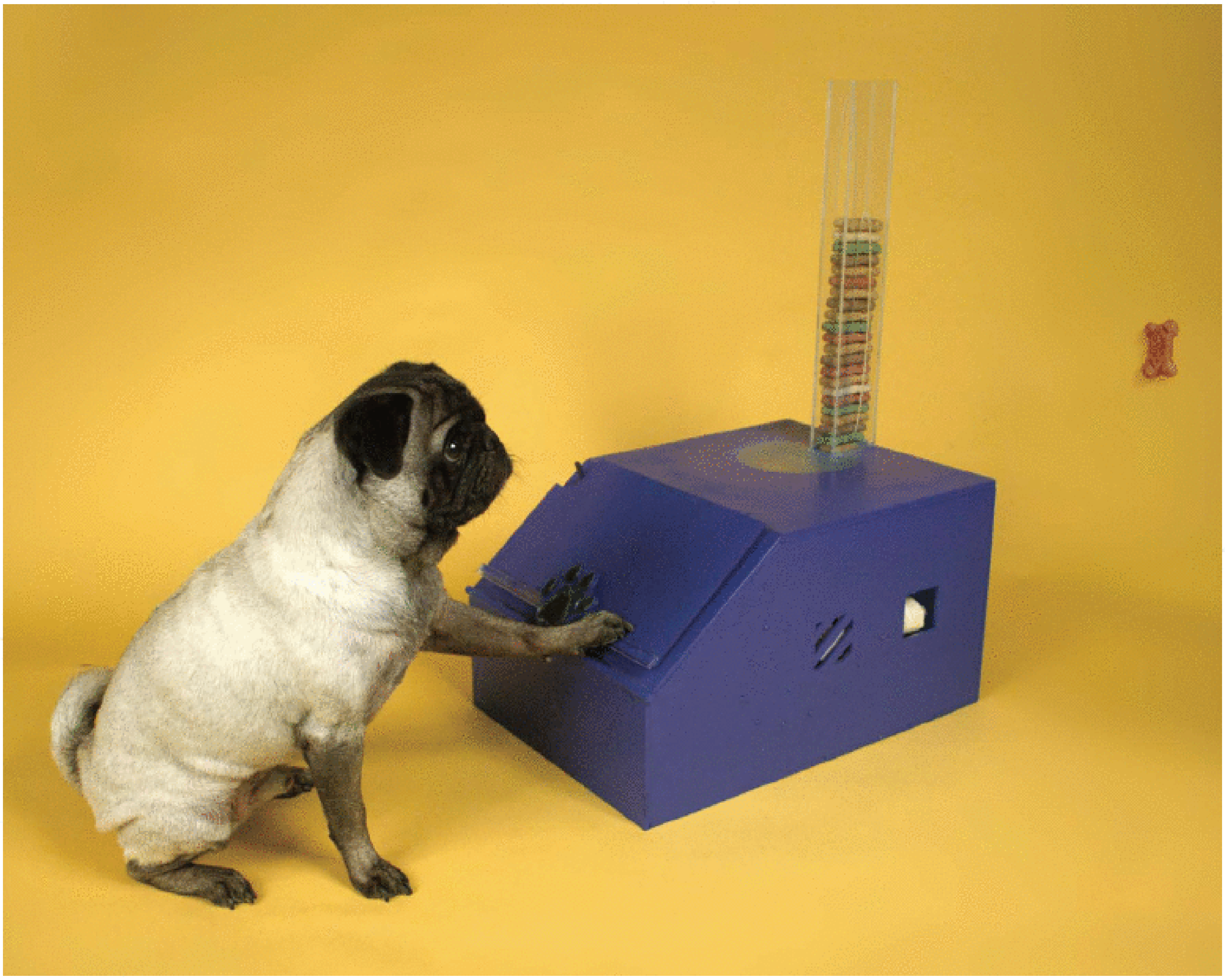
To use the device, you lay on a bed suspended inside a cube-octahedron structure. A coneless magnetic coil under the pillow generates a tuned magnetic field, two Buttkicker-like transducers make the bed vibrate physically, and speakers attached to the geometric shell above and below the bed produce sound. A controller box at your right lets you tweak and mix the various waveforms, insert a radionic command, and add in white noise.

Laurie's studio is filled with other fascinating equipment: a brainwave-to-MIDI converter, Faraday cages, and ultrasound microphones. But the Purr Generator is a popular favorite. Laurie has successfully used it to encourage bone healing for his own hip replacement, and rumor has it the Purr-cure also works for ailments ranging from back pain to depression. Purrfect!

—Steve Nalepa

>> **Duncan Laurie:** duncanlaurie.com

Photograph by Todd Thille



Photograph by Charles Platt

Throwing to the Dogs

When **Ken Schroeder** was repairing appliances for a living, he decided that a spring-loaded switch from a dishwasher would be ideal as a trigger for some kind of device that his dog, Bender, could activate. Two years later, while studying industrial design at the Art Institute of Pittsburgh, Ken mounted the switch behind the sensor plate of the world's first automated dog-biscuit thrower.

Bender places his paw on the sensor plate. An electric can opener turns gears that feed a biscuit from a magazine. Bender waits expectantly. Tension builds. The motor from a hand-held kitchen mixer starts whirring, driving eggbeaters coated in silicone caulking. The biscuit hits the beaters, which kick it out of an ejection port. While Bender chases the biscuit, the machine resets itself, ready for the next cycle.

The bone thrower satisfied three goals for Schroeder. "I had to make a project that involved gears and electrical," he recalls. "Also I made a video about teaching an old dog new tricks, for a psychology class. And, Bender and the bone thrower were attractive to potential girlfriends." He pauses. "Can you express that in the nicest possible way?"

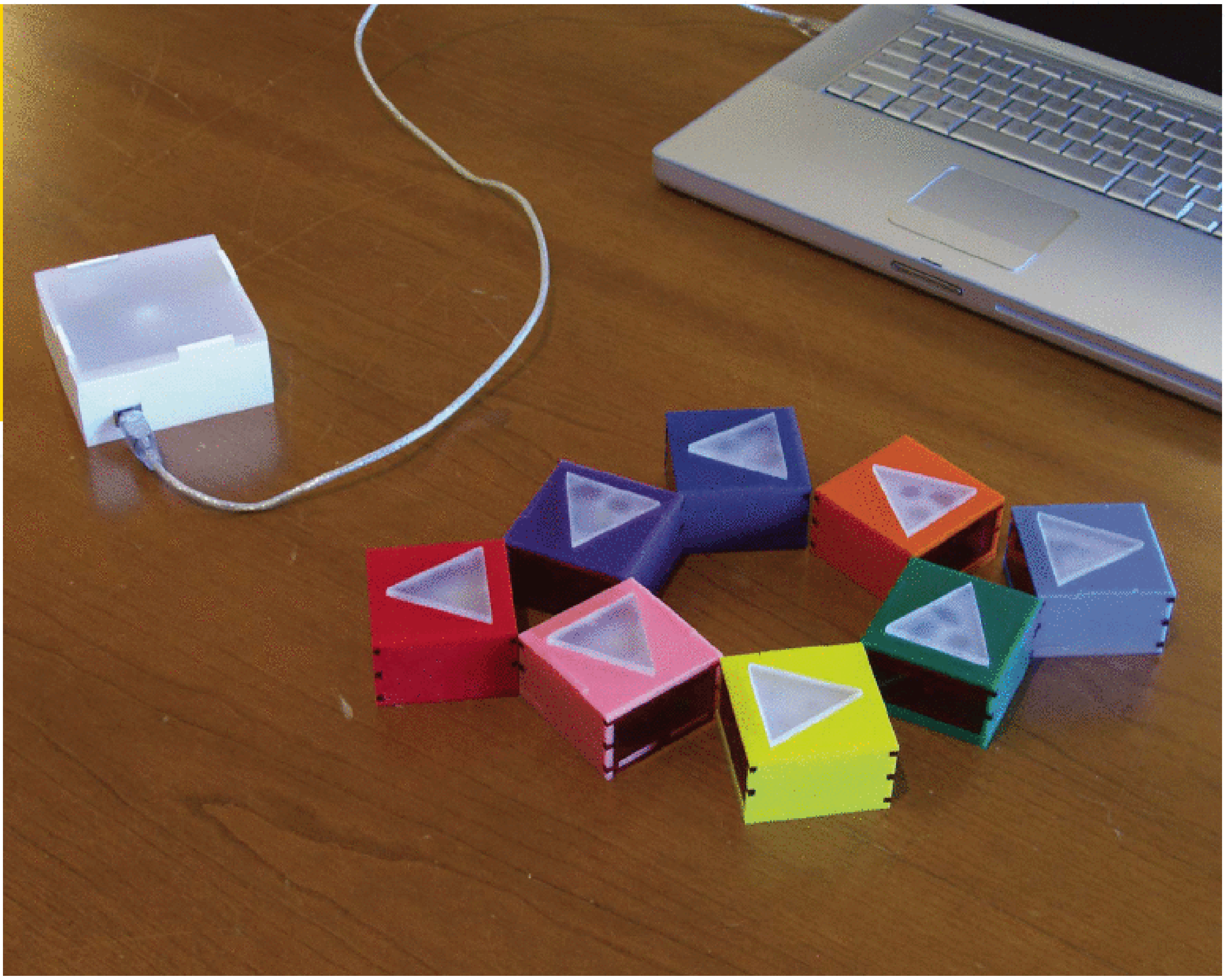
Schroeder has a long history of building gadgets. "When I was a kid," he says, "I used to take Legos and add motors and paddlewheels, and play with them in the pond. Also I used an angle grinder to cut notches in the rims of bicycle wheels, so that I could ride on ice. Unfortunately, that didn't work very well."

Currently Schroeder lives in Florida, where he and his brother hope to start a business selling furniture fabricated from unusual materials, such as string soaked in resin. What motivates him in his design projects?

"It's fun to be creative and make things," he says with a shrug, as if the answer should be obvious.

—Charles Platt

» **Dog Biscuit Thrower:** ktschroeder.com/Products.php



The Sound of Music Blocks

The Tangible Music Sequencer lets people of all musical abilities feel like Julie Andrews conducting an orchestra of robotic von Trapp children.

The Sequencer is a collection of candy-colored, palm-sized boxes that semi-autonomously "play together" by making sounds (and light) and then triggering adjacent blocks to follow. Simple software lets you drag-and-drop any sounds, such as drumbeats, words, or even whole songs, onto icons representing the blocks. You then place the physical blocks in any configuration — next to each other, one after the other, or in forks — and press their Play buttons to hear the sequence of sounds you've created. If you press multiple Play buttons, you can create polyphony or other overlapping sequences of simultaneous sounds. You can also move the blocks back and forth to make them repeat.

"I'm taking advantage of the knowledge people have of interacting with their surroundings, and giving them a simple, yet expressive way of using it," says **Jeffrey Traer Bernstein**, a Ph.D. student at Princeton's Sound Lab, and the maker of the Sequencer.

Each box is controlled by a Freescale 8-bit microcontroller, sends signals via infrared, and uses Panasonic low-power RF modules to communicate with a hub on the host computer. The host doesn't just upload sounds to the boxes; it also calculates what each sound "looks like" in blinking light, and uploads this info to the blocks for great visual effect.

"I wanted to make the simplest musical instrument possible that allows for expression and yet makes immediately recognizable music," says Bernstein. "The idea is not to make John Cage."

For Bernstein, the success of his Sequencer will be determined by the surprising interactions between users and the instrument. He's working on manufacturing his Sequencer, and ultimately getting it into the hands of everyone from DJs to kids to orchestras.

"People have this idea that what they make is theirs, that they have exclusive control over how it'll be used, but I think that's counterproductive."

—Nicole Oncina

>> **Princeton Sound Lab:** soundlab.cs.princeton.edu

Photograph by Jeffrey Traer Bernstein

Hacker of Yesteryear

When **Jake von Slatt** was 14, he was the only kid in his neighborhood (maybe the only kid in *any* neighborhood) who owned his own brazing torch. At 16, he lost part of a finger in a "hovercraft incident" (now that's an emergency room visit you don't see every day). Jake von Slatt's not even this colorful character's real name, but a persona he uses online, his "brand," as he calls it.

By day, he's a Linux sysadmin for an aerospace firm outside Boston, but in his spare time, von Slatt likes tinkering with and modding castoff tech of the past. He has several websites chronicling his progress in everything from converting a 1989 Thomas Saf-T-Liner MVP bus into a gorgeous motor home to his Steampunk Workshop, where he mods kerosene lamps and experiments in brass etching. And then there's his page where he enthusiastically logs his town dump and dumpster-diving finds.

Given Herr von Slatt's interest in tech resuscitation, it's no wonder that one day he looked at a Western Electric Bell Model 500 rotary phone, that icon of 20th century telephony, and saw its future as a 21st century mobile.

Unlike other retro handsets he'd seen tethered to a mobile phone, von Slatt wanted his creation to be totally portable, sans cord, so he got out his Dremel tool and grafted his mobile LG phone's belt clip onto the back of the Model 500's earpiece. He upgraded the electret in the Model 500 with an element from a computer mic, and used a mini-plug out of the Western Electric so he can still unplug the mobile phone and use it without the handset.

Some wire soldering, J-B Welding, and black Krylon painting later, a comfortable, hands-free mobile Model 500 emerged that fits perfectly into the brassy von Slatt lifestyle. Picture him tooling down the street talking on his Western Electric cellie in a steam-powered car (a project he's considering tackling next).

—Gareth Branwyn

» **Jake von Slatt:** vonslatt.com

Photograph by Jake von Statt

MARK TWAIN: TECHNOLOGIST

HOW THE AUTHOR OF *HUCKLEBERRY FINN* COULDN'T MAKE IT AS A VENTURE ANGEL.

By Bruce Sterling

AS A TEEN, HE EARNED HIS LIVING AS A printer in St. Louis, Philadelphia, New York, and Cincinnati. He roamed the Mississippi as a steamboat pilot. He was a soldier for a couple of weeks, and a Nevada silver miner for a spell. He was a roughin' it, hands-on, jack-of-all-trades.

Then his literary genius began to tell on him. Soon it was clear that he was much better at telling stories than he would ever be at making things.

Still, Samuel Clemens never shook off his romance with technology and invention. It's in his books; *A Connecticut Yankee in King Arthur's Court* is a time-travel yarn about a can-do techie who destroys medieval England through his ability to "make anything in the world." Clemens himself was an ardent inventor: he created a perpetual-calendar watch-fob, a self-adjusting elastic strap to anchor his pants, and "Mark Twain's Self-Pasting Scrap Book."

The scrapbook made some money because any book with Mark Twain's name on it would sell. His other hobbyhorses perished through public indifference. This hurt Clemens' pride a bit, but at least he could write about invention: he was ever the stout public defender of the lone inventive genius.

Clemens realized early on that inventors were mostly put-upon, solitary types, rarely properly rewarded. He also knew full well that the profit from Yankee ingenuity went mostly to investors and capitalists. He was an idealist, but he'd been around.

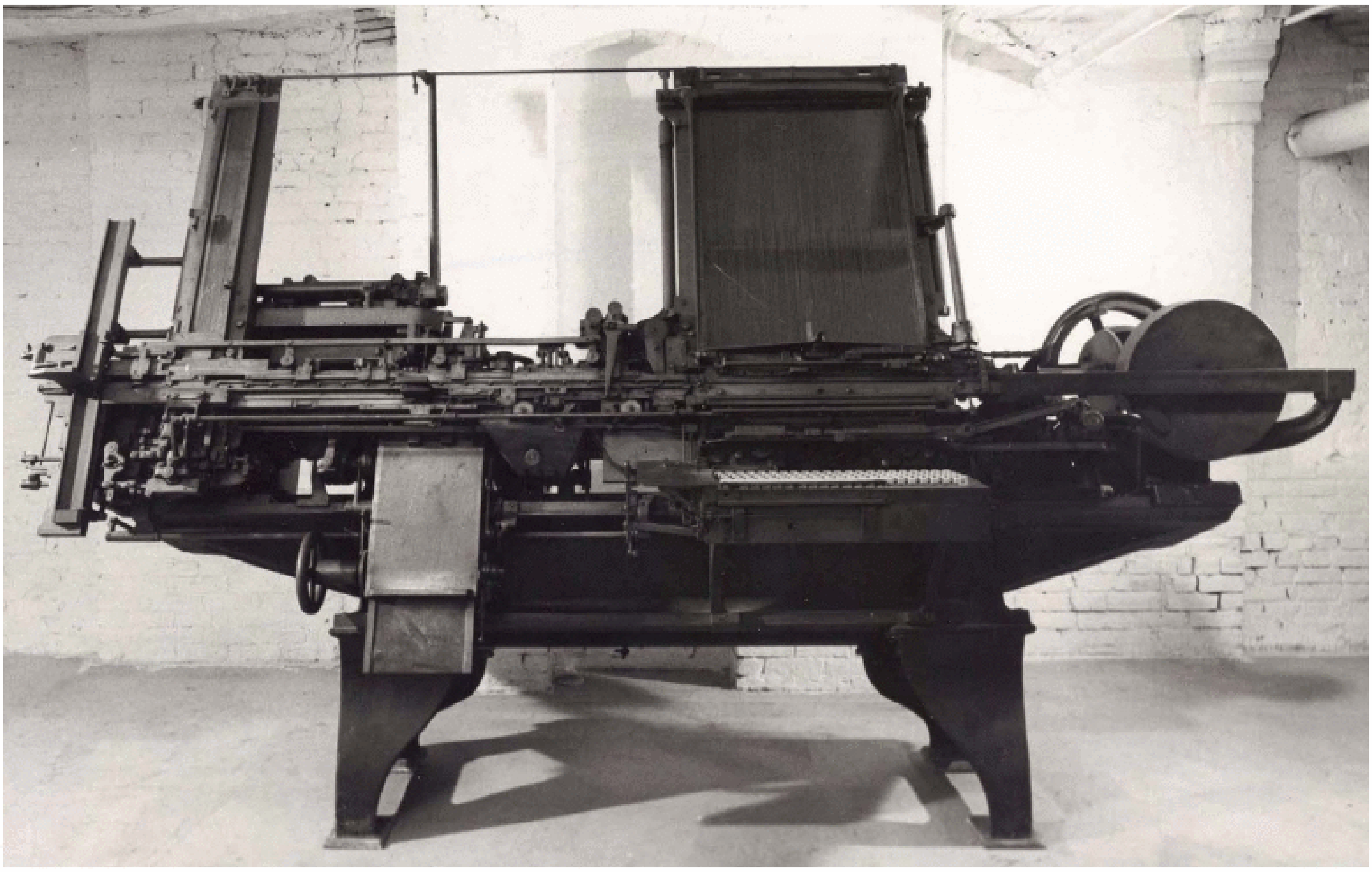
As one of the best-known celebrities of his era, Clemens had money to invest. He badly needed to do this. Like most best-selling writers, Clemens had an impressive income, but it was dangerously sporadic. Furthermore, Clemens was very much living the high life in New York in a grand mansion, built to his specs with all modern conveniences: six servants, private tutors for his daughters, and a needy host of guests, builders, plumbers, doctors, Tiffany decorators, and similar colorful encumbrances.

Even when Clemens was in top creative form, he was forced to hustle and make do, working the treadmill as a lone artist at the mercy of Gilded Age publishers. His lifelong dream was financial independence — a stable way to sit back, breathe easy, and thrive off investments.

> Clemens was an ardent inventor: he created a perpetual-calendar watch-fob, a self-adjusting elastic strap to anchor his pants, and "Mark Twain's Self-Pasting Scrap Book."

One obvious scheme was to start his own publishing house. He did this, and it was a quick success — not through his own writings, but from the best-selling deathbed memoirs of Ulysses S. Grant. This business success emboldened him, but Clemens soon found that the hassles of small publishing were even more repulsive than the hassles of big publishing.

So his attention returned to his first craft: printing. Clemens was fascinated by the technical underpinnings of the printing industry. He was willing to



The "Compositor" of James Paige, the Victorian robotic equivalent of a nimble-fingered, teenage Sam Clemens. The Charles Babbage Difference engine, also a conspicuous failure, was a "mere commonplace" compared to this "awful mechanical miracle."

Photograph courtesy of The Mark Twain House & Museum

take a flutter on many other forms of tech — food additives, bicycles, steam-pulleys, carpet-making machines, a cash register, a steam generator (the list did go on) — but he truly understood printing. He sensed, correctly, that the medium of print was long overdue for a technical revolution. Maybe he, Sam Clemens, could do to printing what Eli Whitney had done to cotton-picking.

Clemens was a classic early-adopter, power-user type. He was a keen student of communication technologies. Patent fountain pens attracted his authorly interest. He was a pioneer user of the typewriter, and he used an early Edison cylinder as a dictation machine. Clemens' mansion had one of the world's first private telephones. Clemens even had electronic music piped in by telephone, through that legendary example of a dead medium, the Cahill Teleharmonium. Toward the end of his life, he was to champion a primitive European television.

Still, he'd grown up inside printing, and he'd been compositor, editor, publisher, journalist, author — he knew that business up and down. If he was ever to strike it rich as a venture capitalist, it made sense that printing would be his field. And in 1889, Clemens found his lone inventive genius: James Paige.

Since the days of Gutenberg, workaday printers had set up lead type by assembling pages one metal letter at a time. The Paige Compositor was a new machine that could hand-set type rapidly and automatically. This ingenious device had been patented in 1877, but the fat-headed printing industry had been too lazy to build it — too sluggish to make the greatest leap in typesetting in four centuries!

It remained to procure the funds to break this device from its visionary blueprints and actually build it, and Clemens, who'd caught wind of it through his publishing house, burned to see it take form.

The Compositor was a stunner. As Clemens wrote: "All the other inventions of the human brain sink pretty nearly into commonplaces contrasted with this awful mechanical miracle. Telephones, telegraphs, locomotives, cotton gins, sewing machines, Babbage calculators, Jacquard looms, perfecting presses, Arkwright's frames — all mere toys, simplicities! The Paige Compositor marches alone and far in the lead of human inventions."

In 1889, Clemens signed a contract, gallantly giving Paige the ownership of his grand invention, but granting himself a hefty 500-dollar royalty for every such machine sold. Clemens struggled hard with the business model for his oncoming tech revolution, but no matter how he tried to figure it, it seemed impossible for him to avoid making millions. There were thousands of printing presses in the world. Every such machine with hand-assembled type was bound to become obsolete overnight. He had a huge, disruptive innovation that was striking at the root of the industry.

And Clemens was right: the hand-assembled press was doomed. And Paige was right, too: his amazingly elaborate invention, elegantly mimicking human movements with its 18,000 parts, could set type ten times faster than any human being could. The Paige Compositor was a kind of robot teenage Sam Clemens; it did just what Sam himself had once done, but on an industrial speed and scale.

Then, however, came the human element. James Paige was brilliant, a great talker, a mechanical genius, and a hacker perfectionist. Obsessed with his own brilliance, Paige couldn't budge his machine out of the start-up garage and into the hurly-burly of commerce. With 18,000 different parts, there was always some nifty upgrade to be made to the Compositor. Then there was the allure of Paige's moonlighting side projects, such as electrical generators. Paige couldn't be bothered to field-test his machine under real-world conditions. His Compositor was always in beta and never quite ready to ship.

In the meantime, the Mergenthaler Linotype appeared on the publishing scene. The Linotype was a rugged, stupid, IBM-PC of a beast. The Linotype was 60 percent slower than the elegant Paige Compositor, but it was also the first to market. Furthermore, since the Linotype wasn't quite so saturated with technical genius, it was easier to maintain, repair, and improve.

Ottmar Mergenthaler had never bothered to mimic any human movements. Trained as a watchmaker, not a printer, he'd invented an entirely new way to line up type mechanically. So, in the race toward a printing revolution, the Paige Compositor never left the starting gate.

Clemens had happily trifled with many tech toys over the years, but the Compositor was his demon. He sank $200,000 of his own wealth into his grand dream of reinventing print. But his steel darling was obsolete before it could hit the streets, and Clemens hit a cash-flow crunch that he could not escape.

He finally wrote: "I've shook the machine, and never wish to see it or hear it mentioned again. It is superb, it is perfect, it can do ten men's work. It is worth billions, and when the pig-headed lunatic, its inventor, dies, it will instantly be capitalized and make the Clemens children rich."

The Compositor was indeed superb, it was perfect, and it could do ten men's work, but as an investment, the Paige Compositor was poison. It never made anyone rich. Superb perfection and the work of ten men were not at issue. Ease of maintenance, ruggedness, mass production, cheapness of operation, room for improvement — a machine that worked like a real machine — that was what the industry required. The Paige Compositor was as rare a thing as Clemens himself.

Crushed by debt, Clemens shut down his mansion, abandoned his crumbling publishing interests, gave up all hope for a settled, bourgeois existence, and fled with his family to Europe, for what turned out to be nine years of globe-trotting exile. Within four years, scraping frantically, he'd managed to pay off his creditors. Still, he never again wrote in the easy, funny, chatty way that he'd written before trying and failing to become a tech mogul.

Clemens sank $200,000 into his grand dream of reinventing print.

Great wealth would always be denied him. Great fame would fall on him in heaps, and that would bury every other aspect of his efforts. He would never become Samuel Clemens, Venture Angel. To this day, he's Mark Twain, Famous Author.

As for James Paige, "a most great and genuine poet, whose sublime creations are written in steel" — he is entirely forgotten, except as the man who bankrupted Mark Twain.

The last models of the Paige Compositor were bought by the Mergenthaler company, picked up as curiosities. In 1964 — while their Linotype was still a going business — they donated the last surviving Compositor to Mark Twain's house and museum. There, the genius machine still stands today, admired by tourists: gorgeous, unworked, and unworkable.

Bruce Sterling (bruce@well.com) is a science fiction writer and part-time design professor.

1+2+3 Aircraft Band Receiver

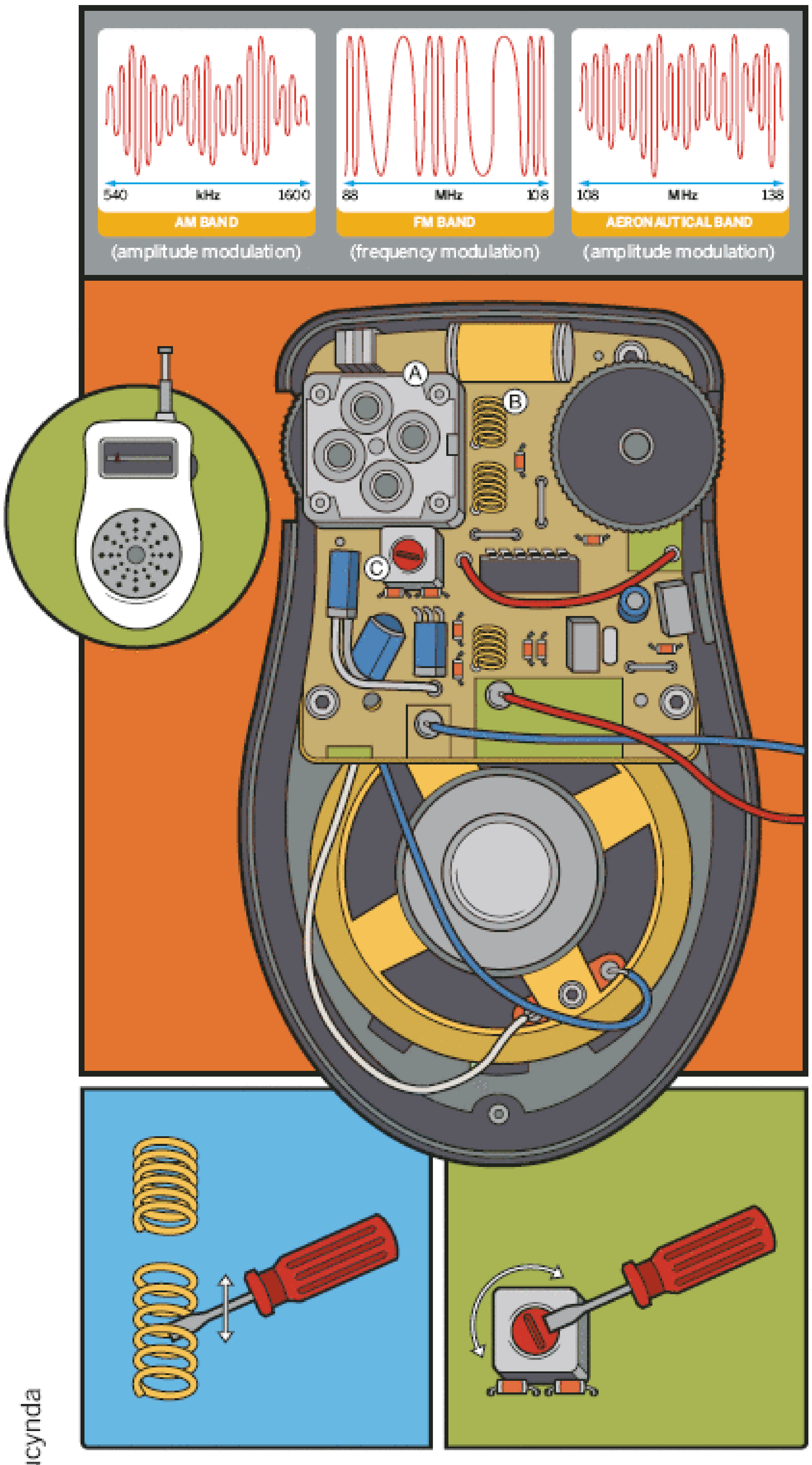
By Cy Tymony

Modify an AM/FM radio to pick up air traffic control communications.

You will need: AM/FM radio, small Phillips screwdriver, small flathead screwdriver

Extending the Range of Your Radio

The aircraft band, 108 to 138MHz, is directly above the FM band. But aircraft signals are broadcast in an AM format. Amazingly, it's possible to modify a typical AM/FM radio to receive aircraft signals in the proximity of an airport, without removing or adding any parts! Here's how.



1. Identify the radio parts.

Use a battery-powered, inexpensive, analog radio. Remove the back cover and locate the main tuning capacitor (A). It's easy to find — just turn the tuning dial, and you'll see its parts move through its clear case.

Near the main tuning capacitor you should see one or two small coils of copper wire (B) mounted on the PC board. These coils are used to limit the frequency range of the radio.

Next, locate the tuning transformers (C). They look like square, metallic boxes with tuning slots in the top. One of the tuning transformers may have a couple of small diodes near it mounted on the PC board. This is the tuning transformer that you'll adjust. Its function is to filter out AM noise.

2. Modify the radio.

Tune the radio to an FM station at the upper end of the FM band. Notice where the dial is positioned.

Spread apart the small coils near the main tuning capacitor using a small flathead screwdriver. When you finish, tune the dial and you'll notice that the broadcast stations have moved down the dial. The radio is now able to receive stations well above 108MHz.

Tune the radio between stations so you can hear a slight hiss. Notice the position of the slot on the top of the tuning transformer that is near the main tuning capacitor (nearest to the small diodes). Slowly turn its screw until the hiss sound is at its maximum level. Note exactly how many turns and in which direction you turn the screw, for easy repositioning later. The radio is now able to receive AM signals in its newly expanded FM band.

3. Test the modified radio.

Replace the radio's cover. Take it — and the screwdrivers — near an airport during a peak air traffic period. Turn the radio on the FM band with the volume up and slowly adjust the dial. You should be able to hear air-to-tower transmissions. If needed, make adjustments to the tuning coils and the tuning transformer.

Illustration by Timmy Kucynda

Cy Tymony is the author of the *Sneaky Uses for Everyday Things* book series.

What Rough Beast Slouches Toward Arcata?

MAKE goes to the World Championship Kinetic Sculpture Race. By William Gurstelle

WHILE IT COULD BE NAVIGATED FASTER, it usually takes at least eight hours to drive up Highway 101 from San Francisco International Airport to Arcata, Calif. If you go, it's worth taking your time, because this road takes in a lot of interesting society and scenery changes along the way.

At the start, you cross the heart of downtown San Francisco, slowly cruising up Van Ness Avenue northbound across the Golden Gate Bridge toward the congested freeways traversing the Bay Area's northern suburbs. Soon, though, the milieu changes for the better as you pass through bucolic Sonoma County; the vineyards of California's wine country are wonderful viewing even at freeway speeds. Farther north, the Japanese and German luxury cars of wine country become less dominant, their space on the highway usurped by pickup trucks and far, far older Fords and Chryslers. Winding on, the 101 slows down, speed limits changing in inverse relationship to the height of the redwood trees flanking the road. As it morphs into the main drag of the small towns of Laytonville and Willits, the 101 slows to 25 miles per hour. Finally, the highway meanders north and west through Rio Dell, Fortuna, and Eureka before reaching the tranquil burg of Arcata, the starting point of the World Championship Kinetic Sculpture Race.

Photography by Karen Hansen

As twisty, turny, and motion-sickness-inducing as the 101 can be in redwood country, kinetic sculpture racers will tell you that it's nothing compared to the road they traverse from Arcata to Ferndale. In fact, it's not a road at all. It's a 42-mile ordeal of land, sand, muds, and suds. The race starts and ends on pavement, but in between, the course encompasses dirt tracks, 30-foot-high sand dunes, open water, and gooey, sloppy mixtures of mud and muck.

Every May in the redwood-friendly moistness of the Northern California coast, a wonderful exhibition of true maker determination and creativity takes place. Approximately 30 racing teams and thousands of spectators descend on eccentric and unconventional little Arcata to attend what might be the most interesting sporting event in the world, at least to the eccentric and unconventional kind of people who read this magazine.

> Below Dead Man's Drop, emergency medical technicians wait, ready to deal with breaks, blood, and twig-pierced eyebrows.

The size and time invested in such an outré event defy easy understanding. On the morning of race day, two-and-a-half dozen human-powered sculptures assemble in the town square. Watching and waiting, the great throng of onlookers stands six deep along the streets.

The elaborate mechanicals and their maniacal makers wait for the blast of the town's noon whistle. At the sound of the klaxon horn, all begin to circle the town square once, twice, and then a third time until the exit gate is flung open and the racers begin the marathon quest for glory. The crowd cheers them, then heads off to its favorite viewing points along the route. For the next three days, the racers pedal their vehicles up hills and down sand dunes, across the waters of the Eel River and Humboldt Bay, and through the towns of Manila, Eureka, and Loleta.

It's grueling work, but the harsh conditions are offset by post-race basking in the personal triumph that comes from merely finishing, and in the wry sense of humor that permeates the entire event. That has to be enough, for there's absolutely nothing to motivate the racers except the glory of participating and crossing the finish line in Ferndale three days later. Luckily, there's plenty of glory to go around.

Polymaths, All

What sets this event apart from other competitions with a homebuilt component is that it celebrates the polymath instead of the specialist. To understand this event, and to excel at it, one can't be only a sculptor, or a mechanical engineer, or a cyclist. One needs to be all three, for the final judgment depends on the sum total of the builder's artistry, engineering, and physical fitness.

This is an event for polymaths, of the sort that Leonardo Da Vinci, Blaise Pascal, and Buckminster Fuller would enjoy. It's not just about having overdeveloped leg muscles, and pedaling fast and long. The best, most glorious participants must be clever technologists, designing gear trains and vehicle superstructures that can finish the marathon-and-a-half-long course of diverse terrain.

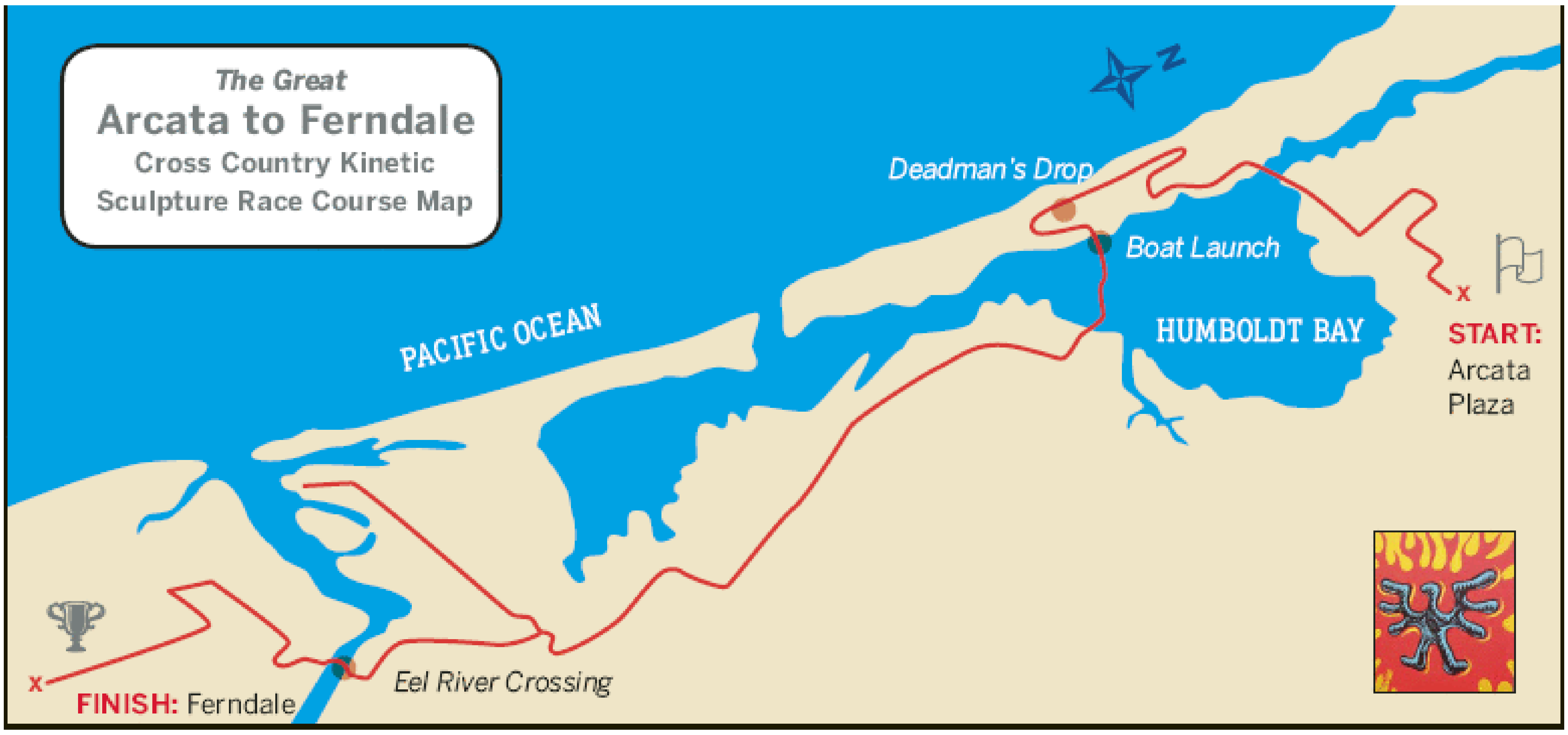
Some of the racing machines weigh more than a ton fully loaded, and a fair amount of engineering is required to make such weightiness sufficiently mobile to be pedaled across the many conditions encountered. Typically, this involves designs incorporating swing-down pontoons, differential gear boxes, variable-angle recumbent seats, and most important of all, massive drive trains, with more gear ratios than you can shake a Cannondale at. The pilots of kinetic racers often have more than 600 different gear ratios from which to choose.

And even that isn't all. To be competitive, a racer has to be beautifully sculpted as well. Builders must have artistic talent, for skill and brawn mean little without artfulness.

The Racers

It's the artistry, whimsy, and imagination that the designers and builders incorporate into their machines that make the experience what it is. The best machines are true works of art, evocative of the sculpture of Marcel Duchamp, Alexander Calder, and Jean Tinguely.

June Moxon's racer is called *Skaredy Kat*, but she



A map of the 42-mile course, which traverses pavement, sand dunes, mud, and water. For a more detailed account of the course, visit kineticsculpturerace.org/map.shtml. Image shown on previous image: *Flash Gourd'n*.

most certainly is not one herself. The year 2006 marked her 24th year of competing. During that time, she's powered herself across a lot of territory. In fact, she and fellow racer Ken Beidleman once pedaled a racer across the United States.

"In 1989, Ken and I left Ferndale on our racer with $200 in our pockets, and we survived by donations and doing odd jobs," she says. "Each day on the road was different: heat, snowstorms, steep hills, rain." Eventually, they pedaled all the way to St. Augustine, Fla.

Skaredy Kat is, as June describes it, "a ginormous, black and white, spooked-out, kinetic kruising kitty kat." More specifically, it's a 500-pound tandem tricycle with an immense gear ratio and a sophisticated system of pull-cords that allows June and her co-rider to move the puppet parts of *Skaredy*'s head, eyes, whiskers, and tail while riding.

June's boyfriend, Ken Beidleman, is equally enamored of kinetic sculpture racing. A metal sculptor from Redding, Calif., Ken first became interested in the activity back in 1987 when he volunteered to work with the event's founder, Hobart Brown, on his racer. Beidleman has participated more or less continuously since then.

"Every year I try to come up with something new," he says. "For instance, I'll say, let's do something contemporary, a racer [with a theme based] on a current event or movie."

In the past, that line of thinking produced the machines he named *Watermelon World*, *Hog Wild*, and *Nightmare of the Iguana*. The 2006 entry was *Flash Gourd'n*, an upgrade of an earlier year's *Gourd of the Rings*, but *Flash Gourd'n* has better steering, fewer squeaks, and reduced weight.

The night before the race, builders work into the wee hours making final adjustments. At the Arcata Kinetic Lab, some pause to chat with the curious. Others are furtively focused behind drawn curtains. In the back corner, sculptor Duane Flatmo is hard at work, putting the final touches on a comically scary, bug-eyed, four-person tricycle.

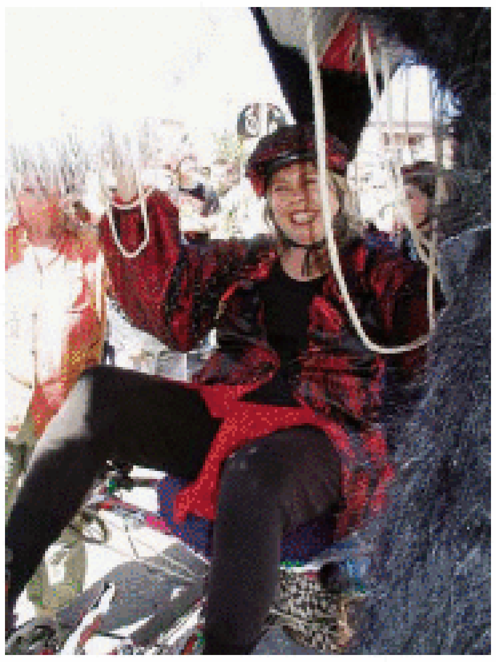
Extreme Makeover is a heavy beast, weighing 1,200 pounds when fully staffed. A good portion of that weight is invested in teeth and eyeballs. Once the race starts, it's the scores of gear ratio choices that allow the pilot to take it over water, turf, asphalt, and even sand dunes.

Like fairy tale creatures, the racers lumber along the beach, making the best time they can before attempting the more difficult parts of the race. The hardest obstacle is a high, steep, and perilous sand dune called Dead Man's Drop.

Atop the dangerous dune, sunburned, mosquito-plagued spectators call out encouragement as racers make the tough climb at tortoise speed. Below Dead Man's Drop, emergency medical technicians wait, ready to deal with breaks, blood, and twig-pierced eyebrows. As the racers plunge over the edge of the dune, the crowd follows in their wake, cheering each guts-and-glory descent.

For what it matters, the 2006 grand champion was *East Shark*, a two-person land submarine designed by high school students from Eureka. They finished the race in under eight hours of actual pedaling time. *Flash Gourd'n* and *Extreme Makeover* finished respectably in the middle of the pack, taking about 20 hours. And *Skaredy Kat*? It, too, finished. Eventually and gloriously.

MAKE Contributing Editor William Gurstelle wrote the rubber-band ornithopter project (*MAKE, Volume 08, page 90*).



Clockwise from top left: ***Skaredy Kat***, June Moxon in ***Skaredy***, ***Stag Party***, ***Brain Power***, ***Pear Country Chopper***, ***East Shark***, ***Mardi Gras***, and ***Extreme Makeover***.

ART WORK

The Joy of YDKEWYGUYGI

By Douglas Repetto

LIKE MOST TECHNOLOGIES, MANY EARLY mark-making machines were purely practical, usually addressing the pre-printing-press need for quick and easy copying. The automaton craze of the 18th century produced the first completely mechanical drawing and writing machines, as well as some of the first machines with mechanisms that were as interesting as their outputs. (And sometimes more so!)

Swiss inventor Henri Maillardet made a machine that could produce four different drawings and three poems encoded on a large set of complex cams. It signed its own work by writing "Ecrit par L'Automate de Maillardet" ("Written by Maillardet's Automaton") in the border of the final poem — perhaps evidence that even the earliest mark-making machine makers were playing with questions of authorship and intention. Maillardet's automaton is on display at the Franklin Institute. It still works!

You might think that advances in printing technology would have meant the end of homemade mark-making machine mania, but they haven't. Although inkjet and laser printers do a great job of creating clean copies of full-color text and images, they're not so great at doing some of the things that make manual mark-making so interesting.

Sure, you can simulate brush strokes in your digital painting program, but making real brush strokes is more fun. While untold thousands of engineering hours have gone into making sure that WYSIWYG when you send a job to your printer, there's still a lot of interest in systems where you don't know exactly what you'll get until you've got it (YDKEWYGUYGI).

Jean Tinguely, a 20th-century Swiss artist, is best known for his large kinetic sculptures made from scavenged industrial debris. Starting in the late 1950s, Tinguely made a series of "Méta-matic" drawing machines, complex jumbles of gears, springs, and weights. The unpredictability of the mechanism coupled with the choices made by the user (selecting different kinds of papers and brushes or making adjustments to the mechanism itself) assures that no two runs of the machine are alike. This is a theme that, ironically, appears often in machine-made art: non-repeatability and the potential (and pitfalls) of infinite variety. If you're ever in Basel, make sure to check out the Tinguely Museum — there's even a working Méta-matic that you can play with for €1.

In the late 1970s, Croatian-American artist Anton Perich built a large, light-controlled painting machine from cobbled-together parts of sewing machines and industrial debris he found on Canal Street in Manhattan. There's a telling quote in *The Andy Warhol Diaries* about Perich's machine (they were neighbors): "Anton was home with his painting machine and I was so jealous. My dream. To have a machine that could paint while you're away. But they said he had to be there while it painted because it clogs up."

> "Anton was home with his painting machine and I was so jealous. My dream. To have a machine that could paint while you're away." —*Andy Warhol*

Warhol was being wry here, but he brought up a common misconception; the motivations of mark-making machine makers are generally more complex and interesting than "I want a machine to do my work for me." For some artists, the output of the machine isn't even the main point; the process or method of making marks can sometimes be as, or even more, interesting than the marks themselves. As for Perich, 30+ years later he's still making big, complex paintings with his original machine.

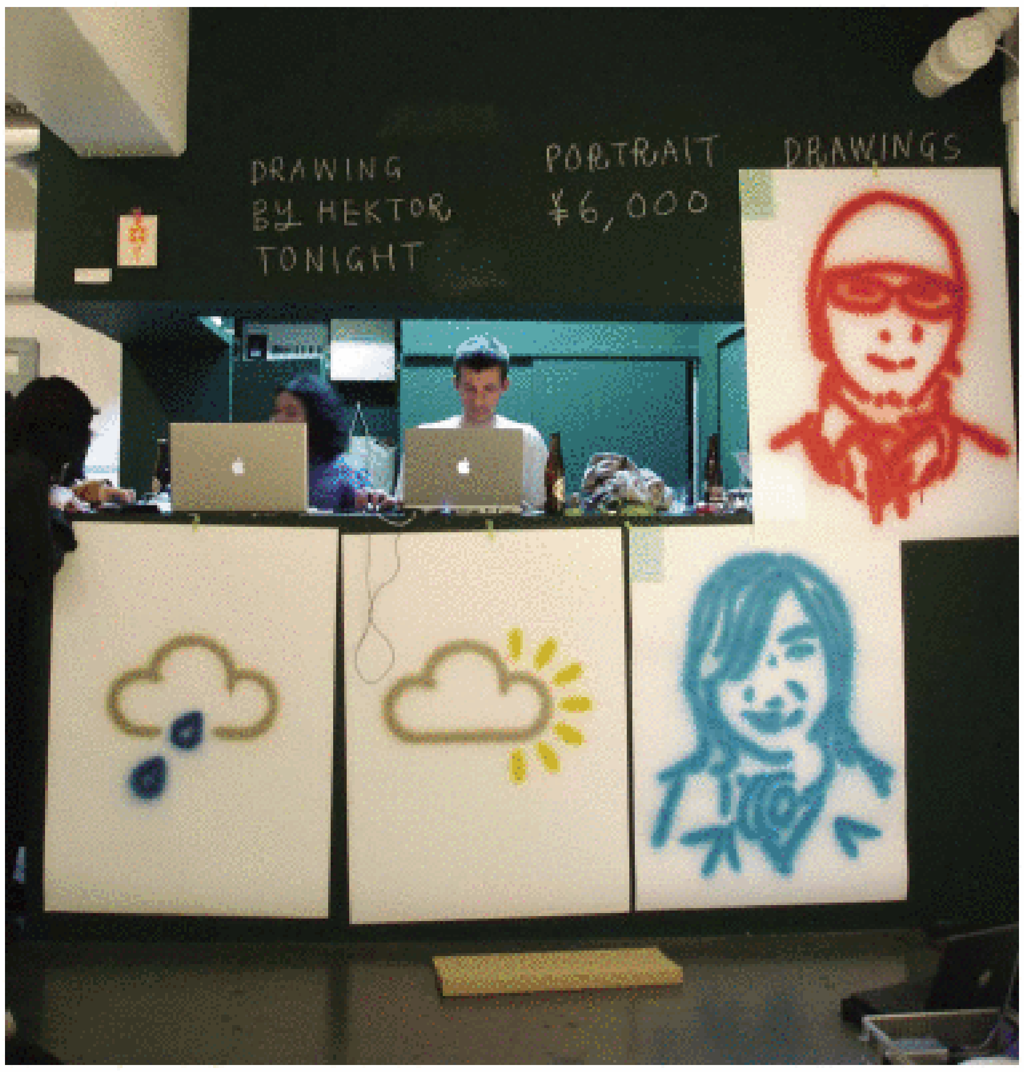
Sabrina Raaf's "Grower" and Fernando Orellana's "Drawing Machine 3.1415926 v.2" are two machines that make marks that would be impossible for humans to make on their own, and both make nods toward early analog scientific recording equipment.

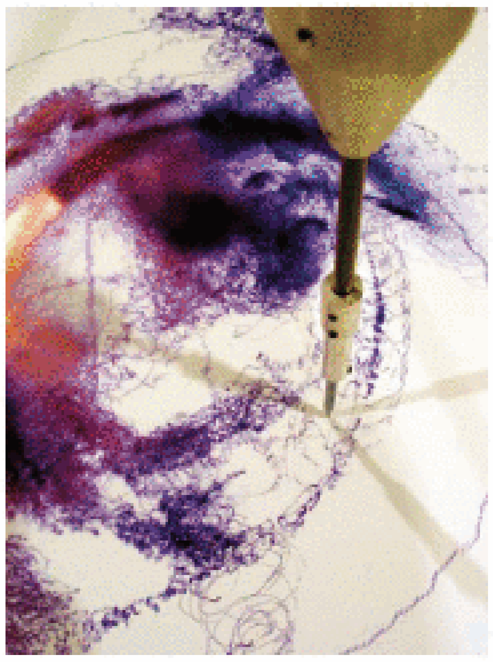
Raaf's machine is a robot that draws green marks (evoking blades of grass) on a wall, the heights of which correspond to the amount of CO_2 in the air. Over the days and weeks that the robot is working, it builds up a field of data-driven "grass" as it tirelessly treks back and forth along the wall.

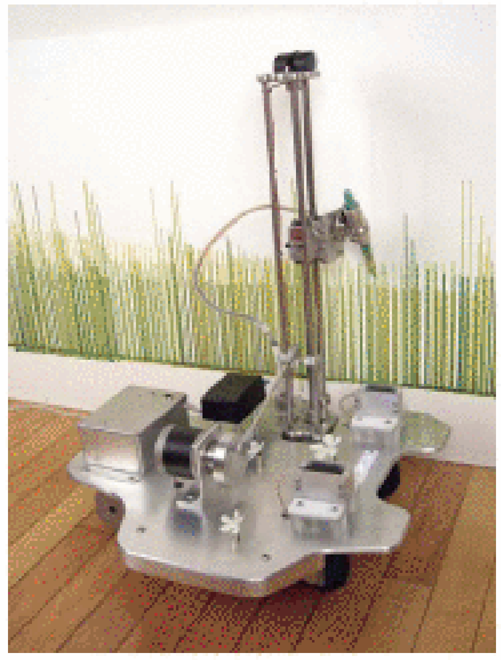
Orellana's machine is a lot like a mobile with a pen attached to it. But rather than just twirling in the wind, the pen's position on the canvas is controlled by the local ambient sound, similar to the way a seismograph pen records shock waves moving through the Earth. Both works create a long-term record of their local environment, but in a highly stylized form meant to leave an impression, rather than an exact accounting of some environmental variable.

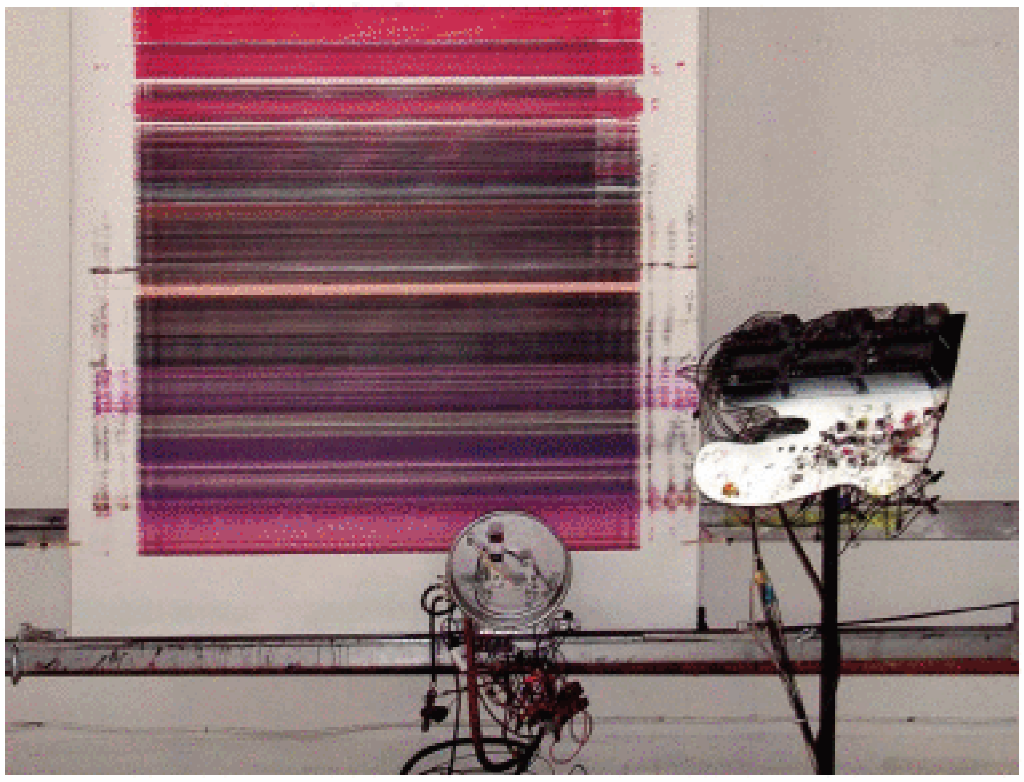
Hektor, a "graffiti output device" by Swiss artists Jürg Lehni and Uli Franke, uses a deceptively simple and elegant mechanism in a small, portable package. Two motors are attached to a wall with a belt hanging between them. A spray paint can and activator hang from the belt, and as the motors turn they pull the spray can around the canvas. Because the mechanism can bring the spray can to any point, the content of the paintings is separate from the machine's mechanism, making Hektor the equivalent of an enormous general purpose plotter (it's even driven by Adobe Illustrator). The catch is that despite its elegant design and vector-based data, Hektor's fuzzy, dripping output is far from pristine. It's another take on the tension between computer-based precision and real-world grunge.

Some people make machines with outputs that are simply expressions of their own construction (Jonah Brucker-Cohen's simple plastic-cup-and-motor "drawbots" are a good example of this). Others focus on environmental inputs, or algorithmic control, or AI, or ... well, the list goes on. Finally, some people just want to make a machine that makes pretty pictures. There's room for everyone in the world of mark-making art machines. What's yours going to do?









Top: Hektor enjoys painting both landscapes and portraits. Middle: Orellana's Drawing Machine and Raaf's Grower sense the world and then leave their marks. Bottom: Perich's steampunk painter is half airbrush, half sewing machine.

Photography by (clockwise from top): Jürg Lehni (Hektor); Sabrina Raaf (Grower); Anton Perich (machine at bottom); Fernando Orellana (machine at middle left)

Douglas Irving Repetto is an artist and teacher involved in a number of art/community groups including dorkbot, ArtBots, organizm, and music-dsp.

P.O.K.E.R. Night

Or, Let's Build a Vortex Tube Party!

By Mister Jalopy

Photography by Mark Frauenfelder and Mister Jalopy

IN 1867, SCOTTISH PHYSICIST ROBERT Clerk Maxwell proposed a "thought experiment," suggesting that it may be possible to break the second law of thermodynamics, if you could find a molecularly minded demon that was willing to cooperate.

Start with two hypothetical containers of equal temperature with a connecting trap door controlled by a gatekeeper to sort hot from cold molecules. When the demon sees a fast/hot molecule racing toward the door, he opens the trap to let the hotter molecule speed into container A. Similarly, if a slow-moving molecule is headed toward container B, the demon would allow it to pass until the two containers are at different temperatures. Assuming that the demon would have modest demands for his efforts, you would break the cornerstone of physics laws — something for nothing.

The Hilsch Vortex Tube

After an impressive 72-year run, the "Amateur Scientist" column fell victim to a 2001 *Scientific American* modernization effort. A terrible loss, the "Amateur Scientist" was an inspirational resource that dedicated considerable effort to explaining the hard science behind the projects.

Whether working on "Cloud Chambers to Detect Nuclear Events" (*see page 156 for MAKE's version of the cloud chamber*) or "An Inexpensive X-Ray Machine," you really felt like you were in the midst of serious scientific pursuit and the feeling of exploration was very high — especially with the scant direction.

In November 1958, *Scientific American* published one of my favorite projects — the Hilsch Vortex Tube. Invented in 1933 by a French physicist named George Ranque, and improved by a German physicist named Rudolf Hilsch in 1955, it uses nothing but compressed air. The design of the device created a vortex that acts as a demon to "split" the hot molecules from the cold by spinning air to very high speeds. How fast? Half a million rpm fast.

Spinning air is enough to generate a temperature change of a couple hundred degrees? Yes, but at the time of the original 1958 article, they weren't exactly sure how it worked. As a very amateur scientist, I will try to explain the process. Compressed air is shot into a vortex that creates a hollow cyclone of fast, hot air that travels down the interior of the hot pipe. If it were visible, it would look like a tube of hot air that lines the inside of the pipe, and then a smidge of the hot air is exhausted through the almost-closed stopcock.

The remainder of the air is reflected off the nearly blocked stopcock through the center of the hot-air cyclone — in effect, a column of air shooting through the hot-air tube. As this happens, this column of air "gives up" its heat to the surrounding cyclone as it passes through the center. When the cold column reaches the vortex, it shoots through the center and exits the cold side. Whoa.

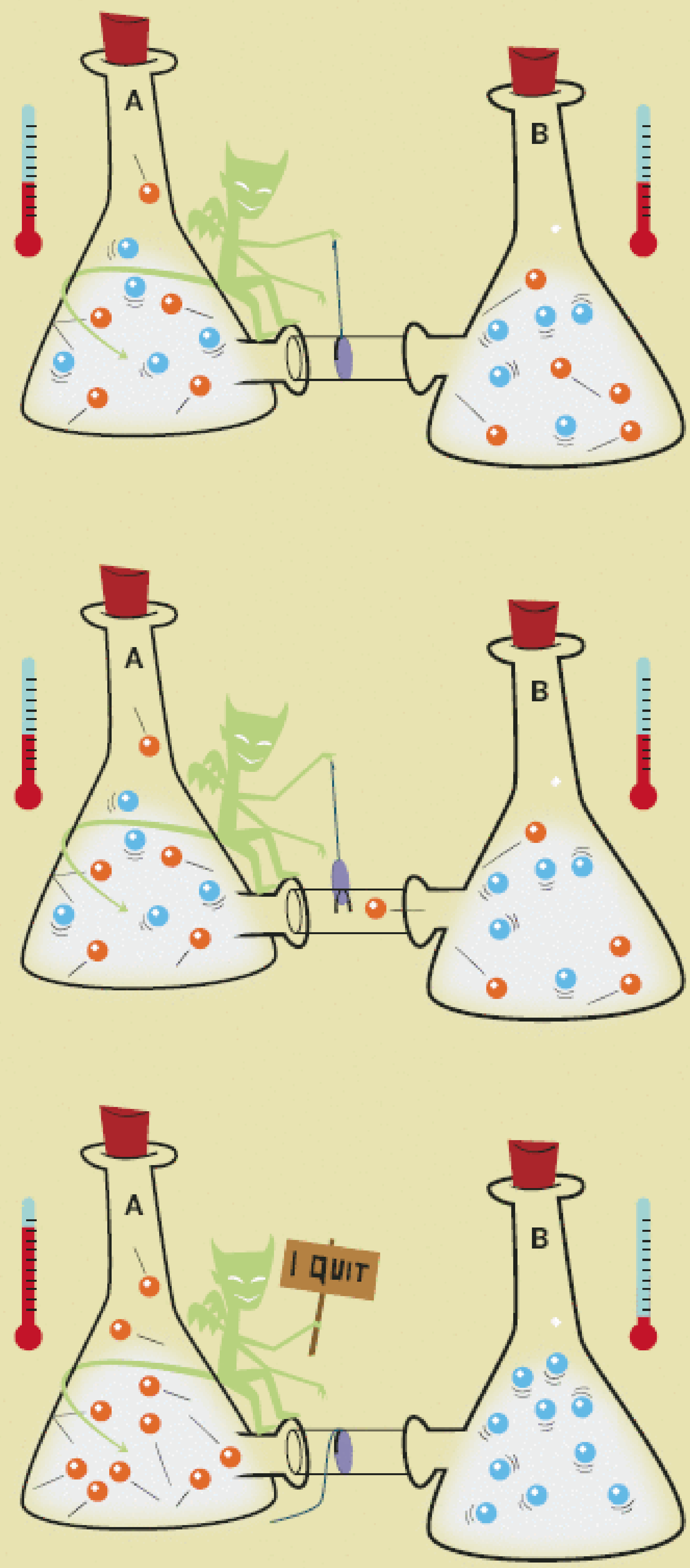
Cold-Cut-and-Soda-Pop Engineering

Anticipating a lukewarm response from my buddies for a "Let's Build a Vortex Tube Party," I invited my amateur scientist friends for a poker night (little did they know that "poker" was an acronym for Proof Of Koncept/Experimentation Revue).

Fearing a rebellion when they discovered there were no poker chips or one-eyed jacks, I made certain to lay out an impressive spread of top-notch cold cuts, provolone, olives, marinated pepperoncinis, and plonk chianti. I would have served a better wine, but I figured these wily characters would have realized they had been duped by my dodgy scheme, checked that their wallets were intact, and hit the door.

Original Mister Jalopy Proposal

With a deep breath and steely resolve, I told the fellas that instead of a freewheeling night of gam-



MAXWELL'S DEMON THOUGHT EXPERIMENT CIRCA 1867

1. Chambers A and B contain gas at equal temperature. The demon has the door closed but is ready to move quickly to let the molecules through.
2. As a fast/hot molecule approaches from chamber B, the demon throws open the door to admit the molecule to the soon-to-be-hotter chamber A.
3. Much door opening and closing ensues until the demon has tirelessly isolated all the cold from hot molecules.

Demon illustration by Mark Frauenfelder

bling and tasteless jokes, we would be attempting to channel Maxwell's demon. They went for it — though they insisted on keeping the tasteless jokes. Using segments of iron plumbing pipe as the hot and cold sides, I suggested that we epoxy together a vortex assembly with three ½" slices of a Delrin plastic 3" rod.

Revised Approach

The guys are not scientists or machinists but they are talented, creative folks that are deeply interested in how things work. Hoping that would be enough, the group reduced the vortex assembly design to use a single Delrin disk. In my original plan, the washer was replaced with a ½"-thick slice of Delrin, but the revised plan brought back the washer. We didn't know if the thicker Delrin disk would affect performance, but since we had no idea what we were doing, we decided the fewer changes, the better.

The finished vortex tube looks like a champion! From appearances, it would seem to instantly freeze tissue samples for plague research or, perhaps, cut 1"-thick steel plate with an awesome 1,000-degree cutting flame! Real life offered slightly less spectacular results, but we did measure a temperature spread of 8 degrees between the hot and cold sides. We raised the flag and declared victory!

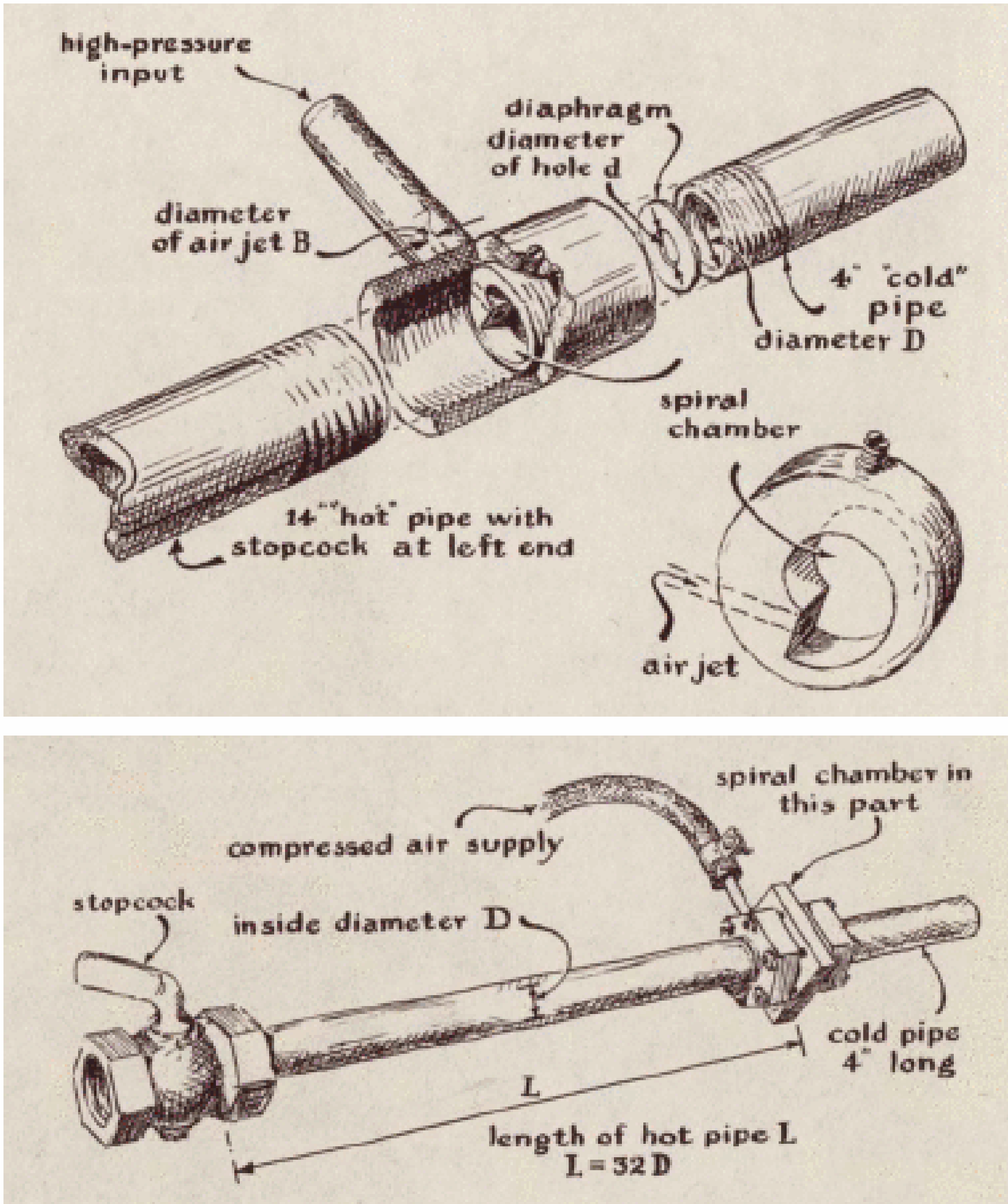
If I were a real scientist, I would continue to refine the design using our modest success as a starting point, but as an amateur, I am happy with the Proof Of Koncept/Experimentation Revue results. Until an engineer shows up with some imported spicy salami, the vortex tube will sit on the shelf as a memento of a fun late night with good friends.

Mister Jalopy referenced C.L. Stong's collected columns from the out-of-print The Scientific American Book of Projects for The Amateur Scientist, *but the complete, 72-year archive is available on CD-ROM (*Scientific American's The Amateur Scientist, Science Fair Edition, *$30, brightscience.com).*

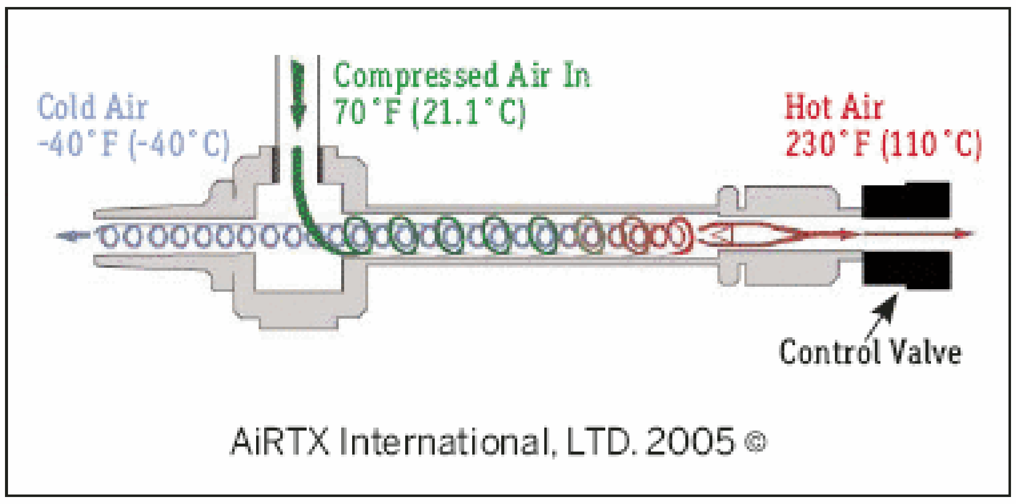
AiRTX International (airtxinternational.com) sells commercial vortex tubes capable of generating temperatures from -40°F to 250°F. We thank them for allowing us to use their superb illustration.

Mister Jalopy is an earnest but *amateur* scientist. Know more about vortex tubes than he does? We wouldn't be surprised. Join us for vortex discussions at makezine.com/09/vortex_tube, as we have lots of questions.

Despite being hoodwinked, my friends met the vortex tube challenge with enthusiasm and a determination to succeed, provided the beer did not run out.

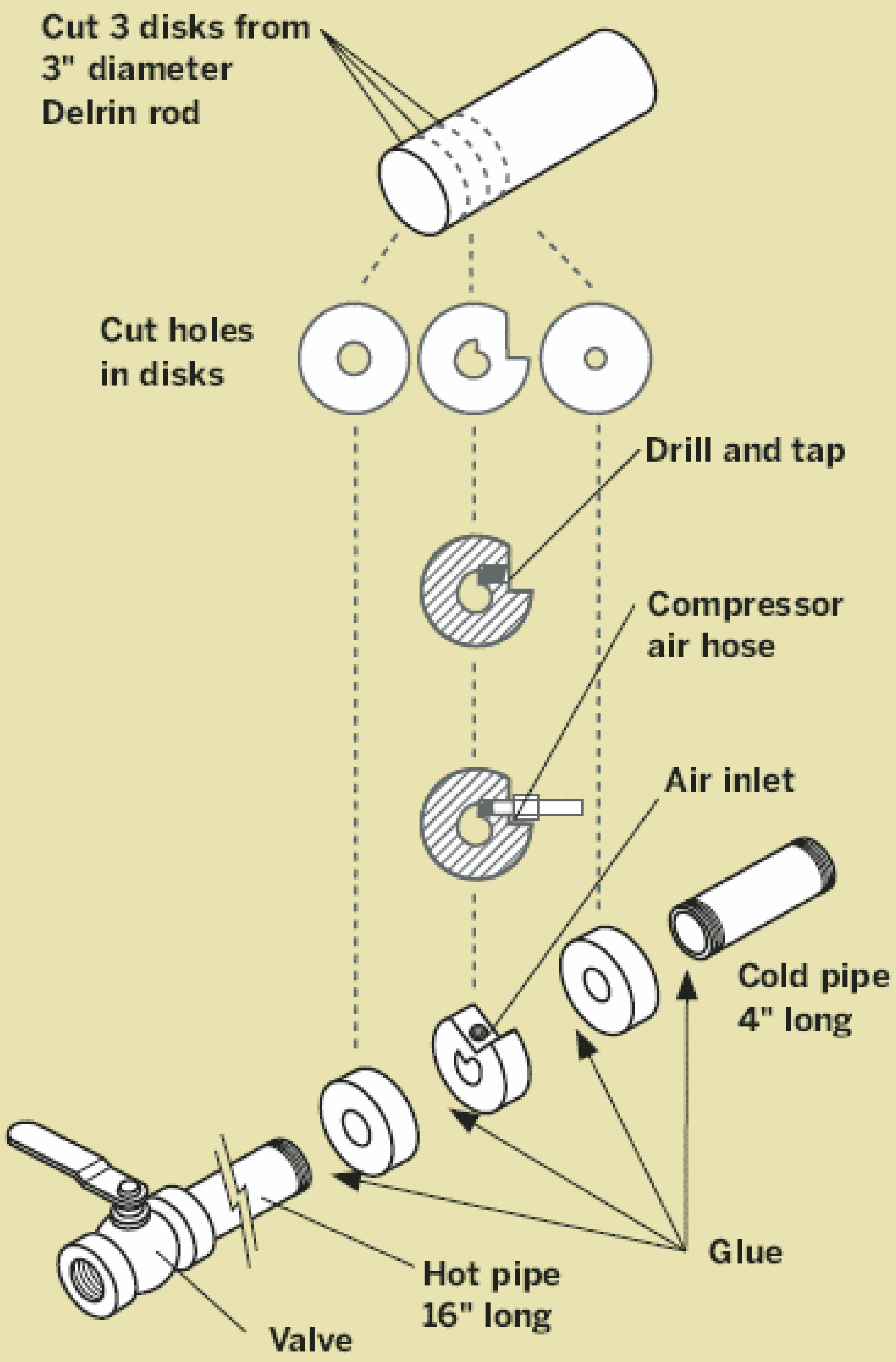


In the original "Amateur Scientist" design, adjustments are made via the stopcock on the hot side and the interchangeable washer on the cold. (Source: *The Scientific American Book of Projects for The Amateur Scientist*, C.L. Stong, 1960)

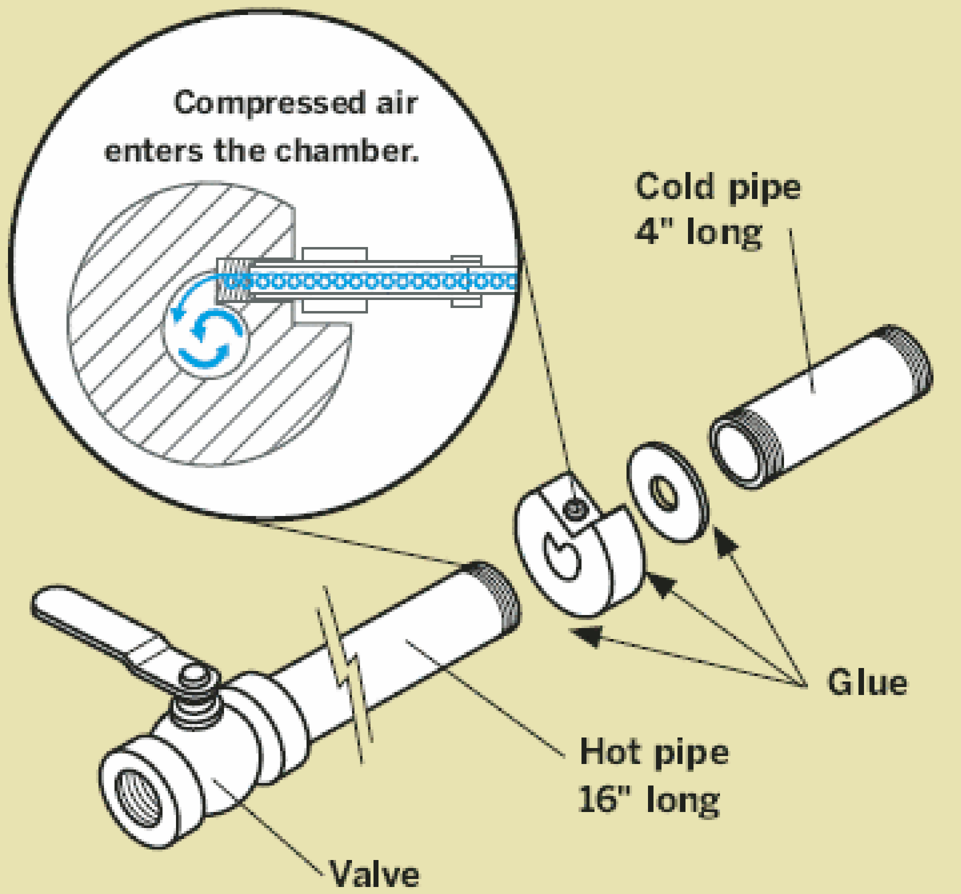


AiRTX International's commercial vortex tube ($109-$149) produces frigid air from room-temperature compressed air.

THE P.O.K.E.R. TUBE, VERSION 1

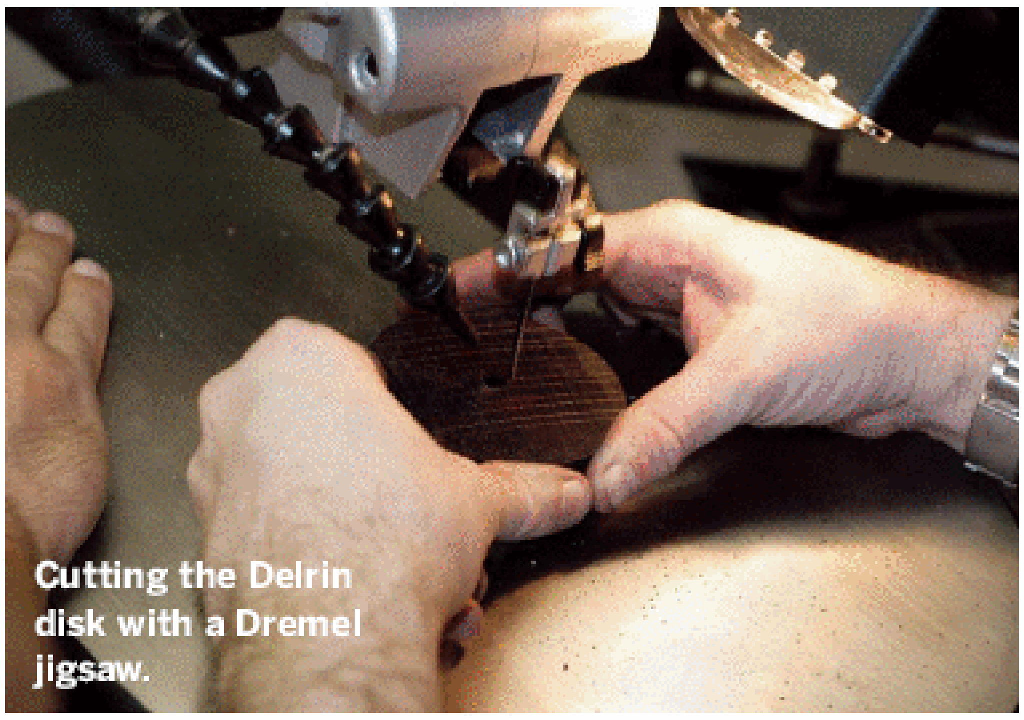


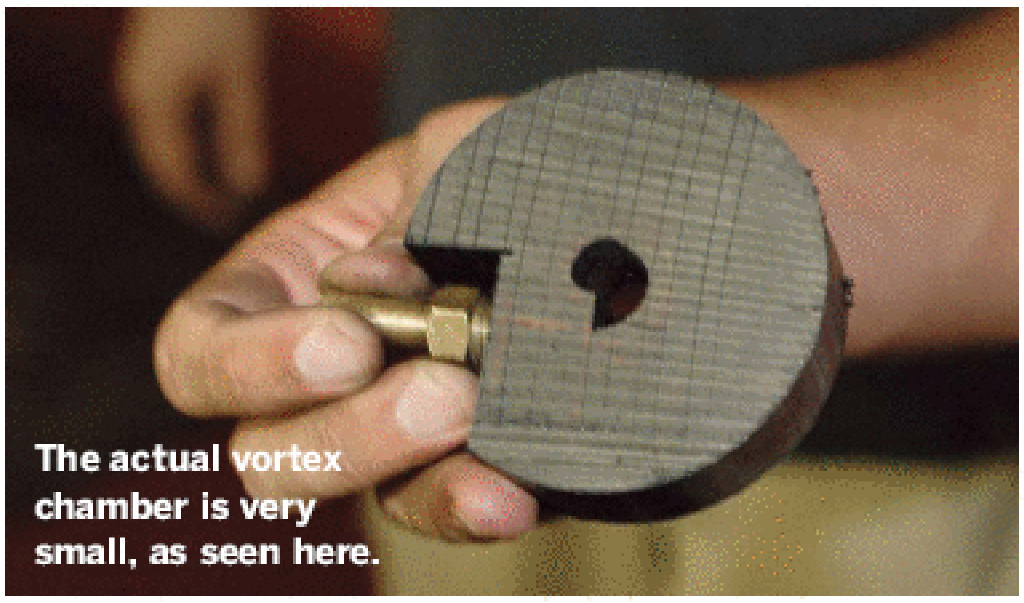
VERSION 2



In just a few hours, we managed to cobble together a proof-of-concept Hilsch vortex tube that produced two streams of air with small, but measurably different temperatures. You're welcome to try to improve on our efforts. If you succeed (or even if you fail) let us know at makezine.com/09/vortex_tube.

Illustration by Gerry Arrington


Cutting the Delrin disk with a Dremel jigsaw.


The actual vortex chamber is very small, as seen here.


The glue only held for seconds; epoxy putty was much stronger.


Our Hilsch tube is not as pretty as SciAm's, but it worked (sort of).

DISAPPEARING APPLE

Remove the logo from an iBook.

By Tom Owad

"**I am writing a book/TV documentary for** Canongate and the BBC called *Bonfire of the Brands*. The short story is that I am attempting to overcome my addiction to brands by burning all my branded stuff on a great bonfire on 17th September 2006. Afterwards, I will be attempting to live a life brand-free."

This was the introduction to an email I received from Neil Boorman last August. It continued, "I have allowed myself one luxury which will be spared from the fire, which is my iBook. But to keep it, I must de-brand the thing, which is why I'm contacting you."

There's a particular problem with removing the iBook's Apple logo: it leaves an Apple-shaped hole. To circumvent this problem, I considered a number of techniques, from molding an entirely new lid, to simply covering the Apple with a big white sticker. Ultimately, I decided the best way was to cut out the logo on a milling machine, then mill a replacement piece out of another lid. I called PreOwned Electronics and ordered a stack of grade B iBook lids to experiment on, then headed down to the

Photography by Tom Owad

garage. My mill is a Homier Mini-Mill (and currently halfway through a homebrew CNC conversion). I mounted the lid on the mill, outside down, using a clamping kit. The Mini-Mill was just big enough for the job — half an inch less travel on the Y-axis would have made the job extremely difficult.

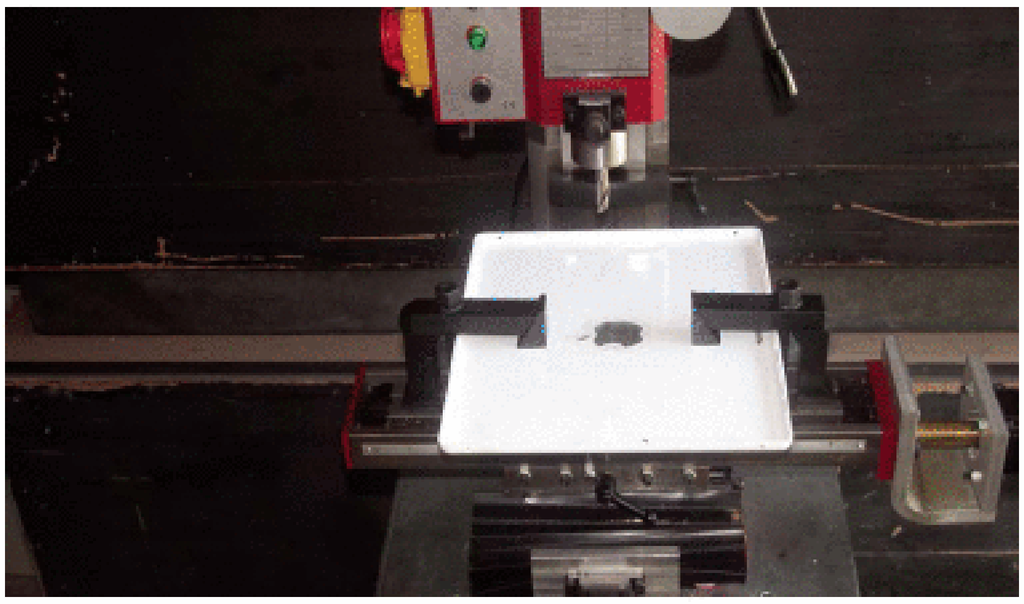
I loaded a ⅛" end mill and cut out a rectangle around the Apple logo. Because end mills are round, the mill can't cut inside right angles, so I then removed the lid from the clamps and filed the corners down (this only took about two strokes with the file). To make the inset, I took another iBook lid and hacksawed it down to a bit bigger than I needed; I then clamped it into the mill and milled it down to the exact size.

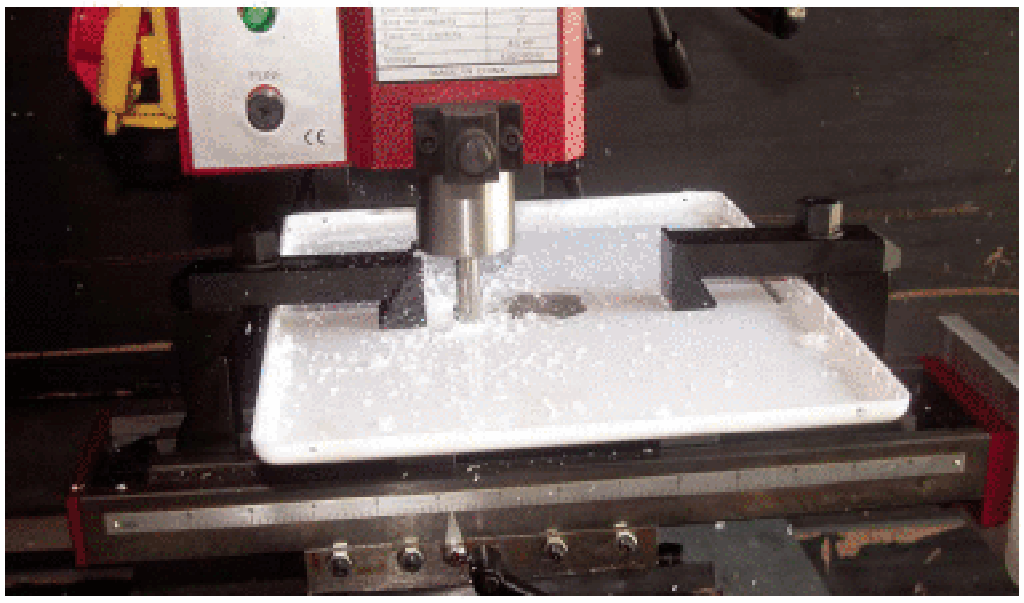
Next I filed off all the burrs and snapped the piece into the lid. A little super glue on the inside of the case held everything snugly in place, but still left a visible crack around the perimeter of the rectangle. I filled this with Bondo Glazing and Spot Putty, then sanded it down. Finally, I spray-painted the lid with Gloss White Krylon Fusion for Plastic. To prevent light from shining through where the logo used to be, I merely taped on a piece of aluminum foil.

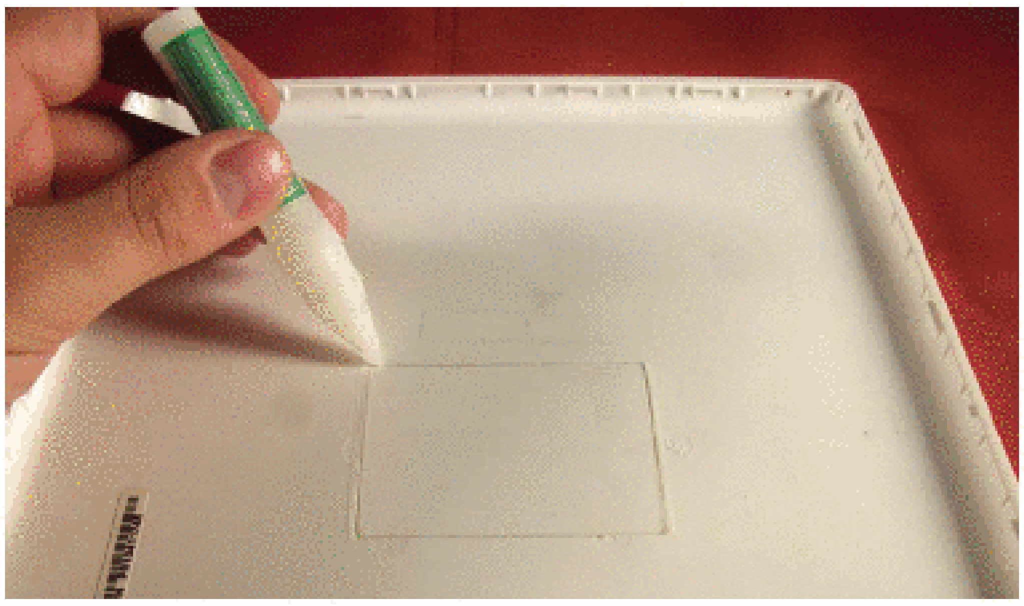
Removing the logos from the operating system (Mac OS X 10.3) was much easier, thanks to a shareware app by Geekspiff called ThemePark (geekspiff.com/software/themepark) and CodeServant's open source application ThemeChanger (codeservant.com/themechanger.php). ThemePark presents a window with the graphical elements in the user interface and allows the user to just drag and drop replacement images over them. I replaced each Apple logo with Neil's initials. Once I was finished with my changes, I saved the theme and installed it with ThemeChanger.

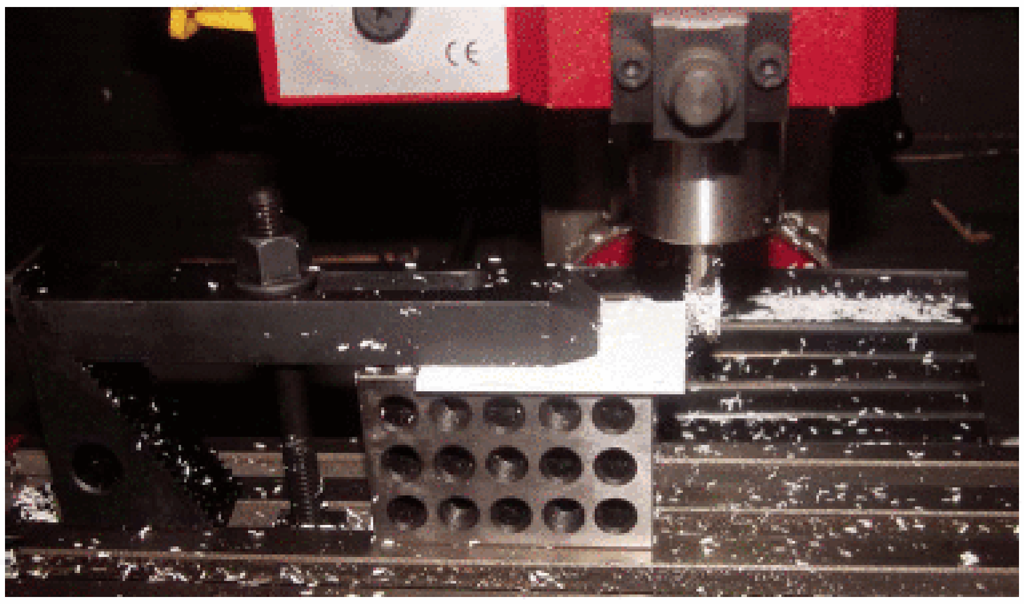
The boot panel — the window that appears during startup with the Apple logo and progress bar — can be modified just by replacing the PDF stored at */System/Library/CoreServices/SystemStarter/QuartzDisplay.bundle/Resources/BootPanel.pdf*. This leaves a single Apple logo: the dark grey apple that first appears when you turn on your Mac. With Ryan Schmidt's Startup Syringe (ryandesign.com/jagboot), replacing it is just drag and drop.

Tom Owad (owad@applefritter.com) is a Macintosh consultant in York, Pa., and editor of Applefritter (applefritter.com). He is the author of *Apple I Replica Creation* (Syngress, 2005).



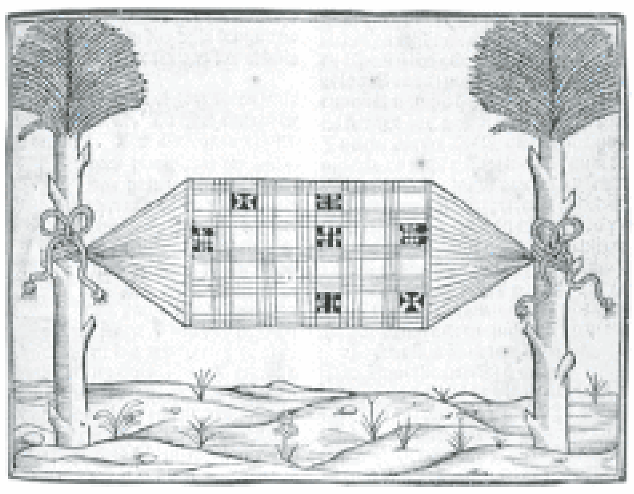






INSTANT HAMMOCK

By Tim Anderson



Make your own hammock in less time than it takes to read this.

Hammock. Barbecue. Canoe. Hurricane. All are important elements of life in the Southeast and Caribbean. And it turns out these are all words from the Arawak Indian language, dating back to before Columbus arrived in the "new world."

Some things just don't change, and it's a good thing. The hammock is one of those things. There are lots of types of hammocks. The ones we've all seen are fancy, complicated ones that are good to sell to rich, industrialized people like us.

There are other types that are much easier to make. Ever wanted a hammock and not had one? You probably weren't more than a few feet away from the materials needed to make one, and it wouldn't have taken you more than a couple of minutes to make it.

Here's how to make your own hammock in less than a minute:

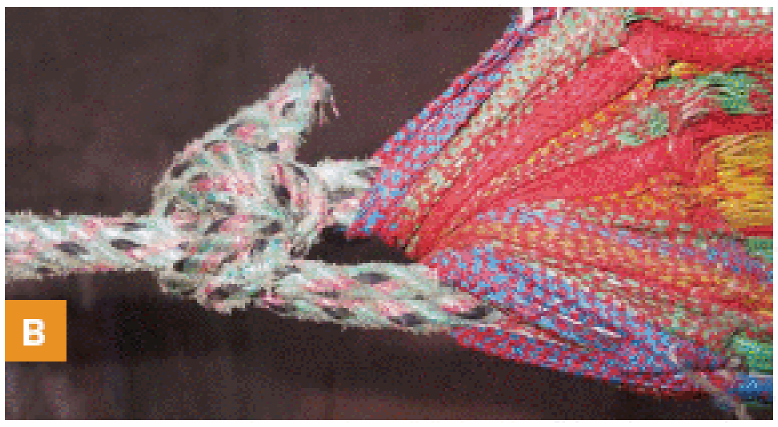
1. Get a large piece of cloth such as a bed sheet. I didn't have one to spare so I bought two roll ends of cotton cloth for a dollar a yard at a discount store. Use any kind of cloth that appeals to you. Most types of cloth will be strong enough when new.

SAFETY WARNING: When it gets old, eventually it will rip and you'll fall onto the ground, just like the fancy commercial hammocks you've fallen out of in the past.

2. I'm making a big hammock, so I sewed the pieces of fabric side by side using a "flat felled" seam. Skip this step if you're in a hurry or if you're starting out with a sheet that's big enough.

A

A few hammocks and tying techniques:



B

A. Varieties of hammocks are found all over the New World. These Nicaraguan students are sleeping while waiting for nesting turtles to come ashore in their study area. These very small hammocks are one of the traditional styles and are surprisingly comfortable. The ones shown are made of uncoated polypropylene and are sold in all the markets for next to nothing. Stacked on a shelf they look like shopping bags, and you wouldn't know they were hammocks.

B. Detail of how this hammock is hung: The rope is passed through a large hem at the end of the hammock, bunching the cloth together. Then that end of the rope is tied with a bowline knot to make a loop. The other end of the rope is tied to a pillar or tree.

C

C. A fancier style of large hammock, this denim model is in a hotel on Isla Ometepe, Nicaragua. It was sewn just the same as the smaller hammocks seen above. Then a dozen or so slits were cut in the hem. The fingers of cloth thus created are tied with bowline knots to the ends of 5-foot chunks of colorful cord, forming loops to make the bridle.

D

D. Other end of the bridle: The loops of cord are gathered together into a single loop. This is whipped with a covering of cord knotted with a series of half hitches, one at each turn. The covering keeps the bridle lines from slipping and prevents the suspension rope from chafing through them. The suspension rope is tied to the loop with a lark's head knot.

3. Bunch up both ends of your cloth. If your cloth is long enough and you want to be extra secure, tie an overhand knot in the ends of your sheet to keep the rope from sliding off.

OPTIONAL: If your cloth is long enough and you want to be extra secure, tie an overhand knot in the ends of your sheet to keep the rope from sliding off.

4. Tie a chunk of rope to each end of your sheet using a lark's head knot (*see MAKE, Volume 01, page 77*).

5. Hang your new hammock between two stationary objects, get in, and relax. A nice feature of these cloth hammocks is that you can pull the sides closed over yourself and be very cozy inside. If the hammock is large, you can lie diagonally in it and have your spine totally straight. That's how the Mayans do it.

Tim Anderson, founder of Z Corp., has a home at mit.edu/robot.

Photography by Tim Anderson

Turn On, Tune In, Bliss Out

Dr. James Hardt hopes his DIY neurofeedback tech will fire up the global brain.

By David Pescovitz
Photography by Howard Cao

BLUE. THE COLOR OVERWHELMS ME AS I STEP inside a nondescript office park building across the street from the San Jose airport. There's blue everywhere. Blue carpet. Blue walls. Blue fabric draped here and there. Even the wall art, cosmic fantasy framed prints that are the New Age equivalent of black light posters, is heavy on the azure.

The cracked geodes decorating the conference table are bluish-purple. This is the Biocybernaut Institute, home to neurofeedback technology that the inventor believes could someday be used to awaken the global brain. Enter the mind-machine maker himself, Dr. James Hardt, sporting what else but a blue fleece jacket. "You apparently like blue?" I ask him.

"It's not about liking blue," Hardt says. "It's about the fact the blue enhances the brain's alpha state."

Hardt should know. Over three decades he's trained hundreds of people to use a neurofeedback system of his own design to control their own brain waves and spend more time in an alpha state.

For those who may not have lived in California during the 1970s, the alpha state is a brainwave pattern with a frequency of 8-13Hz that's commonly associated with relaxation and meditation. Increased alpha wave activity has also been shown to help alleviate ADHD and depression, boost creativity and alertness, and facilitate out-of-body experiences and other psychic phenomena, depending on who you ask.

Hardt claims that one week of alpha training can yield changes in brain waves comparable to 21 to 40 years of Zen meditation training. All for the low, low price of $15,000 per person. That's how much a weeklong training session of roughly 12-hour days at the Biocybernaut Institute runs. Bliss doesn't come cheap.

"Alpha power, when it's high, is like being in heaven," Hardt says. "You're filled with joy, enthusiasm, and a sense of wonder."

Neurofeedback was born during the psychedelic 1960s out of earlier experiments to detect the current in our heads. The core technology is the electroencephalograph (EEG), a device used to record electrical activity in the brain by sticking electrodes to the scalp. The field began in 1908 when Hans Berger wired his son up to a galvanometer and recorded his brain waves. Berger named the signals alpha waves because they were the first ones discovered.

But the real biofeedback breakthrough occurred in the 1960s, when UC San Francisco psychologist Joe Kamiya closed the loop by providing subjects with real-time data of their brainwave activity in the form of audio tones. Kamiya hooked up all kinds of people to his machine, from Zen monks who exhibited heightened alpha states, to Summer of Love seekers eager for a new trip, to a curious physics graduate named James Hardt.

One day, a lab technician left for lunch, forgetting that Hardt was in the chamber. Over the next several hours, Hardt says he went on a transcendental "adventure" in the alpha state, complete with "ego dissolution," that hooked him for life. Learning to control your mind from the inside out, he believes, is the first step to manifesting a human superconsciousness.

"If you've got a mess in your mind, you're not going to be as good a candidate for a linkup," he explains. "You usually take a shower before making

"In physical fitness, the goals are strength, flexibility, and endurance," Hardt says. "In mind fitness, the goals are the same. You want to learn to increase and decrease the strength of your alpha waves and then build up the endurance to do that for long periods of time. It's literally pumping neurons."

love, right? This is the mental equivalent of that."

From 1971 to 1977, Hardt worked closely with Kamiya to see how neurofeedback might push the limits of human potential. Meanwhile, he rolled his own belief system from a smorgasbord of spiritual traditions and philosophers.

Two decades later, the Biocybernaut Institute apparently has no shortage of students. Hardt says he's trained everyone from Silicon Valley big shots to pro football players to U.S. Army Green Berets. The latter group signed up during the 1980s at the bequest of Maj. Gen. Albert Stubblebine, onetime head of the United States Army Intelligence and Security Command, better known for his involvement in recently declassified psychic spying programs.

Every weeklong training at the Biocybernaut Institute begins in the conference center, where Hardt gives a PowerPoint-powered rap to orient the participants. Next, his staff applies a half-dozen scalp electrodes to each trainee's head. After the trainees are wired up, each moves into one of four soundproof chambers (blue, of course) where the neurofeedback session actually takes place. Every chamber contains a surround sound system, a computer on a desk, and a task chair. (If you're doing theta training, you get to kick back in a La-Z-Boy. Theta brain waves are associated with deep relaxation and light sleep.) Baseline EEG measurements are taken, and then a symphony of electronic tones reminiscent of a minimalist techno album signals that the long, strange trip is about to begin.

"When you go to the theater, you have to practice suspension of disbelief," he says. "To participate in this training, you need to have a suspension of belief and go in only with what you discover. With that mindset, you have the openness of a baby and of an advanced mystic."

Rip off its New Age wrapper and the real magic of the Biocybernaut training lies in the technology behind the blue curtain. An array of amplifiers and filters extract the brain's electrical signals collected by the scalp electrodes. That data is then analyzed by PCs that generate the feedback tones heard in the chambers. All of the neurofeedback gear — except two hulking polygraphs that print out the raw EEG data — is Hardt's own design. No commercial product was ever good enough, Hardt says, so he assembled and patented his own. One former student posting online describes the Biocybernaut facility as "having an 'I built a rocket ship in my garage' kind of feel." Indeed, a fair bit of, er, unconventional engineering went into the system.

"This advanced technology allows scientists to talk the language of mystics, and mystics to talk the language of scientists. I look at what we're doing as creating the science of spirituality."

Early on, Hardt explains, he had a quality control problem with components on the filter boards. Some of the resistors and capacitors behaved erratically at the boards' operating temperature of 104 degrees. Hardt's solution was to heat a room to 104 degrees and test each component individually.

"Once the room was hot enough, my staff and I went in wearing bathing suits and metered each part," Hardt recalls. "We put them into labeled bins so we had known values."

Next, Hardt wrote software to specify how those resistors and capacitors with slightly different values could be combined into circuits that would operate within his strict tolerances. Only then could his circuit board assembly line begin.

"This advanced technology allows scientists to talk the language of mystics, and mystics to talk the language of scientists," Hardt says. "I look at what we're doing as creating the science of spirituality."

Back in the chamber, the trainees hear various synthesized tones that change according to how their alpha states increase or decrease. The tones,

Hardt sits, wired with eight scalp electrodes, in one of the Biocybernaut Institutes's four brain wave training chambers. Multiple speakers deliver separate feedback tones in response to activity in four parts of the brain.

he explains, "are like an auditory mirror for your mind." The trainee is taken through a series of survey questions and alpha suppression and enhancement exercises. Numbered scores appear on the computer display, providing more feedback to the trainee. Hardt won't tell me how much "objective time" each trainee spends in the chamber. Wristwatches are confiscated at the door.

After each session in the chamber, the trainees retire to the "canopy room," a lounge that reminds me of a cheaply decorated chill-out room at a rave. Here, Hardt or his staff debrief with the trainees about their time in the chamber.

The cycle repeats every day for a week per training, with various levels of training offered. (Prepay for 12 trainings and you get a 30% discount!) It's not until the more advanced trainings, though, that Hardt's vision for a global brain comes into play. Shared alpha biofeedback trainings involve two students pairing up in one chamber to synch their own alpha states and "jam together," Hardt explains, "with one playing the (psychic) oboe and the other the violin."

Those shared sessions are practice for the mental orchestra Hardt hopes to help conduct in the future. He believes that with 5 to 10 billion Biocybernaut students all linked up, a self-reflexive human superconsciousness may emerge. When I ask him how that could possibly work at a cost of $15,000 a head just for the basic training, he explains that economies of scale could cut the cost in half. As a step in that direction, he's planning to open new centers in Canada and two in Austria this year. Then it would just be a matter of getting, say, the U.S. military to subsidize the training cost with a percentage of the annual defense budget.

"After we were done, there'd be so much mind power that they wouldn't need a defense budget."

MAKE Editor-at-Large David Pescovitz is co-editor of boingboing.net and a research affiliate of the Institute for the Future.

WHO WANTS TO BE AN INVENTOR?

DON'T WORRY, NO ONE IS GOING TO STEAL YOUR SECRETS.

By Saul Griffith

FAR, FAR OUT THERE ON THE FRINGE OF society's imagination is the backyard inventor who strikes it rich with some cunning little gizmo that improves life. You've seen this person portrayed by Wayne Szalinsky in *Honey, I Shrunk the Kids*, Doc Brown in *Back to the Future*, Bruce Wayne in *Batman*, and countless other fictional characters, including my favorite, Wallace, and the real brains of the operation, Gromit.

Every time Squid Labs is in the news somewhere, we receive a new batch of emails from home inventors: "Dear Sirs, I've invented an energy device. I need help in patenting it and prototyping it. It will revolutionize the world and save the children of Africa from starvation."

Against my better judgment, I often send a reply: "Can you tell me a little more about your device so I can figure out if we can help?" Generally, I get the paranoid response: "If I tell you any more, you will know what the invention is!" To which I have to say, "Without more information I can't help you. Good luck." And in the back of my mind I imagine another perpetual motion machine.

This phenomenon reminds me of Tim O'Reilly's writing regarding authors: "Lesson 1: Obscurity is a far greater threat to authors and creative artists than piracy." Which might just as easily be translated as: Obscurity by secrecy is a far greater threat to inventors than having your ideas stolen by corporations.

I know a lot of people who invent things, even for a living, but I can't say I know anyone who represents the mythical backyard inventor who retires to live a life of luxury on the royalties of their patent. It is a concept fueled by the American dream and in the media offerings that support that dream, but it is not a reality.

I suspect that what would be most helpful is to step back and understand what it is that "inventors" really want, and figure out what would be their best strategy to get it. Like musicians, artists, and the other obsessively creative types, most innovators really just want to earn a good living doing what they love. Inventors, deep down, would like to be paid for full-time tinkering. If they could retire with the proceeds and buy yachts, that would be ideal, but I suggest that having the resources to do what they love and a workshop to do it in is way more important than the pot of gold at the end of the rainbow.

I'll return to O'Reilly's words to string my own thoughts together: "For all of these creative artists, most laboring in obscurity, being well-enough known to be pirated would be a crowning achievement." Again, these words apply directly to inventors and the process of invention. You'll be better off in the long run being known for inventing something — even if you give it away — than hoarding the idea in a padlocked file cabinet in your basement.

I know a lot more people who publicized ideas that turned into careers or job offers than I do people who made it big with that mousetrap. I don't actually know anyone who has been "screwed" by "bastard corporations" or other "thieving inventors."

Of course I always console my friends when they don't think their licensing deal was good enough, but it's really the same counseling they get from me over thinking about exes: "Of course they were [insert epithet] but now you are out of it, and better off for it."

Let's briefly look at the other option, the "patent and sell" dream. A single patent through to prosecution will cost you anywhere from $20,000 to $100,000, depending on how much of the world

Famous inventors of fiction and reality. Top: Bruce Wayne and Wayne Szalinsky. Bottom: Thomas Edison and who knows? It could be you. Just don't expect to retire to a life of luxury after filing a single patent.

Illustration by Dustin Hostetler

it covers. This is before you've gone through the expense of trying to license your patent to someone (before you make any money, you'll have to spend a lot letting interested parties know about the idea). Alternatively, you can wait until someone infringes your patent and then try to recover monies from their error. This is even more expensive. I rarely recommend this process to any individual inventor. The likelihood of a yacht retirement outcome is similar to the likelihood that you look like Bruce Wayne.

Patents and secrecy don't really serve the individual anymore. Unfortunately, they have become trading cards in a grand corporate shell game. I'd stand by the statement that the most likely road to the tinkering nirvana is to become known for what you do. That means doing it well and telling people about it, even telling them how to do it.

The reality is that the invention or the idea is a tiny fraction of the work to be done, and in all probability other people have already had the idea or patented the same thing. The real tradeable value is your capacity to implement the idea. I've hired people because they've built cool projects on instructables.com that demonstrated their skill, and I've seen people turn their kit-building websites into profitable small businesses. It all started with pretty much giving a few of their inventions away — loss leaders to support a lifetime of tinkering.

To read Tim O'Reilly's essay "Piracy is Progressive Taxation, and Other Thoughts on the Evolution of Online Distribution," go to makezine.com/go/piracy.

Saul Griffith thinks about open source hardware while working with the power nerds at Squid Labs (squid-labs.com).

Tales & Projects from the

FRINGE

Photograph by Howard Cao

FRINGE

Patently Curious

One sunny morning in the environs of Washington, D.C., I'm standing in an overgrown suburban backyard, slapping mosquitoes while trying to get a photograph of a "free energy" model railroad car on a small folding table. Tom Valone lines up the car, lets it go, and an array of cunningly oriented magnets draws it forward. The little car accelerates, runs off the end of its track, and tumbles into the grass.

This is more impressive than I had expected. But what would happen if the track were circular? Would the magnets on either side of the track push the little car around and around indefinitely?

Valone isn't sure about that. "You should look at a different patent from the same inventor," he says. "It uses magnets in the form of archways. Two witnesses have told me that when they visited the inventor, they saw a model running in a circle continuously for two hours."

I always seem to have this kind of problem with free-energy demos. The real demo is someplace else, or it happened at some other time, or the people who saw it have disappeared, or the inventor refuses to talk to a journalist because he's afraid that his idea will be stolen. "Where, exactly, does the inventor live?" I ask.

"In Virginia."

Valone's own house is in Virginia. "So why haven't you visited him?"

"Oh, I'm too busy."

This is the odd thing about Tom Valone. He has a fevered interest in fringe phenomena, catalogs them with obsessive zeal, yet seems more interested in describing them than evaluating them. As he puts it, "I hope to create a ripple effect. If I make people aware of things, their perception of what they should do on their own may change."

Despite his unconventional interests, Valone has a solid background in conventional science. He received a Bachelor of Science in physics and a Bachelor of Science in electrical engineering at SUNY Buffalo in 1974, and remained at SUNY, teaching college classes in subjects such as engineering physics, technical physics, electronics, digital logic, microprocessors, and environmental science. After he received a master's in physics in 1999, he took a job as an examiner at the U.S. Patent Office, specializing in the utterly conventional subject of electrical testing and measurement.

He had an ulterior interest, however. "Academic scientists," he says, "tend to value journal publication exclusively. That's their benchmark for credibility. If they don't see it in an academic journal, they don't think it's true. But this is a very tunnel-vision approach. Patents provide an alternative view of innovations occurring in the world, from authors who usually don't publish journal articles."

And so in his spare time he gathers information — patents, especially — on every obscure invention he can find. At this point he is probably the most broadly informed authority on the kind of basement tinkering that ventures into gray areas beyond the conventional laws of physics. While most of us tend to dismiss such work, Valone is like an open-minded juror who regards a defendant as being innocent until proven guilty. In his world, claims are worthy of consideration until proven false.

His open-mindedness led him into big trouble in 1999, when he conceived a "Conference on Future Energy." He obtained permission to hold it in an auditorium at the State Department, taking advantage of an Open Forum Speakers Program that existed "to explore new and alternative views on vital policy issues of the day." Unfortunately, "new and alternative" didn't mean the same thing to them as it did to him.

Robert Park, a PR writer for The American Physical Society (APS), is notorious for denigrating, ridiculing, humiliating, and eviscerating any individual who propounds propositions that Park, in his wisdom, finds implausible. When he learned that Valone's

Photography by Charles Platt

Physicist Tom Valone looks at technologies most scientists consider junk. By Charles Platt

Tom Valone outside the main building of the Patent Office, where he is employed as a patent examiner.

conference would include a former Los Alamos scientist discussing cold fusion, he was appalled that federal real estate should host such heresy. He contacted Peter Zimmerman, who had just been hired as a State Department science advisor, and Zimmerman duly used his clout to have the conference evicted.

Worse was to come, as Valone found himself the target of a jihad waged by guardians of establishment science. At a meeting of APS, Zimmerman boasted about his efforts to have the conference shut down. Meanwhile, Valone was fired from his job at the Patent Office. He tried to get it back, but the process lasted more than six years, during which he furthered his education and received a doctorate. Finally an arbitrator reinstated him and awarded back pay for the entire period, less 30 days.

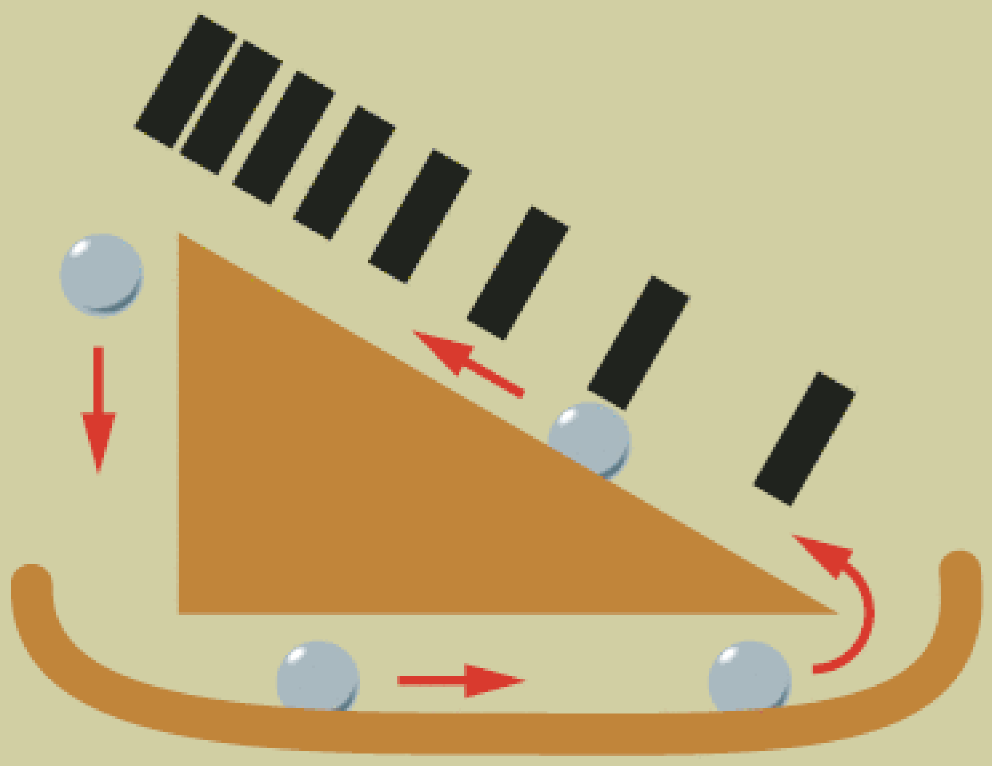
"My conference was just an open forum for people who had unusual inventions in the energy arena," Valone says, still sounding genuinely puzzled that it could have sparked such retaliation. "Some were deserving of critical review, but others were solidly acceptable."

The magnetically powered railroad car in his backyard does not seem solidly acceptable (to me, at least), but the local mosquito population is waging such a relentless jihad of its own that I decide I have given the railroad car as much critical review as it is going to get. We retreat into Valone's house, where two walls of the living room are covered with shelves carrying books on topics from yoga to UFOs. A back room crammed with disorderly stacks of papers serves as an interim office for the Integrity Research Institute, a small enterprise that he runs with his wife.

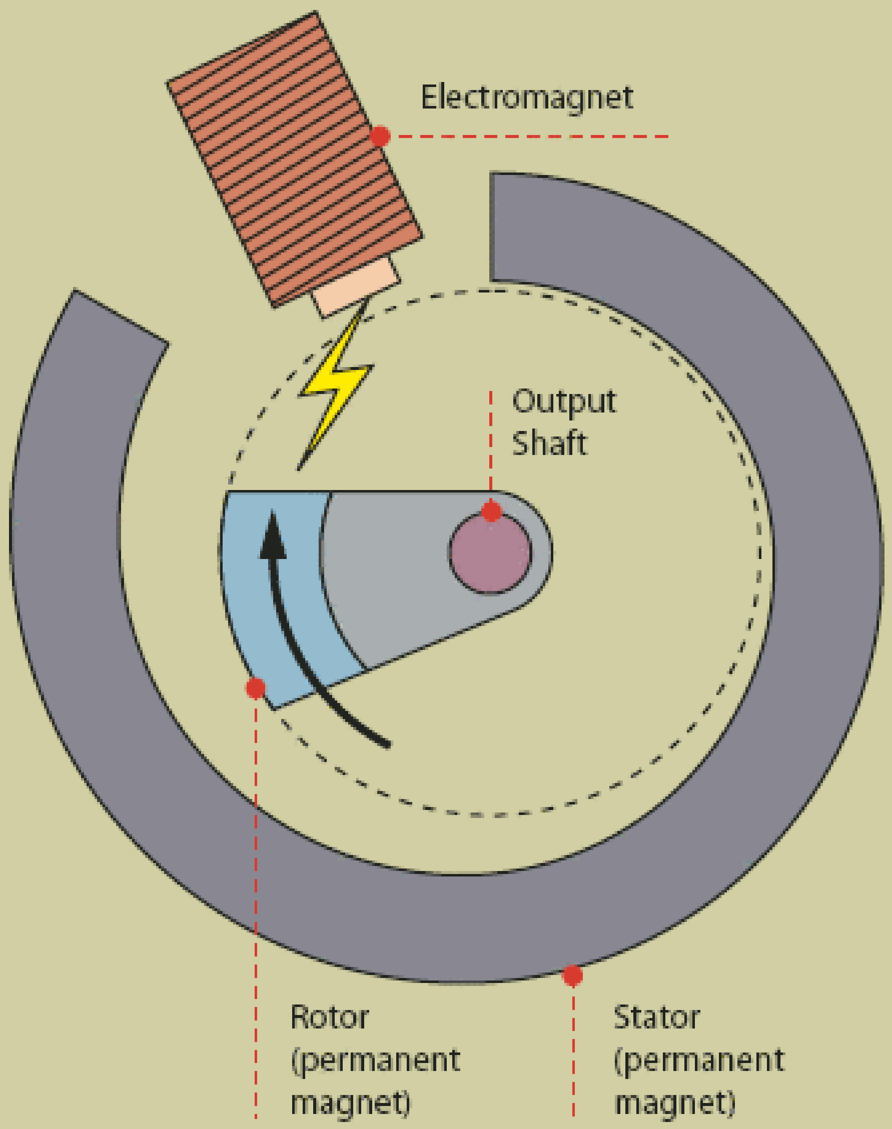
Since I seem skeptical about the railroad car, he digs out the relevant patents: #5,402,021 for the linear track and #4,877,983 for the one with archways, both issued to Howard R. Johnson. The magnets are mounted in such complex configurations that analysis of the aggregate force is almost impossible. Valone nods enthusiastically. From his point of view, this means the design cannot be refuted. From my point of view, it means it cannot be evaluated.

He shows me another patent, #4,215,330, issued in 1980 for a similar array of magnets that entices a steel ball up to the top of a ramp, where it drops down and apparently could roll back to its starting point, ready for another trip. This idea has been picked up by Jean-Louis Naudin, a French free-energy advocate who provides detailed construction blueprints at jnaudin.free.fr/html/s102jlnp.htm.

PERPETUAL MOTION DEMO: Magnets separated by diminishing intervals provide a net force to drag a steel ball up a wooden ramp. The ball falls from the apex of the ramp into a channel, guiding it around for the next ascent. Would it work? The best way to find out would be to build it.



THE KURE TEKKO MOTOR: Mutual magnetic repulsion forces the rotor around inside the spiral stator until it reaches a gap where an electromagnet encourages it to make the next revolution.



Valone is probably the most broadly informed authority on the kind of basement tinkering that ventures into gray areas beyond the conventional laws of physics.

Right: Valone in a shed he uses as a workshop in his backyard. Above: The magnetically powered model railroad car in the backyard of Valone's suburban home.

Valone unearths another magnetic propulsion concept, described in *Popular Science* in June 1979. This is the Kure Tekko magnetic motor, which interests Valone because it uses the under-exploited concept of a "magnetic gradient." A magnetic rotor turns inside a spiral-shaped stator that is also magnetic. Mutual repulsion accelerates the rotor as its distance from the inner surface of the spiral increases. At the end of the spiral is a gap that the rotor must cross before it overcomes the repulsion of the stator to begin its next cycle.

"The Japanese used a solenoid to take the rotor across the gap," says Valone. "Of course, this consumes electricity. But there may be a better way." He shows me a paper from the IEEE, entitled *Transactions on Magnets*, describing a piezoelectric laminate that may be capable of switching the force from a static permanent magnet in the same way that a transistor switches electricity. This indeed has fascinating implications — depending how much switching power it consumes.

When I ask Valone how he came to be so open-minded, he turns the question around. "I always wondered why other people were less open-minded," he says. "I promised myself that as I grew older, I would never lose my curiosity, and the ability to solve mysteries that others had overlooked. I felt that this was a youthful quality I needed to keep."

He agrees that his open-mindedness has the potential to lead him astray. "My ability to perceive reality is conditioned by my beliefs," he says. "If I believe in free energy, I'll start thinking I see it in all the wrong places. So many inventors have been self-deceived. Ninety percent of the people who claim they have free energy don't have it."

Still, he suggests that open-mindedness is precisely what the world needs right now. "Where are we going to get energy from in the future?" he asks. "None of conventional science can answer that question. Unfortunately federal dollars are tied into projects that aren't going anywhere, because politics have dominated science, and scientists all over the world are afraid to stick their necks out. We are losing our innovative ability in this country." He pauses to emphasize the point: "The only approaches that have promise today are unconventional."

+ Additional Sources:

Tom Valone's Integrity Research Institute (users.erols.com/iri).

The Basement Mechanic's Guide to Building Perpetual Motion Machines (makezine.com/go/simanek) includes actual photos of construction projects which, unfortunately, don't quite work. (*See Donald Simanek's article about perpetual motion, page 70.*)

Wikipedia article about the Simple Magnetic Overunity Toy (SMOT), which some claim produces more energy that it uses (wikipedia.org/wiki/SMOT).

Wikipedia article about Steorn, Ltd., a Dublin, Ireland-based company that claims to have invented a perpetual motion machine (wikipedia.org/wiki/steorn).

Charles Platt has been a senior writer for *Wired* magazine and has written science fiction novels such as the *Silicon Man*. He wrote "Electric Avenue" in MAKE, Volume 05.

FRINGE

5 Fringe Power Plays

Since Tom Valone maintains such a generously stocked clearinghouse of unconventional concepts, he's well-situated to suggest a Top Five of those that he believes could have the most far-reaching consequences. Here are his picks, in no special order:

THE CONCEPT	THE PROMISE	THE PROBLEM
1 **ZERO-POINT ENERGY** Quantum physics predicts that a minimum state of energy always exists, even in a vacuum with a temperature of absolute zero.	Inexhaustible power permeating every cubic centimeter of the cosmos.	Energy flows from areas of higher potential to lower potential. Since zero-point is, by definition, as low as you can go, energy would be more inclined to flow to it than from it.
2 **BIOELECTROMAGNETICS** Nikola Tesla advocated "electrotherapy" in 1898, and electromagnetic radiation enjoyed a brief vogue as a rejuvenation treatment. Recent research shows that near-infrared LEDs provide symptomatic relief from neuropathy while also accelerating cell growth (see makezine.com/go/nasa). Valone points out that light is a form of electromagnetic radiation, and suggests that since antioxidants inhibit the transfer of electrons, an electromagnetic field could encourage this beneficial effect.	Feel-good pick-me-ups, plus a possible cure for terminal cancer.	Evidence for far-reaching claims is anecdotal.
3 **AIR-POWERED AUTOMOBILES** In France, the MDI Aircar is powered by tanks of air compressed to more than 4,000 pounds per square inch. In Australia, a rotary air-powered engine has been developed by a startup named Engineair. Carbon-fiber air tanks may be cheaper, smaller, and lighter than other power storage systems such as batteries, and the electricity to pressurize them can be generated by non-oil sources such as hydro, wind, solar, nuclear, or coal.	Zero local pollution, reduced global pollution.	The first MDI prototype had a practical range of only about 5 miles. The manufacturer claims that a higher tank pressure and other enhancements may raise the range to at least 100 miles, but these claims have been questioned. Combustible fuels offer much more energy per pound than compressed gas.
4 **ELECTROGRAVITICS** Legendary American physicist Townsend Brown believed that an asymmetric attraction between high-voltage electrodes might partially nullify gravity. His British patent number 300,311 for "A Method of and an Apparatus or Machine for Producing Force or Motion" led him into research that may have hit a dead end — or may have been incorporated in secret military aircraft.	Low-powered levitation.	The work has never been fully replicated.
5 **MAGNETIC MOTORS** The seemingly mysterious nature of magnetism has always attracted perpetual-motion enthusiasts. Howard R. Johnson's classic paper is at makezine.com/go/johnson. It begins, "Using the Bohr model of the atom, and knowing that un-paired electron spins created a permanent magnet dipole, I kept wondering why we couldn't use these fields to drive something."	More power comes out than goes in.	Working models remain elusive.

CURRENT STATUS	OPTIMISTIC ASSESSMENTS	REALITY CHECK	OPPORTUNITIES FOR AMATEUR EXPERIMENTERS
Zero-point advocates suggest ingenious methods such as using molecular nanotechnology to access the energy. These ideas remain unproven.	Tom Valone has written his own book, *Practical Conversion of Zero-Point Energy*. Nick Cook, an editor at *Jane's Defence Weekly*, speculates on military applications in his book, *The Hunt for Zero Point*.	Try the 1997 article from *Scientific American*, archived at padrak.com/ine/ZPESCIAM.html.	Few at this time.
Early adopters can pick up a Healthlight LED infrared therapy pad for a mere $4,496, or a Curatron 2000HT pulsing electromagnetic field emitter for $2,170.	*Bioelectromagnetic Healing*, a book by Tom Valone.	"Magnetic and Electromagnetic Field Therapy" by Marko S. Markov and Agata P. Colbert in the *Journal of Back and Musculoskeletal Rehabilitation*, Volume 15, Number 1.	High. You can buy near-infrared LEDs in bulk, or install a Tesla coil under a plastic patio chair, but we don't recommend it.
Apparent lack of investment capital.	Automotive engineer and inventor Guy Negre describes his vision at theaircar.com. Engineair is at engineair.com.	en.wikipedia.org/wiki/air_car	Doubtful. Achieving and storing the very high necessary air pressure is challenging and potentially dangerous.
An endless source of speculation among UFOlogists and conspiracy theorists.	Try Paul Schatzkin's book, *Defying Gravity: The Parallel Universe of T. Townsend Brown*. Also try the official Townsend Brown website, soteria.com.	en.wikipedia.org/wiki/thomas_townsend_brown	Dozens of sites tell you how to make your own electrostatically energized "lifters" from aluminum foil. Don't expect them to carry a payload, though.
A backwater.	In his home workshop, Tom Bearden claims to have built his own Johnson motor and talks about "oceans of free energy" (cheniere.org/misc/oulist.htm).	The Philadelphia Association for Critical Thinking (PhACT) offers sobering advice regarding magnetic machinery at phact.org/e/z/freewire.htm.	Excellent, so long as you are willing to build things that don't quite work. If violating the second law of thermodynamics were easy, everyone would be doing it.

Illustrations by Scott Barry

FRINGE

In Search of Psi

At the tender age of 13, I embarked on a serious mission to tap the psychic waveband. While other kids were playing team sports or ogling girls, I was fabricating divining rods and a Hieronymus Machine.

My guide into the queasy world of quasi-science was John W. Campbell, Jr., the irascible editor of *Astounding Science Fiction* magazine. He sounded like one part engineer, one part wide-eyed visionary, and two parts drill sergeant. His enemy was unthinking orthodoxy. His precept was that you could crack any problem with the scientific method, so long as you didn't pay too much attention to "experts" warning you that what you wanted to do couldn't be done.

In 1956, Campbell published an informal position paper, asking his readers if they were ready for a serious exploration of "psi," by which he meant the entire subject of psychic phenomena. If psi existed, it should yield to a mix of logical deduction and Yankee ingenuity, just like anything else. So how about it? He wrote as if he were addressing a platoon of fresh-faced recruits. Were we man enough (surely, none of his readers was female) to tackle some really life-changing, head-bending ideas, no matter where they might lead us?

In his June 1956 issue, Campbell reported that his readers shared his zeal. They were gung-ho, ready to lock-and-load and follow him over the top into combat with prejudiced naysayers who dismissed psychic research as frivolous or wacky. So be it! He started publishing a series of revelatory articles that I read with utter fascination.

DIVINING RODS

I especially liked a feature about "divining rods" because they were so simple. All you needed were two pieces of rod and two lengths of tube. You bent each piece of rod at a right angle and hung it in a length of tube. You held the tubes, one in each hand, so that the rods pointed away from your body, like a pair of handguns. If you rotated your wrists slightly, the rods would swing from side to side.

Supposedly they would detect cables, conduits, water pipes, sewer pipes, aquifers, or anything else that ran in a straight line underground. You held the divining rods and started walking. As you approached the linear underground object, the divining rods started to turn. When you were directly above the object, the rods aligned themselves with it.

The rods were said to be standard equipment among hard-hat maintenance workers across Heartland America. The magazine published a picture of the Distribution Supervisor from a water company in Flint, Mich., holding a pair of the rods — or at least, so the caption claimed.

Campbell theorized that the human brain might have unknown powers to sense underground objects. The brain simply needed a means to express itself, perhaps via unconscious muscular movements of the type that old-fashioned water diviners had applied with a yew twig. The rods probably worked the same way.

I chopped a wire coat hanger into two pieces, hung each of them in a spool of thread that I filched from my mother's sewing kit, and stretched a piece of string across my bedroom floor. I closed my eyes and stepped forward. One pace, two, three. I opened my eyes, and sure enough, I was standing directly on the string, and the rods had turned (or, I had turned the rods) to align themselves with it.

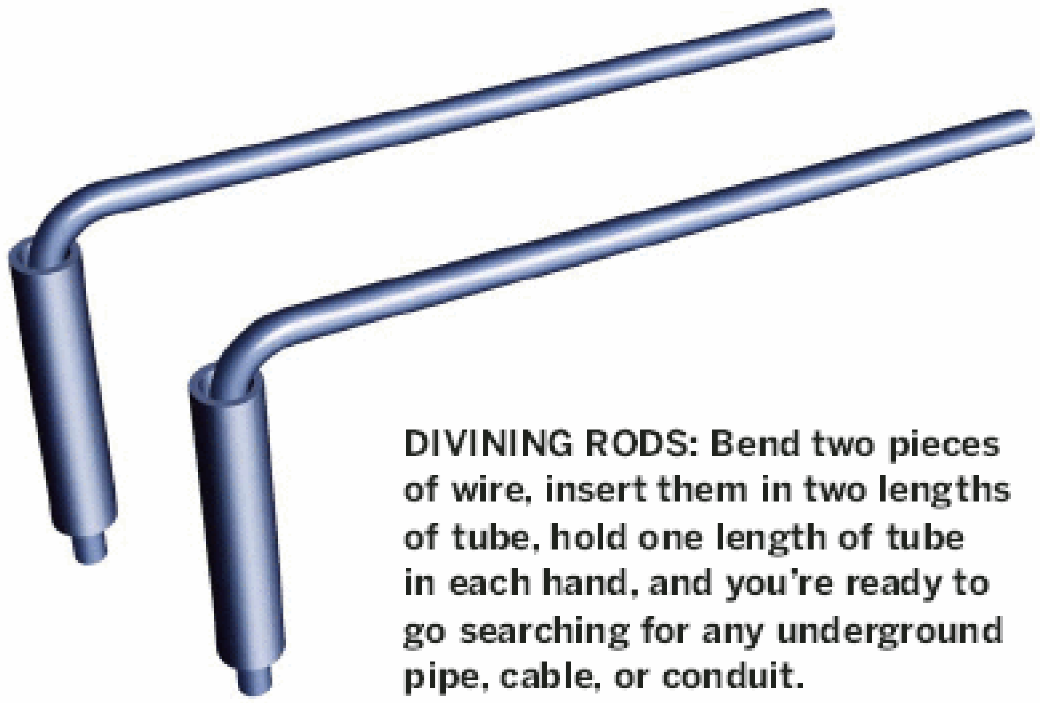
I was thrilled, but of course I realized this was not a fair test, since I had known where the string was located, and I had known the result that I was hop-

Author's note: Since the inventor's patent was filed under the name "Hieronymus," I have used this spelling, even though Campbell, who was in contact with the inventor, spelled his name as "Hieronymous."

A boy and his Hieronymus Machine. By Charles Platt

In October 1958 this seemingly undistinguished science fiction magazine contained a revelatory story on "divining rods." (Original cover by Kelly Freas.)

The brain simply needed a means to express itself, perhaps via unconscious muscular movements of the type that old-fashioned water diviners had applied with a yew twig.



DIVINING RODS: Bend two pieces of wire, insert them in two lengths of tube, hold one length of tube in each hand, and you're ready to go searching for any underground pipe, cable, or conduit.

ing to achieve. I asked my father if he knew of any underground objects buried outside the house, but he said he didn't. So I rode my bicycle to the home of a friend whose father was an electronics engineer in the Air Force.

My friend and I took turns holding the rods while we walked to and fro across his backyard. The rods swung in our hands, and we started drawing a map of underground objects. The objects formed an X-shaped pattern, linking opposite corners of the yard. But what, exactly, were we mapping?

We turned to my friend's father, who had been watching us with interest. "Is there *something* under your lawn?" I asked.

He nodded very seriously, although he seemed to be having trouble repressing a smile. "There are two drains," he said. "They run from corner to corner."

My eyes widened. "In an X-shaped pattern!"

"Absolutely right," he said.

PSIONIC DETECTION DEVICE

Well, after that, John W. Campbell was more than just a guru to me. He acquired godlike status. In a previous issue he had published a piece about a "psionic detection device." This had seemed an overly ambitious project at the time, but I was willing to work a little harder, now, as a foot soldier in the resistance movement against blinkered orthodoxy.

The psionic device had been invented by a lone experimenter named Thomas G. Hieronymus who claimed that it could detect "eloptic radiation," emitted by every object in the universe. (He received U.S. patent number 2,482,773, and although he is no longer alive, his legacy lives online at sites such as rexresearch.com/hieronym/1hieron.htm.)

The Hieronymus Machine featured a tuning dial coupled to a prism that would refract the eloptic radiation, feeding it through an amplifier to an output coil. To use the device, you placed your hand on a "sensor plate" above the coil and rotated the tuning dial. When the machine resonated with matter in front of the prism, the sensor plate would feel sticky to the touch (although some people described it as hot, or cold, or oily).

Campbell built his own version of the machine and announced, with utter certainty, that it worked. Six months later he came up with a creative modification. If he was correct that psychic phenomena were inherent in the brain and merely needed an output device to express themselves, the choice of raw materials in a Hieronymus Machine was no more important than the type of metal you used to make a divining rod.

Why not reduce the electronic components to a symbolic level? If you merely printed them on paper, they should still work (if they worked at all), in the same way that other psychic phenomena worked symbolically. For instance, some people claimed you could kill pests in a field by dripping a chemical on a photograph of the field, while others believed you could induce pain in a person by sticking a pin in a doll. Supposedly the symbol enabled expression of a latent mental power.

Campbell duly published a circuit diagram, advised his readers to add a symbolic prism and sensor plate, and told them to let him know what happened.

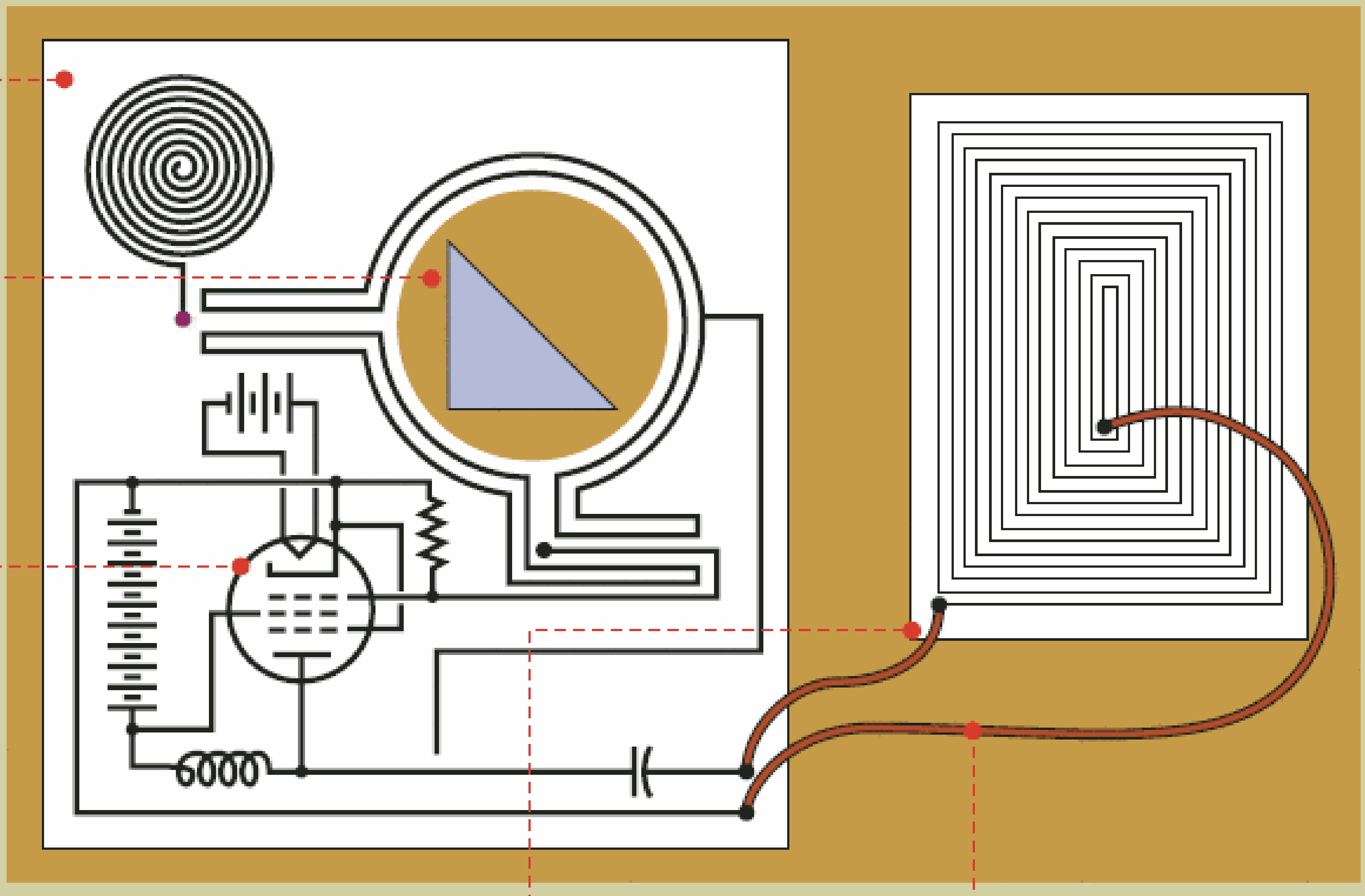
The more I thought about it, the more I wanted a Hieronymus Machine. I craved it with the same intensity that I craved Lucilla Stanley, a golden-haired, freckle-faced goddess who sat opposite me

SYMBOLIC HIERONYMUS MACHINE

Draw the circuit on a piece of card.

Cut out a circular hole in which a triangle of clear plastic can rotate on the end of a shaft attached to a dial.

Symbolic vacuum tube amplifies the psionic signal, powered by a high-tension symbolic battery. A transistorized version might have a shorter warm-up time.

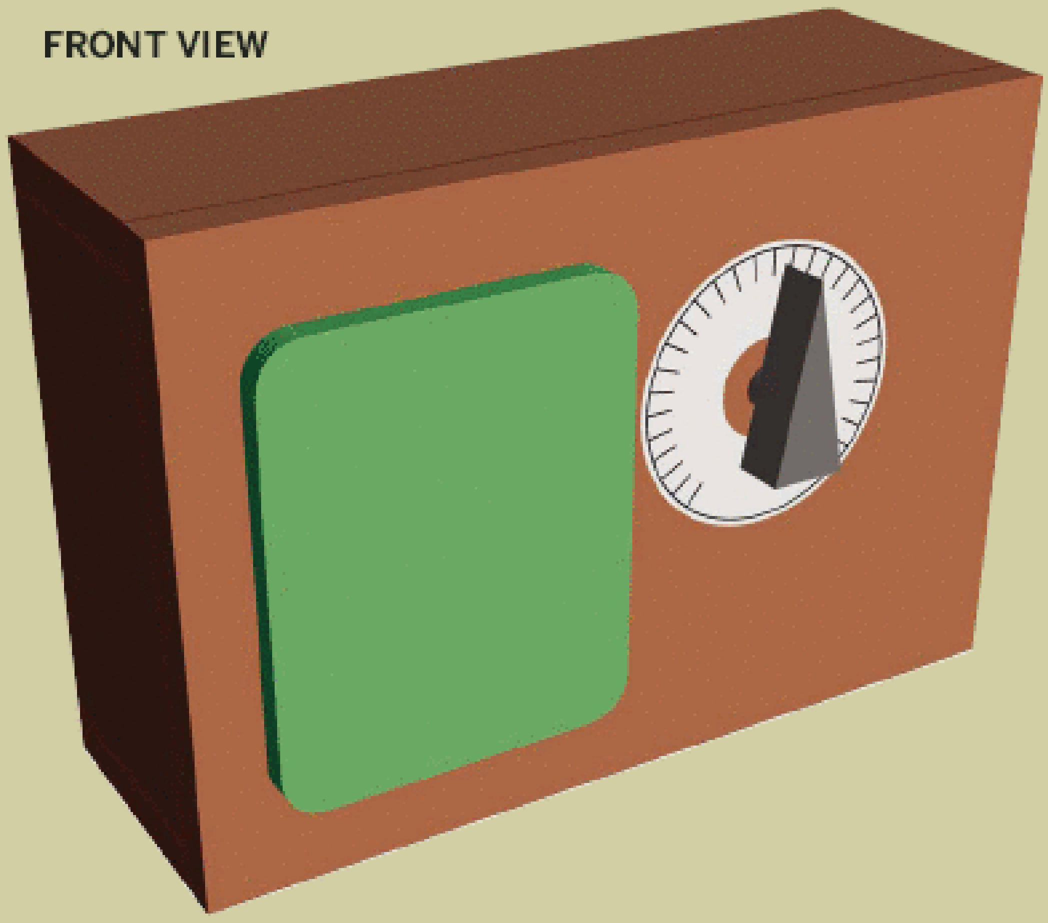


From a concept by John W. Campbell, Jr.

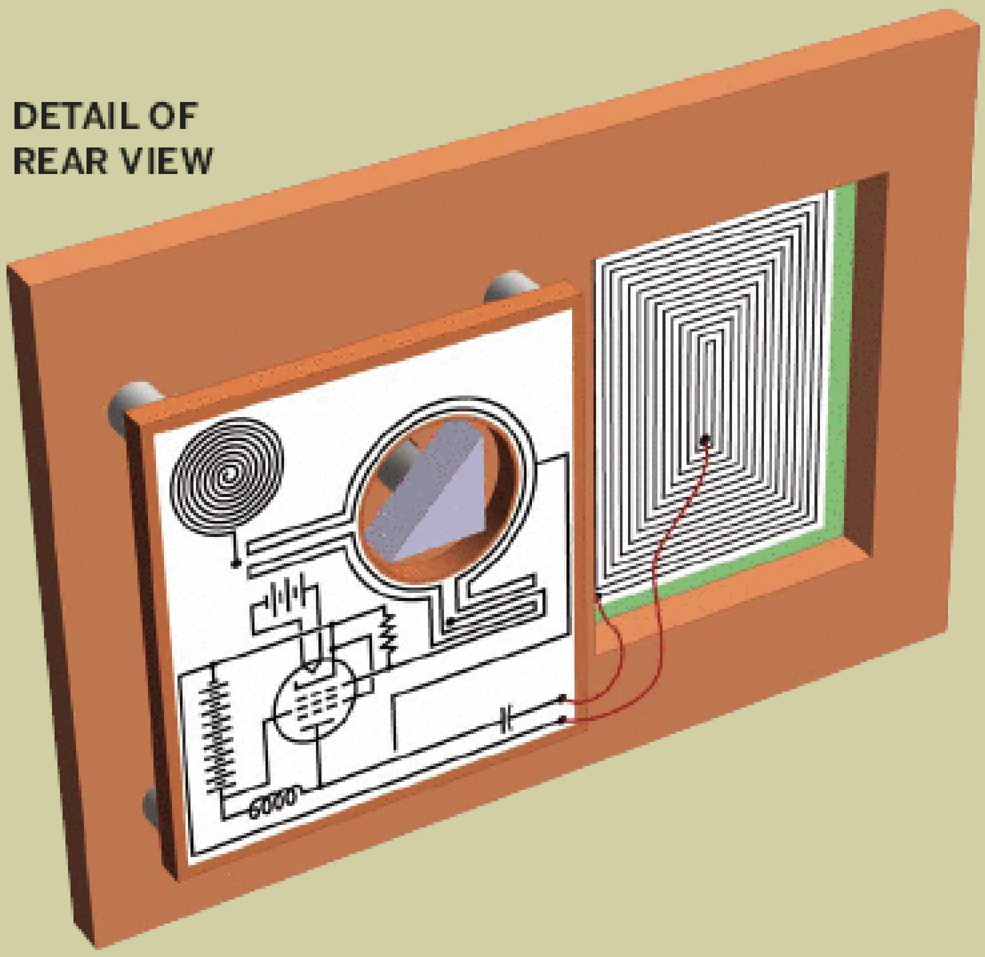
Draw the symbolic output coil on another piece of card, which you will glue under the sensor plate.

Attach the amplifier circuit to the coil with some pieces of thread glued at both ends.

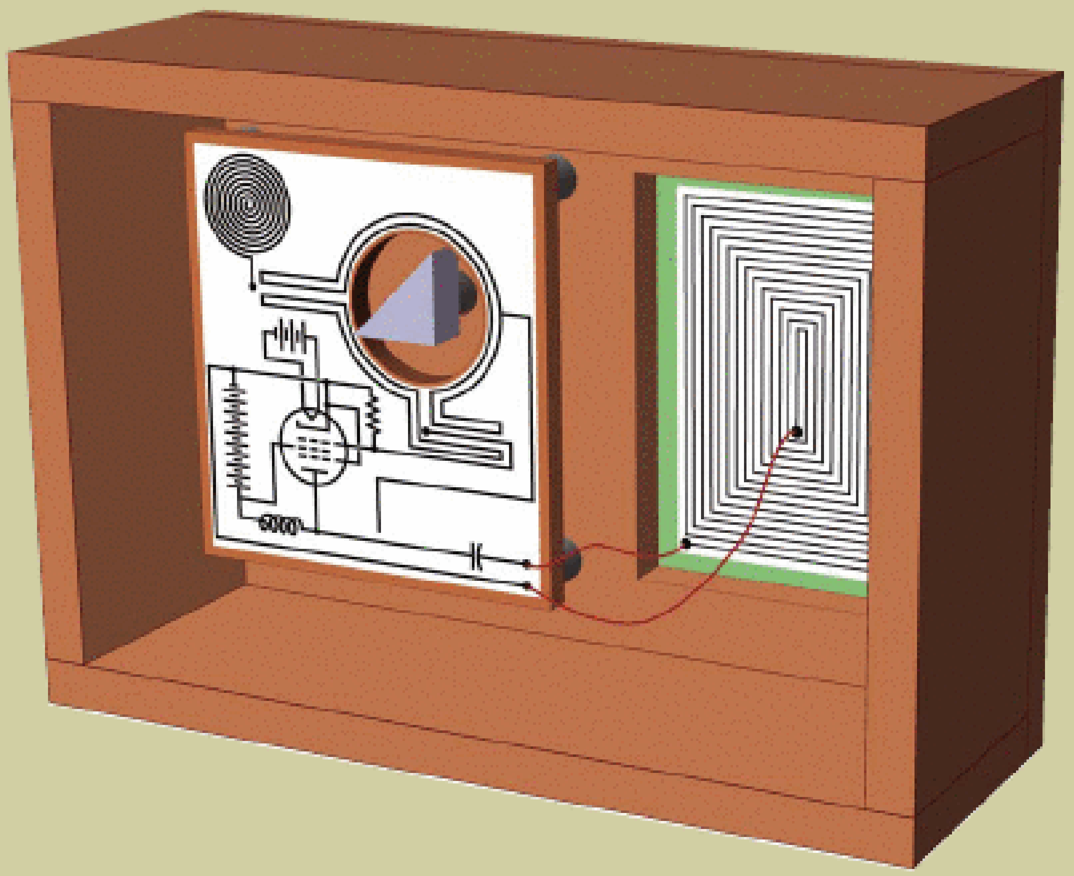
FRONT VIEW



DETAIL OF REAR VIEW



REAR VIEW



Illustrations by Charles Platt

These renderings suggest a simple construction project using plywood, a control knob on a shaft, and a plastic prism on the other end of the shaft, rotating in a hole cut out of a circuit board. No need for tiresome electrical wiring; just paste a printed copy of the circuit onto the board, and a printed coil under a “sensor plate” such as the lid of a lunch box. Connect the coil to the circuit by gluing the ends of sewing thread or string, and you’re ready to search for eloptic radiation on the psionic waveband.

in my French class in school, inducing adoration that made me powerless to speak. Realistically, I had to admit that the Hieronymus Machine would be more easily attainable than Lucilla, so I banished her from my mind while I made a laborious hand-drawn copy of Campbell's schematic circuit diagram (this was before the invention of Xerox machines). I used a triangle of Lucite as the prism, attached it to a wheel and a rod from my Erector Set, and contrived a sensor plate from the lid of my lunch box. Now I was properly equipped to boldly go into the unknown territory of psi!

During the next week I reduced my popularity among kids at my school to a new low as I pestered them to put their hands on the sensor plate while I twiddled the tuning dial — keeping its position hidden from them, naturally. Did the plate feel sticky? Or hot, maybe? Or different in any way at all?

I received a lot of positive responses. Definitely, the characteristics of the plate seemed to change.

The only problem was that these alleged changes did not coincide with any position of the dial. Positive results were scattered randomly across the entire 270 degrees of rotation. I was forced to face the fact that the only power I had detected here was the power of autosuggestion.

There was one last candidate for my test. His name was Leonard Fisk. Leonard was a gawky kid with a bad haircut and exceptionally large ears. He was not especially good academically, and not popular in team sports either. He was a bit — odd. I hesitated to add him to my list of experimental subjects because I wasn't sure he would cooperate.

I was wrong about that. He turned out to be very enthusiastic, and to my amazement, he detected a change in the sensor plate when the tuning dial was in the same position every time, within a margin of plus or minus 10 degrees.

I wondered what the difference was between him and all the other people (including myself) who had tried unsuccessfully to get results from the Hieronymus Machine. Maybe it had something to do with his oversized ears. I imagined them functioning like psychic antennas. It seemed unlikely, yet who was to say how these things worked or didn't work?

I went home and wrote a letter to John W. Campbell, Jr. describing my results, although I decided not to mention my theory about Leonard's ears. A few weeks later I was thrilled to receive a reply from Campbell, telling me that he had forwarded my mail to someone named Smith, who was working to collate results from serious experimenters such as myself, scattered across the entire globe.

After another two weeks I received a letter from Smith. Unlike the fancy publisher's stationery that Campbell had used, this letter was a ragged, plain piece of paper on which text had been badly typed with numerous handwritten corrections. Smith wanted me to conduct a whole series of new experiments. The trials should be double-blind and independently witnessed. I had to record the age, gender, body weight, and other details of my experimental subjects. They must all perform the tests in the same place, ideally at the same time of day, and in the same room temperature.

I didn't like the sound of this at all. I had been able to persuade the kids at school to stop for a couple of minutes on their way to lunch, but getting them to sit still in a "controlled environment" was never going to work, especially since my school's heating system was notoriously unreliable.

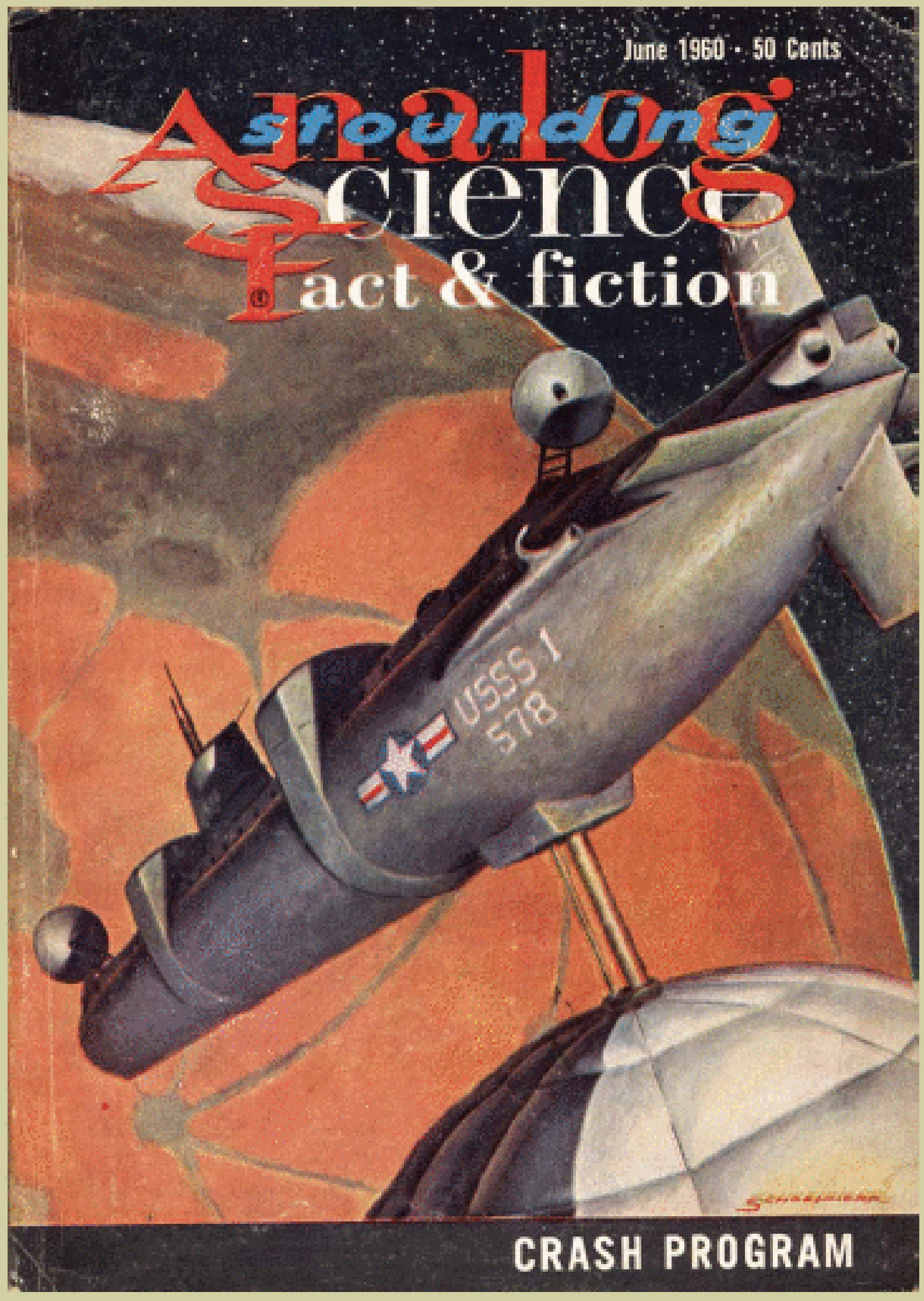
THE PROCESSES OF SCIENCE

Campbell had excited me with the idea that a few gifted amateurs in basement workshops could validate ideas that conventional scientists had been too prejudiced to take seriously. He made it seem as if psychic research could be a slam-dunk, a quick fix. But now Smith wanted meticulous data collection under controlled conditions, requiring weeks of repetitive work. There was no excitement in this scenario. It sounded really boring — like real science.

I have to admit that I lost interest in the Hieronymus Machine. John W. Campbell, Jr. issued more wake-up calls in his magazine, more rants insisting that "We Must Study Psi!" but he no longer captivated my attention. In June 1960 he ran a big feature on the Dean Drive, a system of rotating weights that was supposed to lift itself by taking advantage of an undiscovered nonlinear correction to Newtonian laws of motion. Forget about NASA's costly boondoggle, trying to use dangerous liquid-fueled rockets to put men on the Moon by the end of the decade. We could bolt a Dean Drive to a submarine that would serve as an ad-hoc airtight space vehicle, and move men to Mars within a year — if the Dean Drive worked the way it should.

Somehow I didn't quite buy it. I had learned a painful lesson about the processes of science. In the real world, science is not quick, not simple, and seldom

By January 1959, Campbell was still insisting, in an editorial, that "We Must Study Psi!" (psychic phenomena). But his table thumping was attracting fewer takers. (Original cover by Kelly Freas.)



In June 1960, Campbell proposed bolting a Dean Drive to a submarine to create an instant airtight spaceship, ready to put men on Mars within a year (assuming the Dean Drive actually worked). By this time he was changing the name of the magazine from *Astounding Science Fiction* to *Analog Science Fact & Fiction*, in a bid for respectability that was never entirely successful. (Original cover by John Schoenherr.)

exciting. I was now 16, the same age at which Einstein had suddenly wondered if he would be able to see himself in a mirror if he and the mirror were traveling at the speed of light. From this moment of intense conceptual excitement came the theory of relativity; but the details, of course, consumed the rest of his life, and he never did come up with a unified field theory. As Thomas Edison supposedly said, genius is one percent inspiration and 99 percent perspiration.

I never went into science, or even pseudoscience. Instead I became a science writer, which enabled me to enjoy all the excitement of discoveries vicariously, without the hard work of making them. In retrospect, I think John W. Campbell, Jr. was not so different. He was another scientist-wannabe looking for a shortcut around the monotonous, challenging terrain of real-life research.

This does not mean that he was necessarily wrong about everything. Discoveries may come from unexpected sources. Divining rods still may work (for some people, at least), and even Thomas G. Hieronymus could have been onto something.

In fact, maybe his machine still merits a couple hours of construction time. Your friends may be sufficiently intrigued to tolerate a few sessions at the sensor plate before they wander off to do something more important, such as browse YouTube or check email. Depending on your attention span, you may even gather some usable data.

I only ask one favor. If you find someone, as I did, who yields positive, repeatable results — please be sure to note the size of his ears.

Charles Platt is a frequent contributor to MAKE, has been a senior writer for *Wired*, and has written science-fiction novels, including *The Silicon Man*.

The Music of Chance

How random is this? I'm sitting in an empty classroom at Princeton, a few feet away from Roger Nelson, the founder and director of the Global Consciousness Project. The setting seems plucked right out of *A Beautiful Mind*, with a thin band of blackboard framing the room, broken by windows overlooking an immaculate campus. There are chalkboard leavings from the previous occupants: elaborate differential equations from a math class, Arabic conjugations from some linguists. And in the nearby engineering quad sits a server, quietly humming away, polling dozens of computer randomizers around the world for Nelson's grand experiment. Based on that data, he's written several carefully worded scientific papers that claim that human minds are somehow influencing the random numbers in subtle ways.

The project surprised me when I first heard about it. Nelson uses well-documented statistical methods to look at 10 million datapoints per day from 65 computers around the world between San Francisco and French Guiana. Nelson examines trends that he claims correspond to global events. Many of his best examples tend to be large catastrophic occurrences — embassy bombings, earthquakes, 9/11 — anything that "rends the social fabric and holds human attention." There's more: in a November 2006 paper published by the American Institute of Physics, he explores the idea that trends in random numbers begin hours *before* an event.

I wasn't sure I believed it, but Nelson impresses me as a straight-up guy in the first few minutes of our meeting. Herbal tea in hand, he walks around looking for a quiet place for us to talk, finally ducking into the empty classroom. He's in his mid-60s, with a neatly trimmed beard and striped broadcloth shirt, eminently professorial in appearance.

The Global Consciousness Project, or GCP, is unconnected with Princeton University, except that Nelson's friends in the engineering department allow him to keep a server, and Nelson himself worked as a researcher there for over 20 years, retiring in 2002. GCP is a bootstraps project with a tiny budget, mostly stemming from PayPal donations. Friends of the project designed one of the matchbox-sized gadgets that perform random-number generation. Nelson's adult son wrote the software to poll the devices, and 65 volunteers around the globe host the generators in their spare bedrooms, university labs, and home offices.

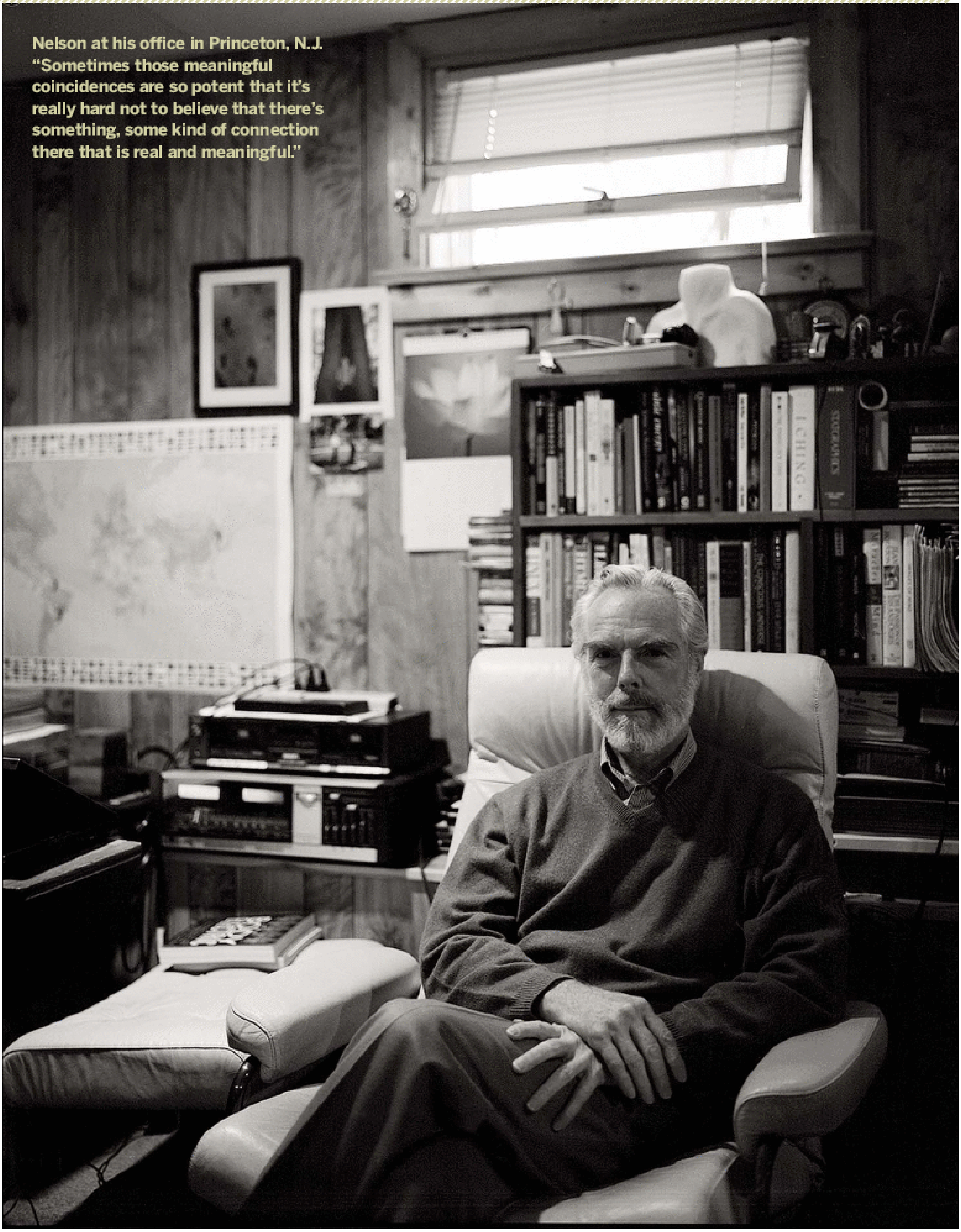
"They're like one-way modems, blasting out random bytes at 9600 baud," Nelson says, holding out one of the randomizing devices used in the project. He passes me the tiny gadget, and I involuntarily wonder if there's something fishy about the apparatus — the image comes to mind of a magician tapping the sides of a wooden cabinet before the lady climbs in. I know he wouldn't appreciate the comparison.

Nelson is diligent in his research. Over the last few years, he's been the focus of respectful, if cautious, articles in *The New York Times* and *Time*, the latter going so far as to point out that many of our greatest scientific breakthroughs were once ridiculed. The November paper came out of a symposium on "Retrocausation" — organized by the respected American Association for the Advancement of Science (AAAS) — exploring the theory that time flows symmetrically.

"The theoretical questions about the direction of time go back 150 years," says Daniel Sheehan, organizer of the AAAS symposium and a physics professor at the University of San Diego. "Nelson and other experimentalists are starting to put some experimental background to the idea that retro-causation may be a real phenomenon. The experimental evidence is not all in, but his results are tantalizing."

Photograph by Erika Larsen

Roger Nelson's Global Consciousness Project searches for meaning in random numbers. By Bob Parks



Nelson at his office in Princeton, N.J. "Sometimes those meaningful coincidences are so potent that it's really hard not to believe that there's something, some kind of connection there that is real and meaningful."

AT THE FOUNDATION OF GCP'S NETWORK are 65 random-number generators. Truly random numbers are important to hard science, and these common devices harvest the white noise from various physical sources, like the heat coming from a resistor, the time intervals between particles arising from radioactive material, or electrical fluctuations in analog components.

The device used by the GCP is called Orion ($550, randomnumbergenerator.nl) and uses two diodes to generate a chaotic signal. The Orion sends current the wrong way through a diode so that only a few miscellaneous electrons make it across the junction. A very weak, fluctuating current results. The circuit amplifies the signal so that a microcontroller can sample and compare it with a threshold value. Current above the line receives a "1" and current below, a "0." The circuit compares the bit streams against stored random data using an exclusive-or gate (XOR) to further eliminate mechanical drift. (The GCP network also uses a similar randomizing device with a field effect transistor as the entropy source.) Host computers on the GCP network sample 200 of these bits per second and add them together for sums of between 0 and 200. Since it's random data, the sums usually come in around 100, with a few outliers in the 80s and 120s.

A few minutes later, the data pours into the Princeton server. The ensuing analysis is a formal, deliberate process. Nelson emphasizes that he conducts research as a scientist, and follows widely accepted research methods. In general, to make a scientific claim, one must set up a formal hypothesis and a null hypothesis before looking at experimental data. Then, he'll fire up his Linux machine to feed the data through a statistical analysis package called XploRe.

As an example, let's pick a day in the life of the GCP network — a biggie, September 11, 2001. Nelson, who lives with his wife on a quiet Princeton street and conducts all research at home, was casually watching the network from the five computers he has running all the time. But there didn't seem to be anything going on in the world worth analyzing. Then an airplane hit.

"By the time the first building collapsed, I realized we had a global event maybe bigger than we'd ever looked at," he says. He started outlining a formal hypothesis with an expected result and the formal time period for the experiment — a window starting ten minutes before the first plane hit to four hours after. With those parameters fixed, he was then free to look at all the data surrounding the event for a more exploratory look. Nelson has since examined the 24-hour period starting at midnight of Sept. 10. Graphed against a pseudo-random line, the data shows a striking upward trend. The calculated probability of that trend is 1 in 100,000. What's more, the break from chance begins at 4 a.m., hours before impact.

As Nelson himself points out, the possibility of network precognition is clearly exploratory. "There's no way you can use that as evidence in the scientific sense," he says. Nelson frequently underscores that he wants to be critiqued principally on his formal hypotheses. But the results of the formal hypothesis are actually pretty boring. In more than 200 time parameters studied under hypotheses, only 21 show a significant deviation against a distribution of purely random events. For example, the formal September 11th events showed 2.8 percent odds of occurring against chance. Some larger odds come from other formal studies such as the May 2006 Indonesian earthquake (.2 percent); the September 2004 Chechen hostage standoff in Russia (1.2 percent); and the March 2000 Papal visit to Israel (.8 percent). Given the number of tests, however, it's possible that the GCP researchers are getting lucky by picking

HOW THE GCP WORKS

1. Random-number-generating devices (right) are placed in spots around the planet. They connect via serial cables to PCs in home offices, workplaces, and the basements of academic institutions.

2. The RNG gadget is the size of a matchbox. It works by sampling a fluctuating signal inside the device, generating a random stream of 1's and 0's. Each host computer grabs 200 samples per second, adds them together, and sends the sums off in batches every 10 minutes to a central computer in Princeton.

3. At the GCP headquarters, a Linux PC collects the data and analyzes it for deviation from normal statistical probability.

"Nelson and other experimentalists are starting to put some experimental background to the idea that retro-causation may be a real phenomenon. The experimental evidence is not all in, but his results are tantalizing."

small, anomalous windows in random data.

"Statisticians will say, 'Well, there are so many opportunities to find anomalies,'" says Nelson. "But sometimes those meaningful coincidences are so potent that it's really hard not to believe that there's something, some kind of connection there that is real and meaningful."

MANY UNIVERSITY ACADEMICS HAVE dismissed GCP on its face, but few have been willing to crunch the numbers themselves (the raw output is available on noosphere.princeton.edu). A common critique involves electromagnetic waves — doesn't the use of cellphones, television transmission trucks, and two-way radios increase during world tragedies? Wouldn't that addle the randomizing hardware? Nelson counters that the devices are carefully shielded. Besides, each device does generate random data during the experiments. It's the statistical trends among the 65 devices that are the subject of study.

There have only been two serious looks by scientists critical of the work. S. James P. Spottiswoode, chief statistician for entertainment-monitoring company Neilsen, reproduced the computer analyses of the formal 9/11 findings, and confirms Nelson's result. He notes, however, that any event with a 2.7 percent chance of happening shouldn't surprise anyone.

Nelson's other auditor, Jeffrey Scargle, a staff astronomer at the NASA Ames Research Center in California, contends that the math Nelson uses to plot graphs makes minor trends look more meaningful than they are. Scargle also questions the XOR operations inside the random-number generators. "They're scrambling the bit stream in order to get rid of drifts in the instrument, but by doing that they're getting rid of any signal that would possibly have a direct effect on the random-number generator," he told me. Nelson himself clearly seems interested in mind-quanta interaction. Why not let the bits fall as they may?

Nelson responds by saying that the XOR doesn't entirely remove the influence of the original quantum events; it merely smoothes out the data. "He thinks I'm throwing the baby out with the bathwater," he says. "But from laboratory tests, we know we still have some baby."

Nelson's critics also dismiss the work as carefully selecting data to guarantee a positive result. The exploratory tests boast larger departures from chance, but these sessions are often conducted by laying out all the statistical deviations on a timeline and zeroing in on the surprising ones. Nelson deflects this by saying the exploratory claims are clearly labeled as such. "It's unacceptable that they criticize the GCP's hypothesis testing on the basis of postfacto analyses," he says calmly. "These are independent projects. It would be stupid not to see what the data looks like."

While we talk, I try to drill down on the exact mechanism of the phenomenon. "During these global events, do you think the devices are not performing in a scientific manner?" I ask.

"That's a pretty logical kind of thought," he says affably. "It sounds as if you're saying human consciousness is changing the way these devices operate. But probably not." Nelson suggests the possibility that the numbers aren't changed at all while they are being generated, but don't become fixed on computer hard drives until they are analyzed. Then he stops talking and sort of shifts in his chair. "This is a lot of hand waving, for sure," he says.

Clearly, there are plenty of other people curious about global consciousness, too. Traffic to the GCP website nearly doubled to 60,000 last May during a busy month that included the Indonesian earthquake and Earth Day. And on Dec. 22, 2006, the pro-sexual liberation group Baring Witness held a "Synchronized Global Orgasm" and used the network data to explore the impact of mass nookie on GCP's spreadsheets. The GCP reported a "positive outcome, but it is a mild trend" from the experiment. "The picture has a feeling of promise, but it is not possible to know whether the trend is evidence of a signal or not."

People are encouraged to try harder next year.

Bob Parks is the the author of *Makers: All Kinds of People Making Amazing Things In Their Backyard, Basement or Garage*, published by O'Reilly Media.

FRINGE

Digital Kirlian Photography

Shoot "auras" without film. By John Iovine

Kirlian photography records a high-voltage corona discharge around objects. Some people call this discharge an "aura" and attribute metaphysical and paranormal factors to its varying parameters. Originally, Kirlian photography was a contact print process that used film. This article illustrates another method of shooting Kirlian photographs, using a digital camera.

The technique can be traced back to the late 1700s, when Georg Christoph Lichtenberg first created "electro-photographs" in dust using static electricity and sparks. Nikola Tesla photographed corona discharges using his famous Tesla coil in the 1880s and in the early 1900s. Others followed, and in 1939, the Russian husband-wife research team, Semyon and Valentina Kirlian, began their 30-year investigation into electro-photography techniques.

In 1970, the landmark fringe book, *Psychic Discoveries Behind the Iron Curtain* by Sheila Ostrander and Lynn Schroeder, popularized the Kirlians' work in the English-speaking world, and electro-photography has been known as Kirlian photography ever since.

Many claims have been made regarding Kirlian images, but most phenomena have conventional explanations. For example, changes in the "aura" of an honest individual who is lying result from the same stress-related increase in galvanic skin resistance that a polygraph lie detector measures. Changes in skin resistance can also be caused by illness, fatigue, drug or alcohol consumption, and other factors, which make these conditions observable using Kirlian photography with no paranormal "bio-plasma" explanation required. The Kirlians themselves believed that their photography could diagnose illnesses before noticeable symptoms manifested, an idea that generated interest, but was never verified by scientific investigation.

One famous Kirlian phenomenon, the "phantom leaf," cannot be explained by known physical laws — but it may be a fake. The experiment is easy to perform: you take a Kirlian photograph of a leaf after cutting off a small portion. Phantom leaf photos from Soviet-era proponents showed the removed portion of the leaf appearing as a ghostly apparition, suggesting an ethereal "bio-plasma body" persisting where the physical leaf no longer existed. Many researchers and experimenters have been unable to replicate this effect (myself included) although it is easy to fake with a simple double exposure: take a short exposure of the entire leaf, then cut off a piece and continue the exposure.

Although I have never observed any paranormal phenomena with Kirlian photography, I like Kirlian photographs, which are unique and often beautiful. I also like exploring, so I've continued to look for the phantom leaf effect over the years, taking sporadic excursions back into Kirlian photography when I think of new twists to incorporate. If the phantom leaf effect exists and someone finds an exact combination of voltage, frequency, pressure, ambient humidity, exposure time, and other experimental parameters that can reproduce it consistently, it will be the starting point of a new paradigm.

FILM AND DIGITAL TECHNIQUES

The process for traditional, film-based Kirlian photography is simple. In complete darkness, place sheet film on top of a metal plate, and then an object to photograph on top of the film. If the object is inanimate, ground it. Then apply high voltage to the plate momentarily. The corona discharge between the object and high voltage plate is recorded onto the film as a contact print. Develop, and you have a Kirlian photograph of the object.

To shoot Kirlian photographs with a digital camera requires a slightly different technique that uses a transparent discharge plate instead of a metal plate. This discharge plate has a coating of tin oxide on one side that is so thin it is visually transparent, but still electrically conductive.

Place the object on one side of the plate and the camera on the other. As with the film process, connect the object to an earth ground if it's inanimate.

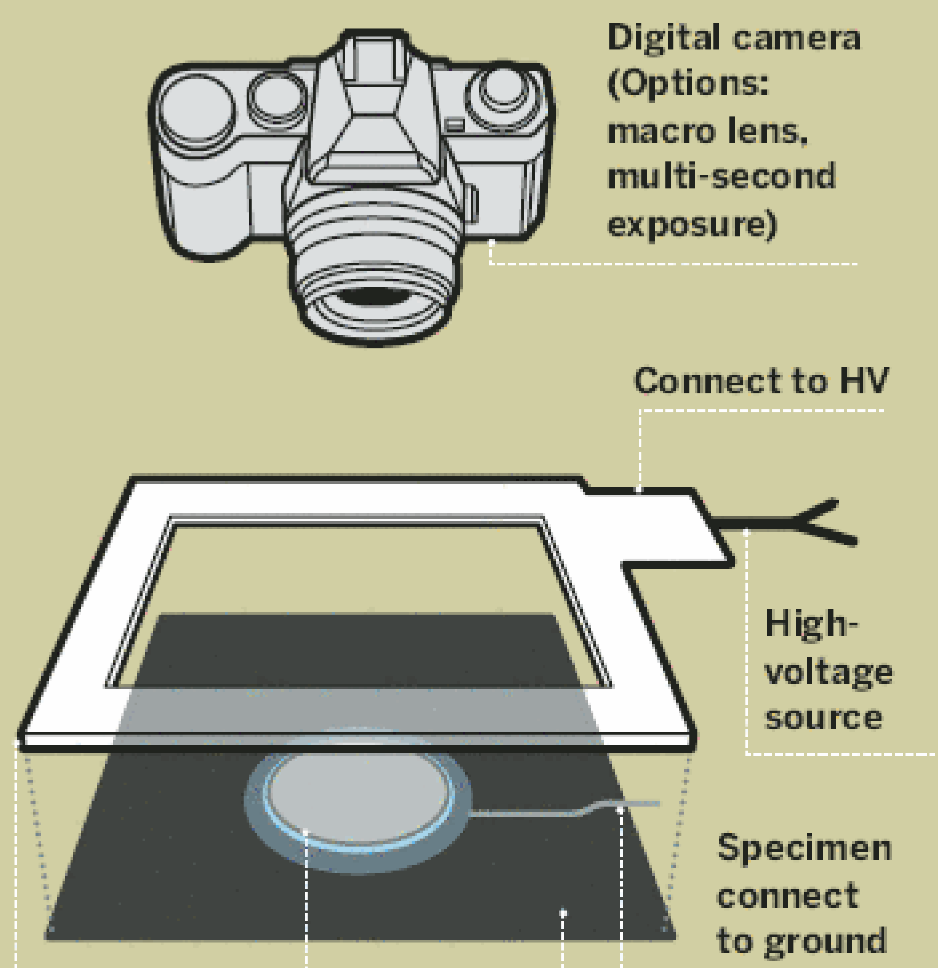
Photography by John Iovine

With all the room lights turned off, open the camera's shutter and apply high-voltage power to the transparent discharge plate. The camera captures the corona discharge between the object and the transparent plate.

With film Kirlians, the electrical discharge has to travel through the film's 3 primary color dye layers and activate the silver crystals in each layer at different depths; whereas with digital, it all happens at one level on the plate. This makes Kirlian photographs with film more colorful around the edges, but less accurate than digital Kirlians.

DANGER: HIGH VOLTAGE!
Do not attempt this project without expert assistance unless you are an adult experienced in working with extremely high-voltage power sources. This project is intended only for very experienced adults. Severe injury, death, or property damage may result from failure to use adequate safety gear and precautions.

KIRLIAN PHOTOGRAPHY WITH A DIGITAL CAMERA



MATERIALS

Digital camera with manual focus and a shutter capable of multi-second exposure times. It also helps to have a macro lens setting for close-ups.

High-voltage power supply You can use a Tesla coil, induction coil circuit, high-voltage flyback transformer circuit, or any other source that puts out 5,000+ volts, between 1-5 milliamps, at any frequency (or DC). Variable frequency lets you experiment. The PG13 supply I sell is great for this; see makezine.com/go/highvoltage.

Transparent discharge plate You can buy one of these, or make one out of conductive glass (tin oxide coated), clear plastic, thin copper plate, silver epoxy, and some HV wire. For sources and instructions, see makezine.com/09/kirlian.

Stand or tripod or another way of holding the camera still

Black paper or foamcore

High-voltage wire, Teflon-coated or other, sufficient for your HV power supply

READY, STEADY, SHOOT

Long exposures are required to capture the corona discharge, so you will need to keep your camera still and the object steady. I use a camera copy stand that holds my camera pointing downward, and I set up the object and plate horizontally underneath it. Once you have a steady arrangement, here's the procedure.

1. A black background works best, so put down a piece of black paper or foamcore (must be nonconductive) on your work surface. If you're shooting an inanimate object such as a leaf or coin, you need to

Illustrations by Damien Scogin

ground it. To do this, cut a small hole in the center of the black background, and attach a length of HV wire to an earth ground (a pipe will work). Then strip the other end of the wire, run it through the hole in the background, and place the object on top, making sure it has contact with the wire. You can also use a small grounded copper plate under the background instead of a wire, so long as the object you are shooting makes contact with the plate through the hole.

2. Attach the high voltage lead from the HV power source to the discharge plate's electrode, and place the plate on top of the object.

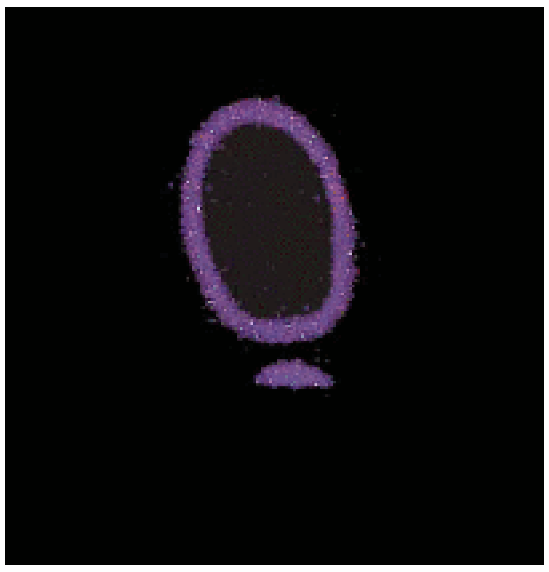
3. Position your camera to frame the object, and focus it manually. If you can set the camera's f-stop, open the aperture (reduce the f-stop) as much as possible. You will usually shoot a flat object, which doesn't require much depth of field. Set the shutter speed to 15 seconds or more.

4. Turn off all room lights. Turn on the high-voltage, and adjust its frequency to provide the brightest discharge. Hit the camera's shutter, and keep the power going for the full duration of the exposure.

5. Evaluate your picture, adjust, and reshoot. Raise the f-stop and reduce the exposure time if the image is washed out; do the reverse if it's too dim.

SHOOTING PEOPLE

Sooner or later you are going to want to shoot people. The best place to start is with a person's fingertip. To avoid electric shock, make sure that the subject doesn't touch ground. They also need to hold still, of course, and they shouldn't put too much skin surface in contact with the discharge plate. Touching an entire hand to the discharge plate can dissipate the corona discharge so much that it won't photograph, even with a long exposure.



WARNING: When shooting people, make sure the subject doesn't touch ground.

DIGITAL MANIPULATION

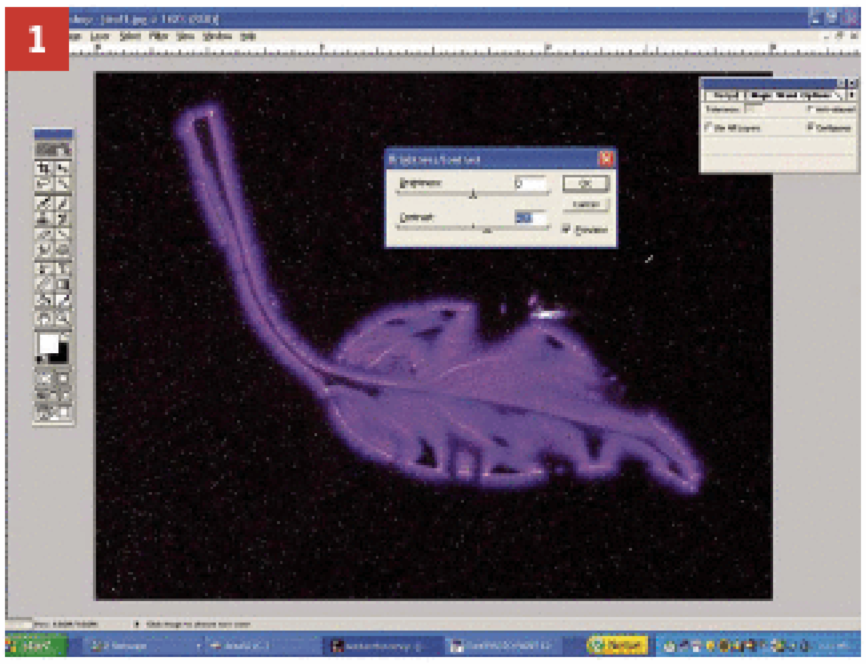
My digital camera has a maximum exposure time of 16 seconds, during which the image accumulates some digital noise — mostly gray, red, and yellow pixels of various shades sprinkled throughout the resulting photograph. I remove this in Adobe Photoshop as follows:

1. Starting with the base image of the leaf, select Image » Adjust » Brightness/Contrast, and increase the contrast.

2. Zoom picture to 500% so you can clearly see the background pixel noise. Using the Magic Wand (set to 30 tolerance), click on a noise pixel. Then go to Select » Similar. Now all the pixels with that color in the photograph will be selected.

3. Set the foreground color to black and hit the Delete key to turn all the selected noise pixels black. Repeat this process by selecting and deleting various other noise pixels, but don't select any noise pixel that has a similar shade to the main image you are trying to enhance.

Kirlian photographs are mostly blue-violet with a little white. This is because the corona discharge in nitrogen (air is 78% nitrogen) generates light in



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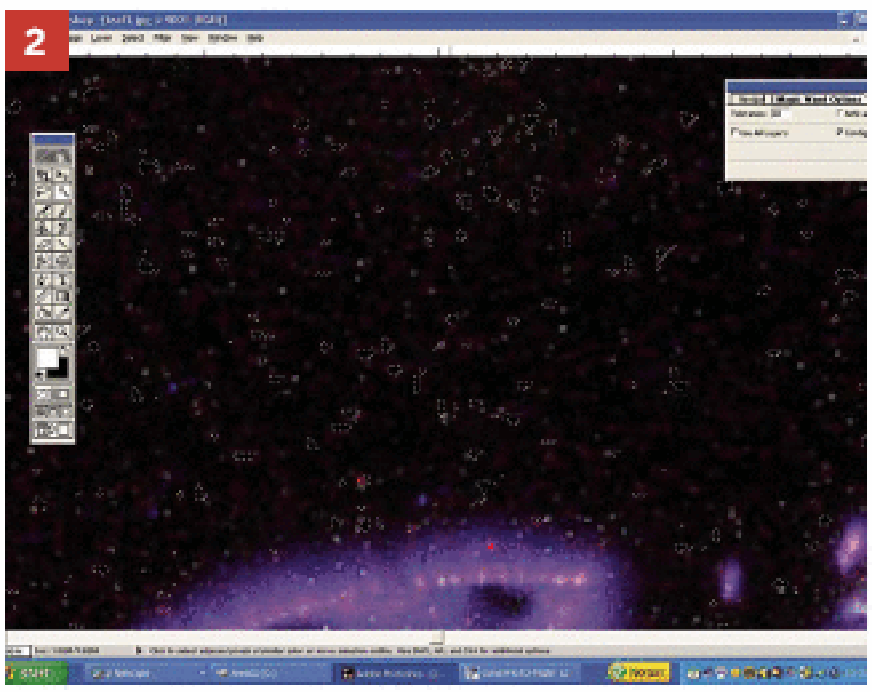

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the blue-to-ultraviolet range. You can use Image » Adjust » Color Balance in Photoshop to change your image's color for some beautiful effects.

GOING FURTHER

Using digital cameras to capture Kirlian photographs is relatively new. Because it's a low-light process, we can borrow techniques from the astronomers who use digital cameras, as well as astronomy software such as AstroStack (astrostack.com), which stacks multiple images of the same object to create a brighter, more detailed image.

Shooting Kirlian photographs in atmospheres with other mixes of inert gases, such as helium, neon, and carbon dioxide, will create corona discharges in different colors. Just make sure the gases are inert.

To learn more about Kirlian photography using film, refer to my book, *Kirlian Photography: A Hands-On Guide* (Images Publishing, 2000).

John Iovine is a science and electronics tinkerer who has published a few books and articles and owns and operates Images SI Inc. (imagesco.com). He lives in Staten Island, N.Y.

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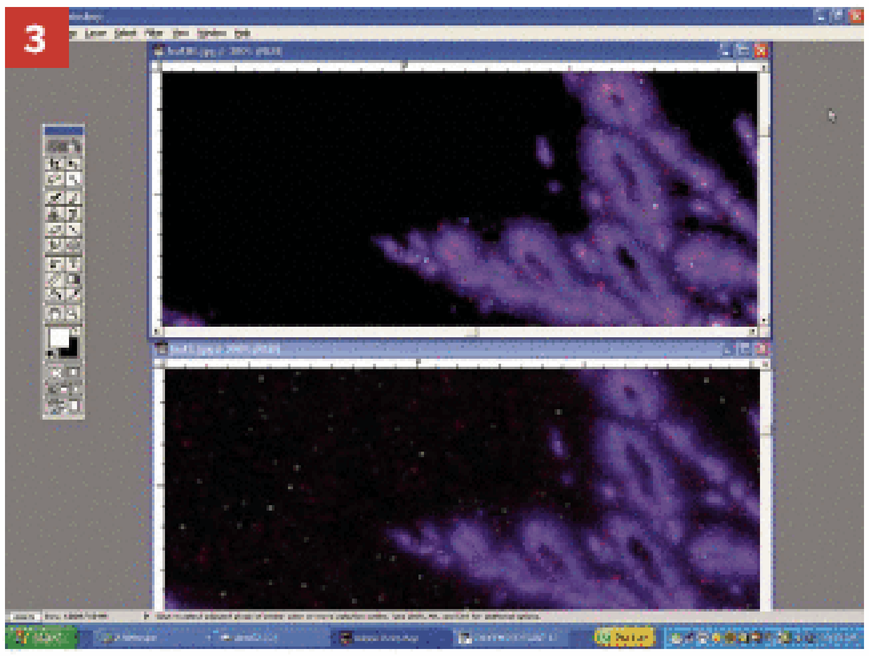
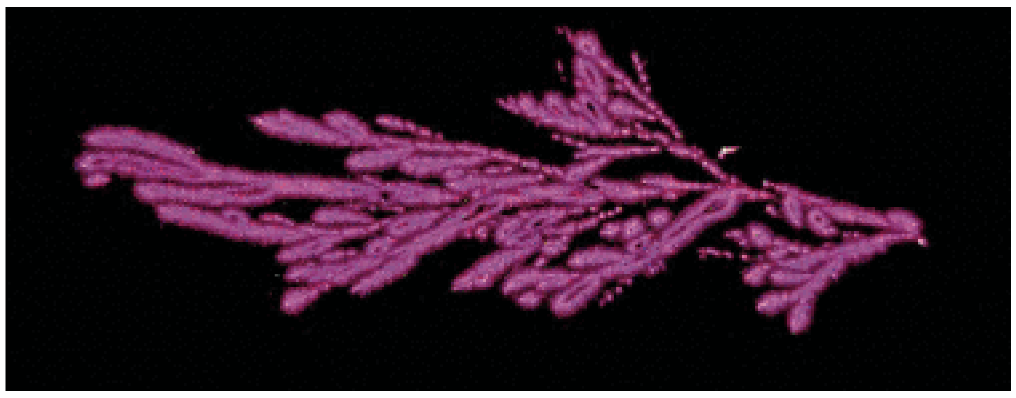


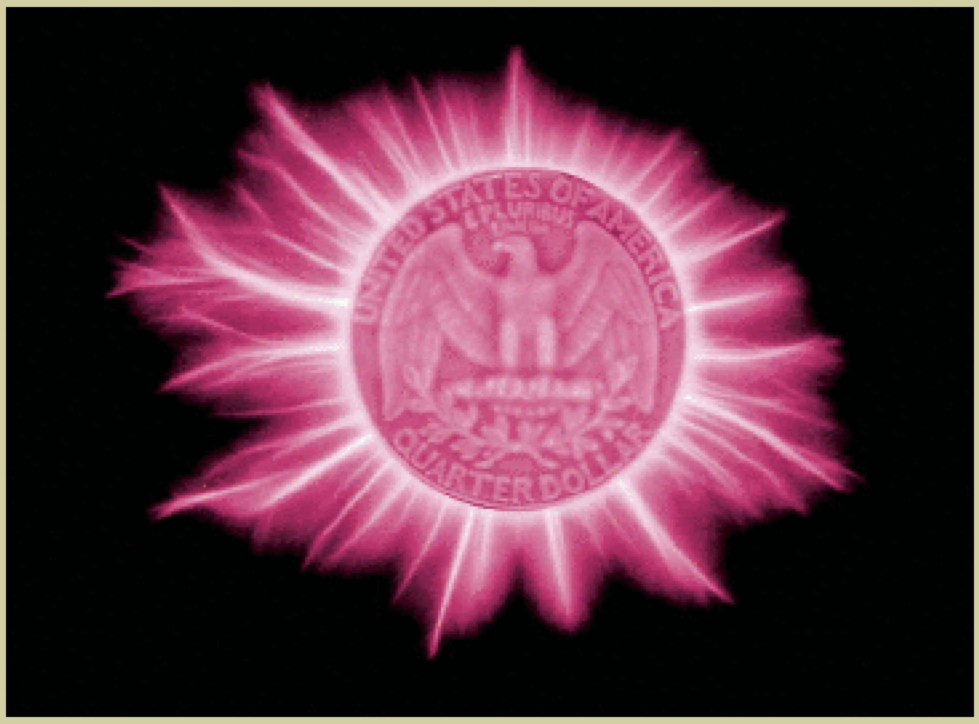


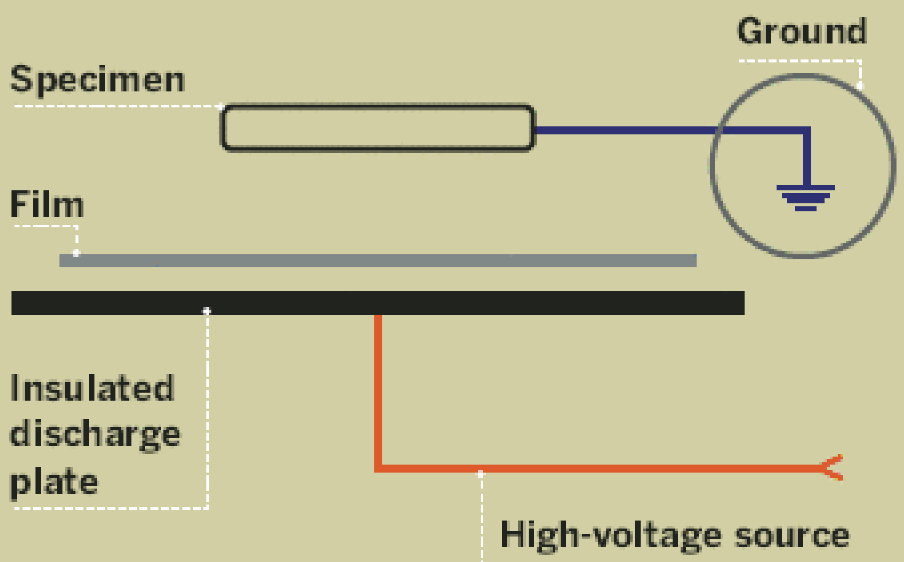
Film-Based Kirlians

The light you see during a Kirlian discharge comes from an electric field ionizing the air and parts of your Kirlian subject. The charged air gives off intense heat and ultraviolet radiation as well as visible light. Photographic emulsions interact with all of these, plus the electrostatic field itself, while digital sensors mainly just capture visible light. As a result, traditional film-based Kirlian images require shorter exposure times than digital methods, and can show the lightning-fast discharge arcs in greater detail.

For example, my Kirlian photograph of the quarter on this issue's cover took only a ¼-second exposure. With faster photo papers and films it might take even less. In addition to improving detail, such short exposures also decrease the chances of vaporizing or burning your subject. And when photographing a human being, short exposure times are less painful!

Open-film Kirlian requires a fully darkened room, tens of thousands of volts, and expensive sheet film. All of this can be daunting and, well, dangerous — or at least expensive. But you can start out and get wonderful results using black and white photo paper instead of film, and working under a darkroom safelight or red LED flashlight to help you steer clear of the power supply. Later, you can graduate to a color image, and the digital method is also worth a try! *—Jasper Nance*





Photograph by Jasper Nance

FRINGE

Reinventing the Square Wheel

Why build an unworkable device? Every basement tinkerer has probably built at least one device that didn't work as expected. One can learn a lot from such failures, because they teach us the pitfalls of design, the limitations of materials, and the restrictions imposed by nature's laws. It's easy to superficially examine a drawing or blueprint of a device, and glibly say, "That will never work." It's quite another thing to reason out exactly why it doesn't work, and one can gain even deeper insight from hands-on manipulation of the recalcitrant mechanism.

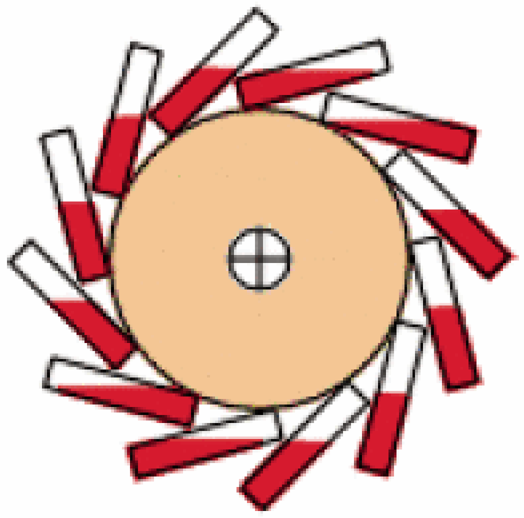
PERPETUAL FUTILITY

When people say, "It'll never work," they may sometimes be right. Most new ideas turn out to be wrong and are swept under the rug of history. But even wrong ideas can be useful because they give us valuable information about what doesn't work, and narrow the field of things we might try that could work. Unfortunately, some people never give up on a discredited idea. Such is the case with the perennial search for perpetual motion. Even today some "perpetual motionists" firmly believe it is possible, devoting considerable time and money to their attempts to achieve it.

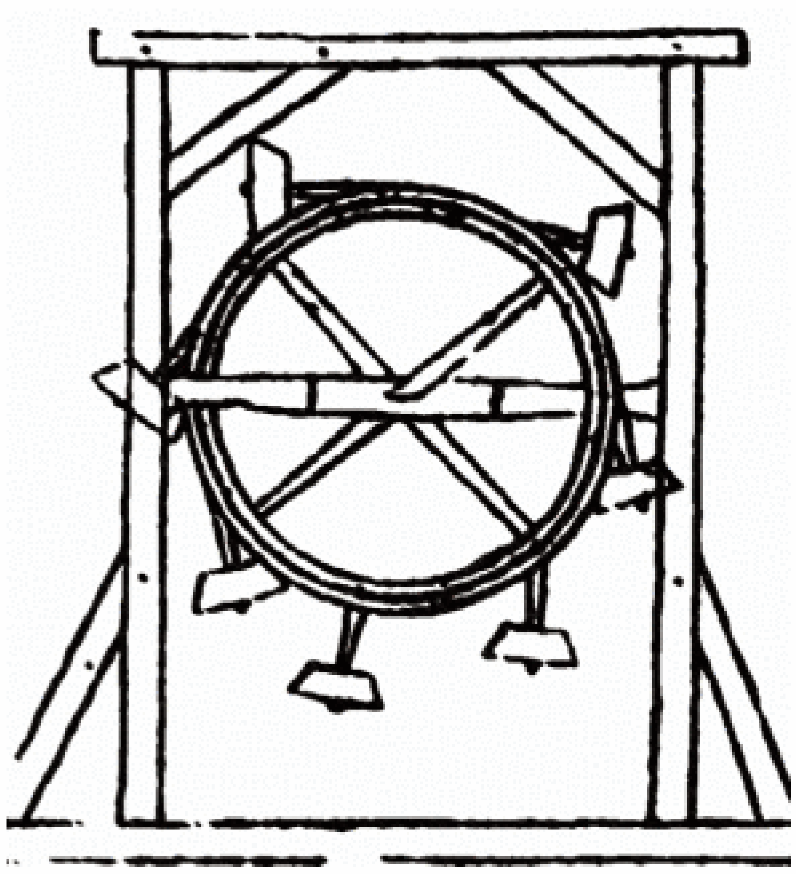
Early Attempts at Perpetual Motion

A perpetual-motion device is easier to define than to make. It is a wheel that continues its motion — undiminished — forever, without input or output of energy. Even better would be a machine that continues its motion indefinitely while continually putting out additional useful power (output power greater than input power). Hopeful inventors call this an over-unity machine, because it would have a power efficiency greater than 1. If some of its output were used to power the input, it would require no fuel, but would simply continue doing useful work. Needless to say, no such machines have ever been successful, or we would not have an energy crisis.

Perpetually turning wheels were described in Sanskrit treatises in the fifth century, and later by



One of Bhaskara's wheels



Villard de Honnecourt's wheel

Top illustration by Hans-Peter Gramatke

The production of useful work is strictly limited by the laws of nature. The production of useless work seems to be unlimited. By Donald E. Simanek

the Indian mathematician Bhaskara (c. 1159). One such wheel had cylinders around its rim partly filled with mercury. As the wheel turned, the motion of mercury was supposed to keep the wheel heavier on one side of the axle, causing it to rotate perpetually. (If you build this model, use colored water. Mercury is an environmental hazard.)

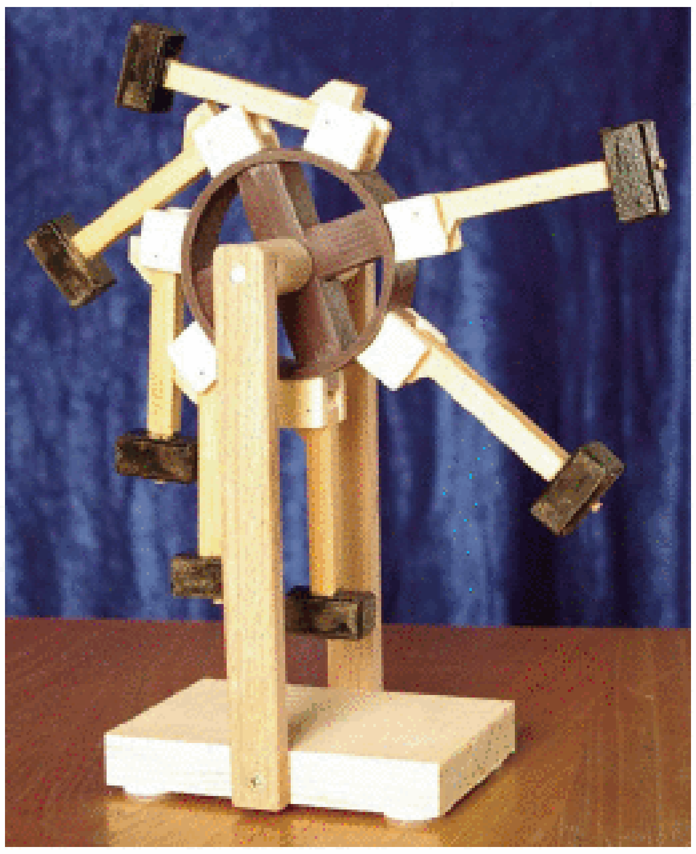
This idea reappears in Arabic manuscripts, one of which contained six perpetual motion devices. These designs later reached Europe. A wheel described by French architect Villard de Honnecourt in 1245 is identical to a design from Arabia — an overbalanced wheel with hinged hammers or mallets equally spaced around its rim. De Honnecourt insisted on an odd number of hammers. He claimed his device would be useful for sawing wood and raising weights.

Villard de Honnecourt's Wheel

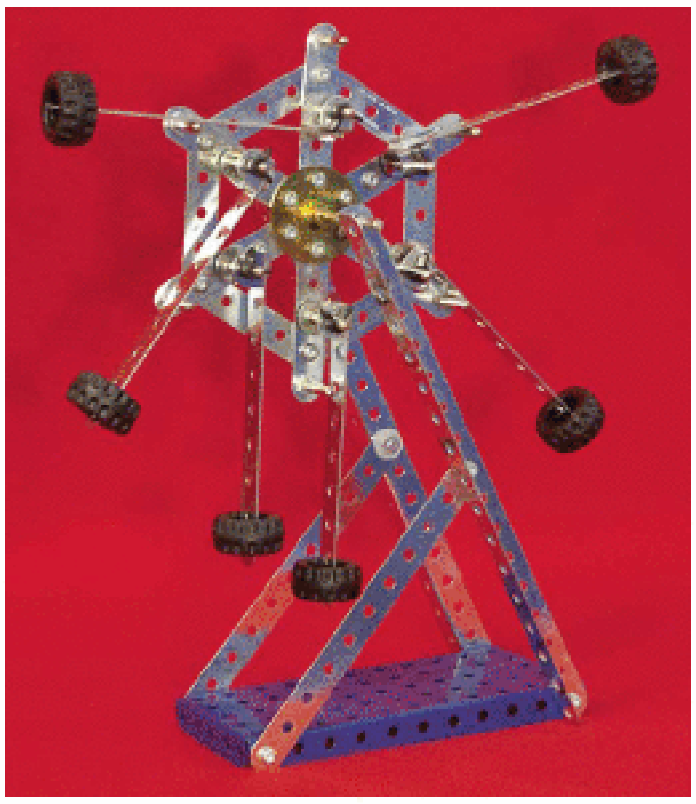
One reason these overbalanced wheels seem plausible to some people is because a static picture is used to represent a dynamic situation. People suppose that the falling hammer gives the wheel an extra impetus. But when the wheel moves clockwise (perhaps initiated by a push), the weight falling from A to B pushes the wheel backward (counterclockwise) during its fall, which probably isn't what the inventor wanted. Casual inspection of the diagram wouldn't lead you to expect this, but it's easy to observe once you build one and try it.

Of course some of the forward motion of the wheel is recovered when the weighted arm hits the peg at position B, but there's a net loss because all materials are somewhat elastic, converting kinetic energy to thermal energy when compressed. The hammers' fall doesn't generate additional energy but causes loss of energy. A simple flywheel without the hammers would work better.

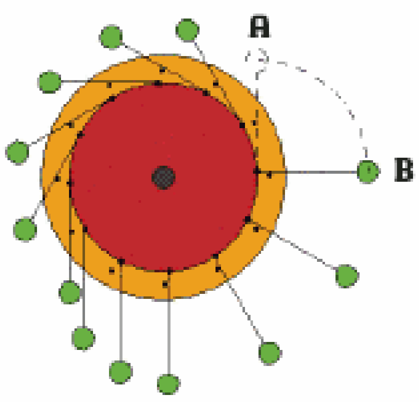
All perpetual-motion machine designs, when carefully examined, can be proven unworkable for at least two reasons: (1) theoretical — they are based on incorrect assumptions about physics, or



Wooden model of Villard's wheel



Model of Villard's wheel



The action of the flipping weight

Photography by Donald Simanek; illustration by Hans-Peter Gramatke they apply physics incorrectly; and (2) experimental — if you build and test them, they don't work.

Simon Stevin's Ball-Ramp and Woodward's Wheel

Flemish mathematician and engineer Simon Stevin (or Stevinus, 1548-1629) analyzed a device consisting of a chain of balls on a frictionless double ramp. The chain was supposed to slide counterclockwise since there was more weight of chain to the left of the vertex. But Stevin's analysis showed that the system had no inclination to move at all, because it was always in static balance. These results led Stevin to formulate a fundamental principle of mechanics, known as Stevin's Principle of Virtual Work, which is found in textbooks even today.

Something about the notion of perpetual motion tantalizes those with restless minds, who think, "Perhaps there's some principle of physics, as yet unknown, that we might discover if we just alter the design a bit." So, through the centuries, these people tinkered with the designs, in a fantastic variety of ways, until the proposed machines became hopelessly complex. Such is the perversity of nature that none of them worked.

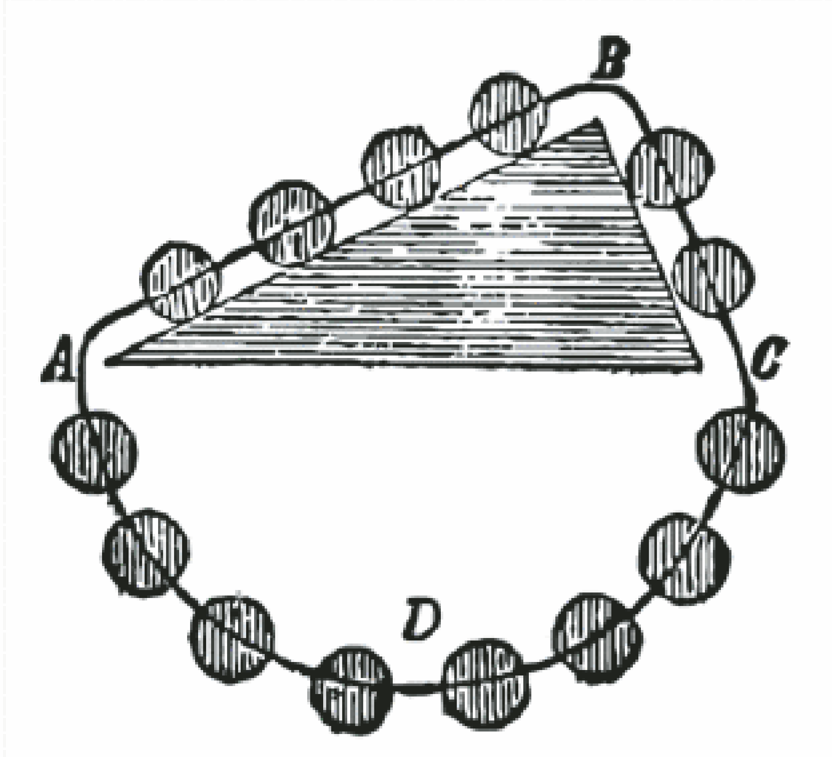
Some inventors were so confident of success that they included a brake in their designs to prevent the machine from turning so rapidly that it would tear itself apart. They needn't have worried.

Some drawings included an arrow showing which direction the inventor supposed that the wheel would turn. This is especially helpful; without it, we physicists wouldn't have the slightest idea which way the wheel should turn. If laws of physics allow the wheel to turn equally well in either direction, you can be quite sure the wheel won't initiate motion by itself and won't sustain motion forever when you give it a push.

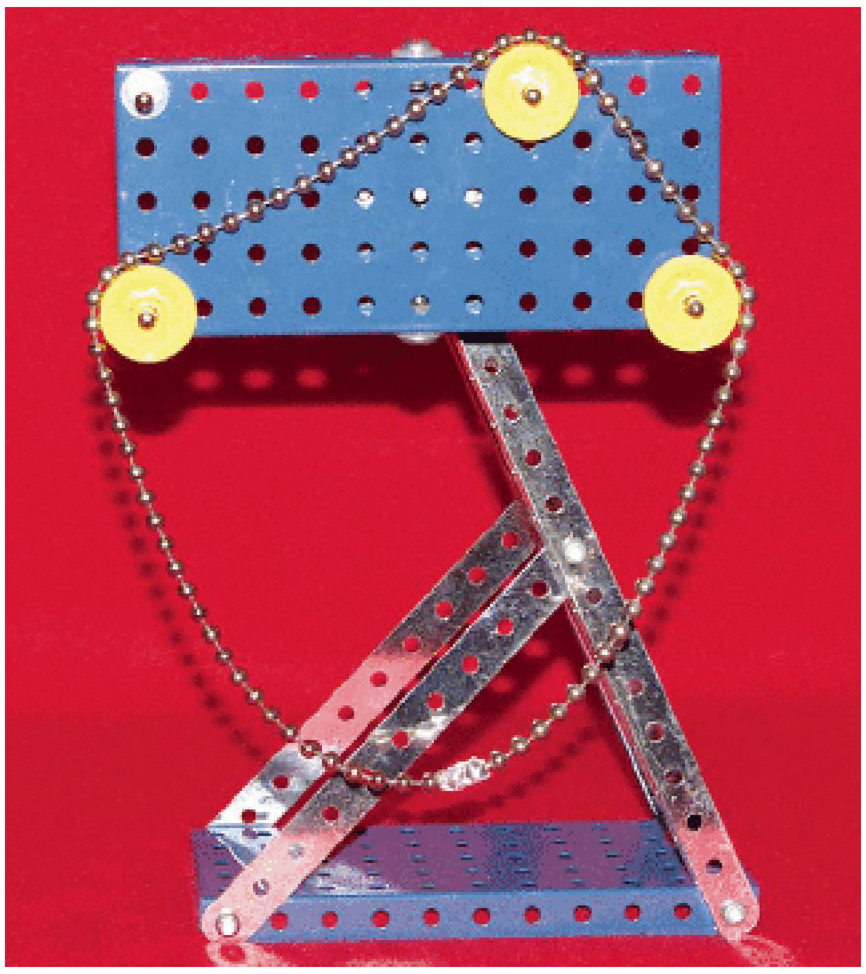
By the 19th century, there was a refreshing return to simple basics. F. G. Woodward proposed a hoop wheel supported by two rollers. This is about as simple a design as you can imagine. Since the wheel always has more weight to the left of the rollers, that side should move down, as the arrow indicates. But the wheel stubbornly defies that "logic," refusing to budge.

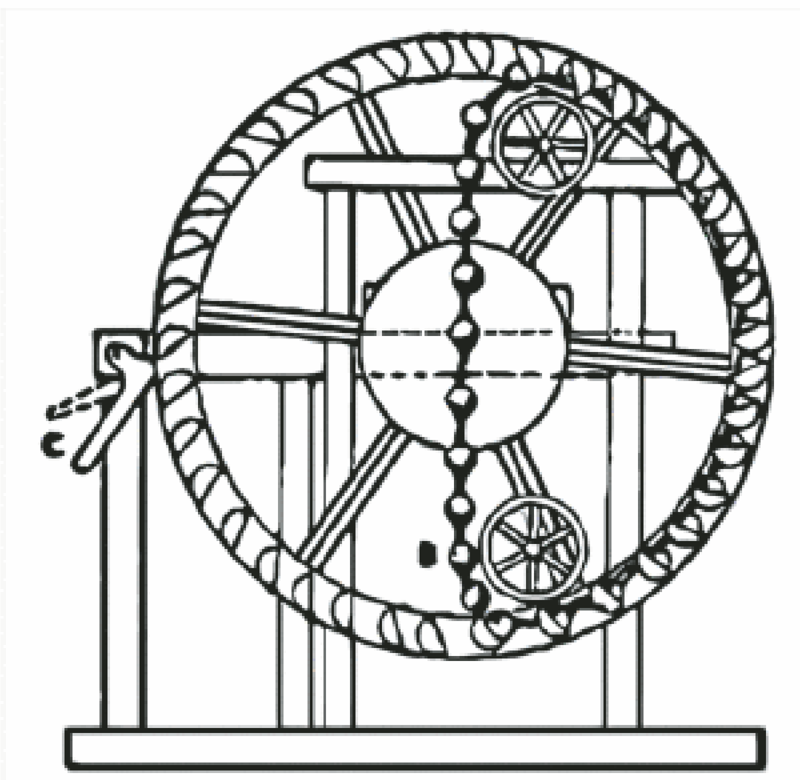
PERPETUAL OPTIMISM

Inventors before the 17th century had no physical laws of energy and momentum that would



Simon Stevin's ball-ramp


Model of Stevin's chain


Richard's overbalanced chain

cause them to doubt the possibility of perpetual motion. But today we have a body of well-tested and accepted laws of mechanics that clearly tell us that certain things are impossible in nature, and no experimental evidence suggests otherwise. So how can anyone still expect to invent a perpetually moving mechanism? Well, many do, undeterred by a long history of total failure, contemptuous of the laws of physics, and oblivious to scientists who declare, "It'll never work."

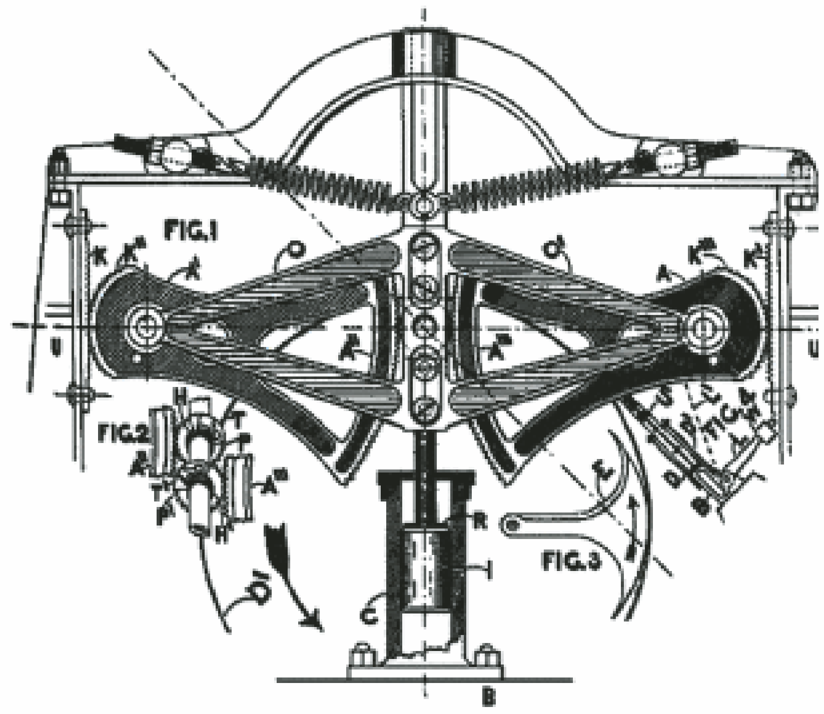
Hans-Peter Gramatke has identified 1,800 perpetual-motion patents in the United States, England, France, and Germany between 1860 and 2000, and a dozen patents from other countries. From 2000 on, an average of about 50 patents per year were issued worldwide. Most were in the four countries named above, although Japan, China, and Korea show recent increases. These are patents that were "obviously" intended to be perpetual motion. There may be many more unworkable device patents in other categories.

Patent examiners do look for serious flaws in patent applications, but their primary criterion for patentability is that a device be a new idea; it doesn't need to be workable or practical. That's why unworkable devices get patented. Today, inventors avoid using words that would signal to an examiner that their device is supposed to get something for nothing, or that it is violating any well-established laws of nature.

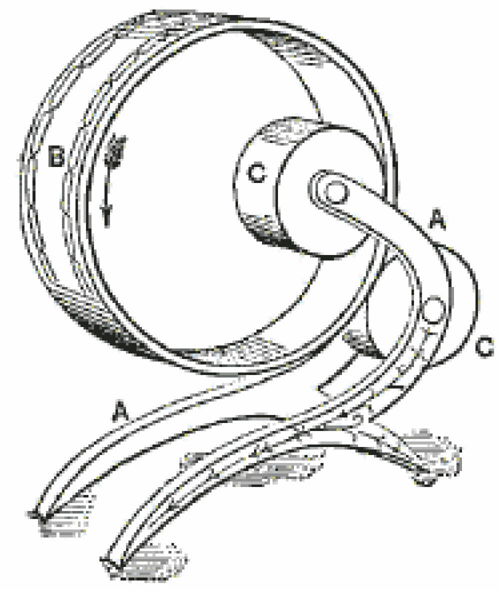
Has all of this effort been a waste of time? Not entirely. Failed experiments give us a better understanding of the inherent limitations in nature's operations. Science learns from its mistakes. Perpetual motionists' mistakes get perpetually repeated.

PIXIE DUST

Perpetual motionists are especially attracted to those parts of physics they don't understand. William Gilbert (1544-1603) summarized his experiments on magnetism in his book *De Magnete* (1600). The book was a sensation, widely read and widely misunderstood. It stimulated all sorts of incorrect, pseudoscientific notions about magnets, some of which still persist today. One fellow, heavily invested in a scam perpetual-motion device, wrote to me that every physicist should know that magnets contain infinite stored energy. As an example, he cited the lowly refrigerator magnet, which, he said, "can hold itself in place forever, working against the pull of gravity, so it obviously has unlimited stored energy." Obvious to him, perhaps, but physicists know that work is the product of force and the distance that force moves something. A magnet does not move as it clings to the refrigerator, so it does no work and expends no energy.



Gilbert's perpetual motion



Woodward's wheel

Since simple mechanisms have been so well studied for so long, perpetual motionists today concentrate on elaborate and complex schemes, and then challenge skeptics to find the flaw. Science writer Bob Schadewald once observed, "A perpetual motionist typically concocts a scheme so complicated that he can't see why it won't work. He then assumes that it will work." Some perpetual motionists pin their hopes on cutting-edge speculations of theoretical physics. Zero-point energy and dark energy are popular now. Perpetual motionists use these as the stage magician uses "magic pixie dust" — to justify apparent miracles. Some postulate as-yet undiscovered laws or hidden energy sources in nature, give them names, and then assume they have just those properties required for the success of their perpetual motion machine. They forget that these properties exist only in their imaginations.

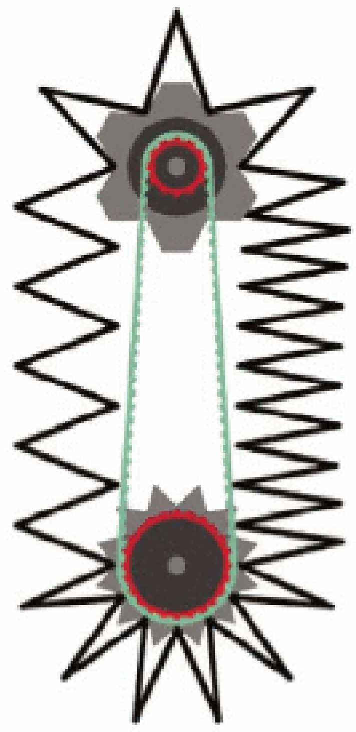
Zero-point energy is a useful concept that has been experimentally confirmed in many ways. But this energy is "locked up" by constraining laws of physics that prevent it from producing useful work. There is not a shred of evidence, from experiment or established theory, that suggests any way to utilize zero-point energy as the driving energy for a cyclic machine. Dark energy is still a speculative hypothesis whose usefulness in physics theory remains to be seen. It, too, seems to be unavailable for conversion to useful work.

HOW CAN WE SAY THAT SOME THINGS ARE IMPOSSIBLE?

Of course, science has not yet discovered all of nature's secrets. In the future we are sure to formulate new principles of physics. Even some of the laws we now know to be valid may need modification or reinterpretation as future discoveries are made. It is even possible that some basement inventor might stumble onto a useful device or even a new physical principle while trying to achieve perpetual motion.

Should we fund research into perpetual motion? I think not. A thing is not necessarily true just because we'd like it to be. It would be foolish to pursue this research because we haven't a single indication, no evidence, no theory — nothing — that even suggests that a perpetual-motion machine is possible, and nothing to suggest how to go about achieving it even if it were possible. Research into antigravity devices, vehicles that travel faster than light, gravity shields, or ways to travel back in time would be just as promising. We haven't a clue how to make them, either, and well-established laws predict that they aren't possible.

Every law of nature that tells us how nature works also tells us how nature doesn't work. The negative part is abhorrent to some people, who desire a magical universe where anything you can imagine is possible, if you tinker with things enough. Laws of nature express the constraints imposed by the geometry of the universe. You can imagine other geometries, but they are not recognized in our universe. For example, you may imagine a triangle in a perfectly flat plane that has exactly equal angles but very unequal sides. But that's not achievable in our universe. Geometry is also the fundamental limitation on the performance of machines.



Simanek's silly spring device

Illustration by Hans-Peter Gramatke

Simanek's Silly Spring Device

Most perpetual-motion-machine designs that people send me are variations of old and discredited ideas. It gets boring after a while, so I decided to invent one of my own — to make a point. It uses a flexible, coiled spring looped over two pulleys. One side of the spring is kept compressed by a non-slipping belt running over smaller pulleys fixed to the larger ones. Clearly it is heavier on one side of the pulley axle, and this "unbalance" is maintained as you manually turn it. It can be rotated freely, in either direction. But it will not turn on its own, even if you could reduce friction to zero. Thanks to Hans-Peter Gramatke's animation, you can see it in motion on my website (see References, below). It demonstrates that computer simulations can model unreality just as well as reality.

References

At these two sites, you can find pictures of many perpetual-motion devices you might want to build yourself. They are guaranteed to be unworkable.

Donald Simanek's Museum of Unworkable Devices:
www.lhup.edu/~dsimanek/museum/unwork.htm

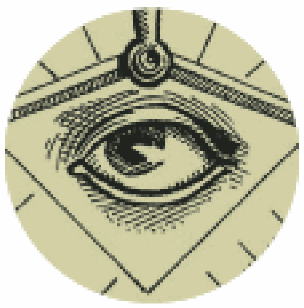
Hans-Peter Gramatke's pages:
www.hp-gramatke.net/index.htm

Donald E. Simanek is emeritus professor of physics at Lock Haven University of Pennsylvania. Visit his pages of science, pseudoscience, and humor: www.lhup.edu/~dsimanek.

Masonic Conspiracy Revealed!

When engineering culture detaches from reality.

By Paul Spinrad



Generations of conspiracy-minded observers have nurtured theories about powerful secret societies such as the Masons. Here is my theory: Occult institutions evolve out of professional guilds after they stop caring about how to actually build things.

In every age, geeks gravitate to where the interesting action is, and in medieval Europe, this was the cathedral — the structure itself, the art, and the pipe organ inside. Like most people, I've always been amazed by the great gothic cathedrals, but it was French historian Jean Gimpel's book, *The Cathedral Builders*, that gave me the real nerd's-eye view.

Gimpel explains that starting in the last half of the 12th century, competitive cathedral builders broke the world's record for the highest interior vault five times within 62 years: from the completion of Notre-Dame de Paris in 1163 (32.8 meters high), through Chartres, Rheims, Amiens, and finally to Beauvais in 1225 (48 meters high, collapsed in 1284). This space-race happened during what's now called the Early Gothic era, when cathedral building was literally at its height.

Engineering culture flourished during this era, and the cathedral builders were the alpha geeks. They and their kind traveled throughout Europe and contracted independently with parishes and municipalities to build churches, bridges, and other public works. They scouted talent by hiring unskilled stonecutters from the local populations, and invited the most promising ones to apprentice. They formed an international maker subculture that was surrounded by an illiterate and innumerate population that relied on their work, but could never understand it. To outsiders (non-engineers), they must have seemed like wizards: they used strange implements and symbols, spoke their own terminology, and produced magical-seeming sights, sounds, and structures.

Meantime, these builders had a unique relationship to the Church, which monopolistically financed and controlled all culture — like today's Hollywood and Madison Avenue, combined. The Catholic Church needed the building expertise of "free masons," who didn't have to buy into any ideology or hierarchy, or even obey the local clergy. This gave the masons an unusually powerful position, which was inevitably eyed with suspicion.

Toward the end of the 13th century, as Europe became more nationalistic and political, Church funding for great cathedrals dried up. Design expertise was also tragically lost, and no one knew how to build as high anymore. This resulted in the Late Gothic style of cathedral, characterized by smaller structures that were built using old plans, but with more ornamentation added — lame.

Not surprisingly, the masons' professional culture also began to change during the Late Gothic period. Inside the guilds, nepotism and politics replaced ability and contribution as the path to master status. What had become known as Freemasonry was more secretive, perhaps out of defensiveness; the great cathedrals stood as prominent witness to all the knowledge that had died with previous generations. By the 15th century, masons in Germany adopted professional codes that forbade speaking publicly of lodge activities or divulging old methods for rendering drawings. Throughout Europe, the building trades carried an overlay of secrecy, antique reverence, and the promise of access to great lost wisdom.

From Operative to Speculative

Jumping ahead, Gimpel describes Scotland in the 16th century, where a boom in castle building took place. Job seekers answered the calls for work, and traveled from all over to converge at building sites. But the assembled workers didn't know each other and had no educational degrees to go on, so the structural-engineering geeks developed a secret system of hand signals to identify themselves to one another at job sites and distinguish themselves from the unskilled stonecutters who could only build walls. After recognizing the signs and gathering together, these masons could then approach the local authority and say, "We're the master builders here, and you need to put us in charge."

Around this same time, the masons in Scotland also formed a network of lodges where traveling members could stay and meet with other builder geeks. Conspiracists point to these Scottish lodges as the cradle of a mysterious occult society tied to the medieval Knights Templar, but as Gimpel writes:

> *Masonic historians have long thought that [the] secrets which the workmen were asked to keep were of an esoteric nature. They were nothing of the sort ... there is no reason to suppose that these secrets contained anything more esoteric than ... discussions in the lodge ... as well as technical secrets of the trade concerning, for example, the design of an arch.*

But then something happened that changed Masonry completely, and (I believe) did eventually turn it into an occult conspiracy. Upper-class men who weren't trained masons wanted to join Scotland's Masonic lodges. They were refused at first, but were later accepted under the provision that they paid double the dues of working masons. We can only guess at the mixture of motivations that led these fancy lads to seek companionship in a professional builders' society, but as a result, they gained access to a nationwide network of lodging and social contacts — an exclusive club, in the more modern sense.

This new membership policy gradually detached Masonry from its engineering roots, and within a couple of generations, more Masons were wealthy gentlemen than actual builders. But as the makers gave way to the schmoozers, the lodge system proved to be a resilient social construct. Masonry became political and social, rather than practical — a cabal of insiders, rather than a collective devoted to expertise and education. Expert trade knowledge and levels of technical proficiency evolved (devolved?) into an artificial system of signs, symbols, and access, whose function was to distinguish insiders from outsiders. But in the social context within which this knowledge operated, it was still powerful.

Here's how it works. Let's say you're an insider who knows some secret mumbo-jumbo. Promoting the belief to outsiders that your secrets have great power makes this belief self-fulfilling because it makes outsiders think you have something on them. The more mysterious and powerful these inside secrets seem, the more effective the hype becomes. Now, if you imagine running this secrets-as-status dynamic recursively, you get concentrically nested levels of power, a hierarchy that runs from complete outsider to innermost circle. Add the human imagination on both sides, and you spawn a thousand occult rituals and a thousand conspiracy theories.

Masonic historians refer to this great shift away from building as the shift from "operative" to "speculative" masonry, and the event that signified the completed transition is considered to be the establishment of the Grand Lodge in London, in 1717. Numerous books trace modern Masonry's lineage from the Grand Lodge to today's Masonic lodges, which combine, to varying degrees, the roles of community service organization, local chamber of commerce, and drinking club.

The Masonic blueprint has also informed other secret societies and organizations, ranging from the occultist Golden Dawn to college fraternities. However, I believe that the true heirs to the Masonic tradition are at makers' fairs, s33krit hackers' conferences, engineering departments, and other places where people share practical knowledge with other wizards.

So, what is to be done? Cities across America have beautiful Masonic lodge buildings sitting on prime downtown real estate. Lodge membership is graying, and many chapters have closed due to the lack of new members. I think this presents a grand opportunity. Let's start a new Masonic Conspiracy! Let's take Masonry back, and convert it from speculative back to operative! Let's get all the makers we know to become Masons, and turn all those gorgeous, unused lodge buildings into temples of geekdom! Who's with me?

Paul Spinrad is projects editor of MAKE.

Freemasonry in a nutshell: 16th century structural engineers invent secret system of hand signals to identify themselves at job sites. Later, non-engineers pay to join the secret society, turning Freemasonry from operative to speculative. Now, it's time for makers to add the geek factor back into Freemasonry.

Illustration by Hal Robins

FRINGE

The Essential Strangeness of Time

Reconstructing Athanasius Kircher's magnetic clock. By Jonah Peretti

Caroline Bouguereau, a French artist now living in Ireland, was commissioned by Stanford University Libraries in 2001 to reconstruct the magnetic clock described by German Jesuit polymath Athanasius Kircher (1602-1680). Jonah Peretti, emeritus director of R&D at Eyebeam in New York City, conducted the interview.

How did you decide which machine to build?
I liked the way the clock was a miniaturized model of the cosmos. It was a puzzle, an enigma ... a fish pointing mysteriously at the globe of the Earth, as it rotates slowly. The visual impact of the engraving appealed to me, and the magic of the machine: how were the globe and fish suspended? What cosmic force made the globe turn around? And, above all, why a fish? As an artist, I've worked with fish before. I also like curious scientific apparatus, machines that have an aesthetic appeal, or an unsettling, disorientating effect.

What were the biggest challenges in making the clock? Was it hard to make the clock work? What techniques did you have to learn?
The biggest challenge was to find a way to suspend the small sphere in the middle of the larger globe. In the reconstruction, I tried to imitate Kircher's methods as closely as possible to produce the Baroque aesthetic effect of his device. To allow the sphere to appear to "float" within the globe, Kircher suspended it at the junction of two immiscible liquids of different densities. My concerns were which liquids to use for this purpose, and how to make the ball stay at the same position, right at the middle of the globe. Most of the organic solvents that worked well had serious risks. Acetonitrile, in particular, suggested enthusiastically by a Stanford chemistry professor, was apt to produce hydrogen cyanide on contact with air — probably not a good thing for an art exhibit in a public indoor space.

Did the project feel contemporary, historical, or both?
I had to immerse myself in the culture of the 17th century for the design; I had some freedom of design

but there were very strict rules. The map of the world painted on the globe is an example. I copied a 350-year-old map. To paint on copper, I looked at how people did this in the 17th century — they rubbed the copper with garlic first, and scratched it to make the paint stick. I think the clock also has a very contemporary "feel," though. I've always found time [to be] something very mysterious. We are so used to clock faces and digital representations of time that we have forgotten how strange it is. I think Kircher's machine restores the essential strangeness of time.

From an artist's perspective, what's important or interesting about Kircher?
Kircher is probably the most diverse and prolific kinetic artist of his time. Kircher is one person who really brought the worlds of mechanical ingenuity and arcane knowledge together in his Wunderkammer [curiosity cabinet]. With Kircher you never know what to take at face value.

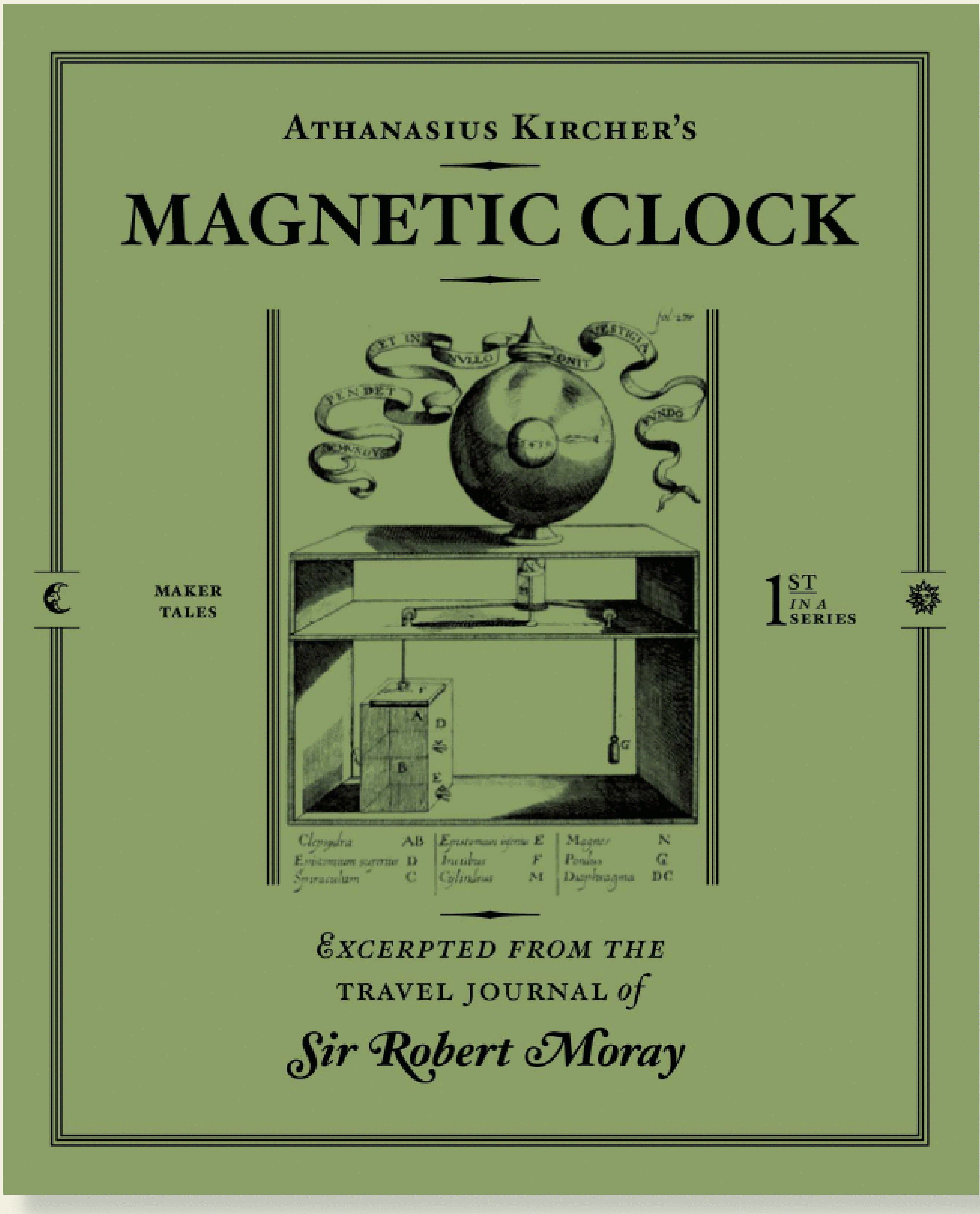
See the artist at makezine.com/09/kircher.

Photography by Jason Forman

A floating fish always faces the current time (painted on a globe) in a reconstruction of Kircher's celebrated magnetic clock from the 17th century. An ordinary water clock "magically" turns the globe with hidden magnets.

Thank you, subscribers!

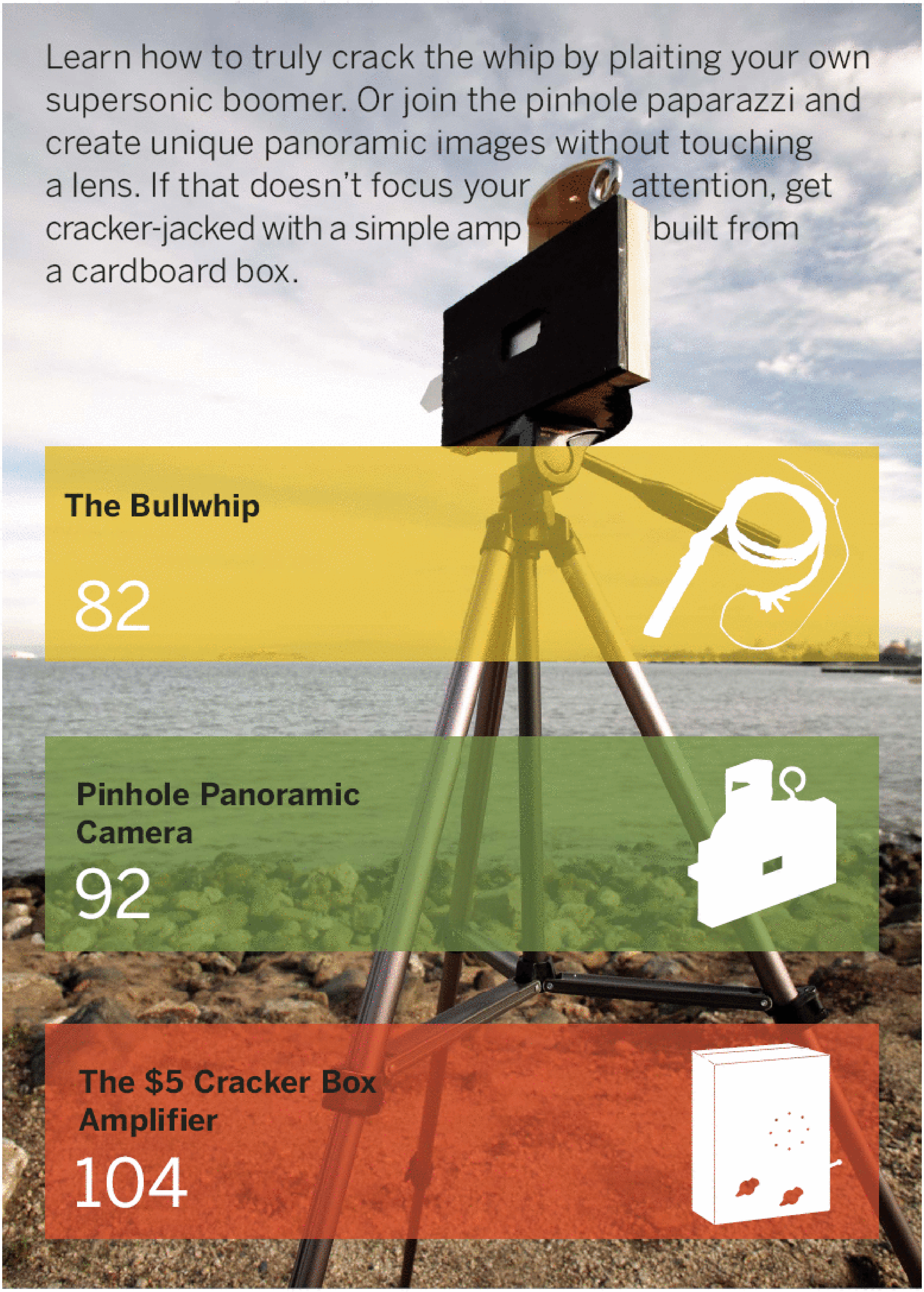
We're giving you a special, limited-edition booklet.



This miniature book, produced as a period-authentic chapbook popular in Europe at the time, tells a historically speculative tale of one of the most remarkably creative inventors in history, Athanasius Kircher. This is the first volume in our forthcoming series of Maker Tales books, and this limited first edition is anticipated to quickly sell out.

In celebration of the start of MAKE's third year, we're giving all subscribers this Maker Tales booklet, which should arrive with your copy of MAKE 09. If you're not a subscriber, you can still get a copy by purchasing one of a limited number available at makezine.com/store, or by subscribing at makezine.com/subscribe, using promotion code M7AK by May 15, 2007.

Make: Projects



Learn how to truly crack the whip by plaiting your own supersonic boomer. Or join the pinhole paparazzi and create unique panoramic images without touching a lens. If that doesn't focus your attention, get cracker-jacked with a simple amp built from a cardboard box.

Photograph by Sam Murphy

THE BULLWHIP

By William Gurstelle

WHIP IT GOOD

You don't have to be Chuck Yeager to break the sound barrier. You just need a good bullwhip, which converts arm movement into supersonic speed and triggers the sonic boom we call a whip crack.

I love the scene in *The Blues Brothers* when Joliet Jake Blues (John Belushi) and his band are playing at a roadside dive. The tough crowd is throwing bottles, and the chicken-wire screen in front of the stage is doing only a mediocre job of protecting them. Jake spies a coiled bullwhip hanging on the wall, and a light bulb flashes in his head. He grabs the whip and gets the band to strike up the *Rawhide* theme. With each chorus, with each crack of the whip, the crowd's demeanor changes, and by the time the Blues Brothers finish the song, the crowd is won.

Everyone loves the sound of a whip. But music and culture aside, whips are interesting physical devices: self-contained, human-powered machines that exceed the speed of sound, which is roughly 770 mph. Bullwhips are easy to make at home, and their deep, explosive crack is far more affecting when you experience it live, rather than just hear it recorded.

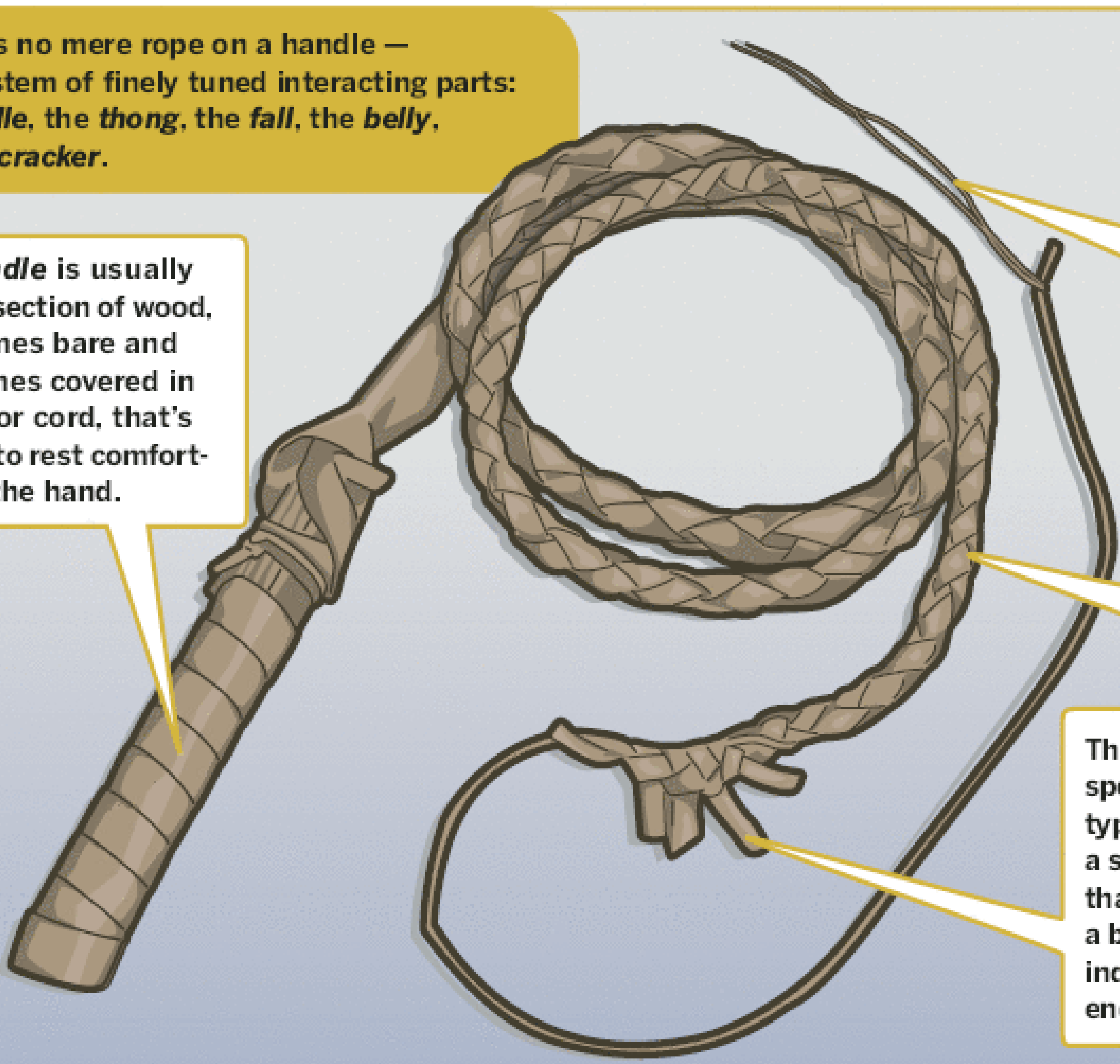
Photography by Sam Murphy

Set up: p.85 **Make it:** p.86 **Use it:** p.90

William Gurstelle is a MAKE contributing editor. He wrote the ornithopter flying machine project in Volume 08. His fifth book, *Whoosh, Boom, Splat*, comes out this March.

WHIP SMARTS

A whip is no mere rope on a handle — it's a system of finely tuned interacting parts: the ***handle***, the ***thong***, the ***fall***, the ***belly***, and the ***cracker***.



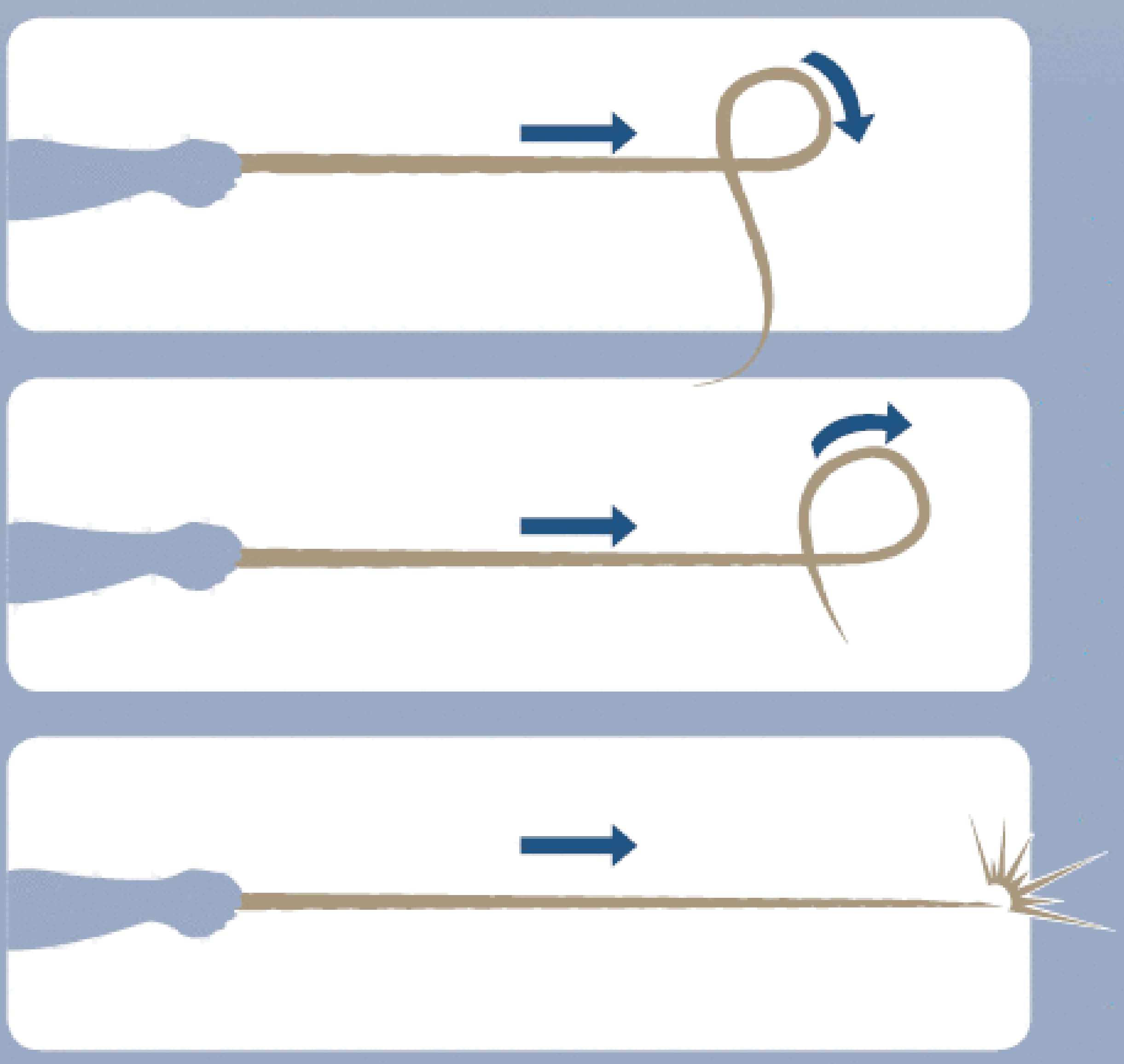
The ***handle*** is usually a short section of wood, sometimes bare and sometimes covered in leather or cord, that's shaped to rest comfortably in the hand.

The ***cracker*** (or ***popper***) is a small, replaceable piece of string or nylon cord at the very end of the whip. Because it moves so fast, this piece is subject to much wear.

The ***thong*** is a section of leather braid wrapped around a flexible core that whip makers call the ***belly***.

The ***fall*** is a series of specialized knots, typically made from a single piece of leather that's 1-2 feet long and a bit wider than the individual braids at the end of the thong.

Speed Over Mass: A whip tapers gradually from base to end, to smoothly transfer momentum and energy from the thick plaits near the handle to the thin, flexible popper.



1. The whip-throwing motion causes a loop to propagate down the whip's length.

2. As the loop continues down, its speed increases following the mathematical inverse of the thickness and weight of the whip's cross-section.

3. By the time the roll approaches the end, the loop velocity has gone transonic, crashing through the sound barrier. ***Crack!***

Illustration by Tim Lillis/narwhalcreativve.com

SET UP.

MATERIALS

[A] Leather hide, about 3/16" thick and at least 8' long Purchase a hide from a leather shop. I purchased mine at Tandy Leather, a large national chain, and found the staff extremely knowledgeable. The shop buys hides from a tannery and then sells its products by the side, hide, skin, split, or belly. The size, thickness, and texture of each hide vary, so you'll need to inspect several to find one that works. Try to get one that will let you cut straight 8'-long strips. Whip makers can cut curved strips from smaller hides, but this adds complexity.

[B] ¾" diameter smooth wooden dowel, about 7" long This will be the handle. You can make it longer or shorter according to your taste.

[C] Saddle soap

[D] Light cotton or nylon cord, at least 1' or horsehair, hemp, or any other thin, fibrous material

[E] Small nails or heavy staples

TOOLS

[F] Vise or C-clamp on a sturdy support

[G] Saw

[H] Hammer

[I] Soft-leaded pencil

[J] Rubber band

[K] Ruler

[L] Straightedge (or use the ruler), the longer the better

[M] Sharp utility knife with spare blades

[N] Eye protection

[NOT SHOWN]

Large, flat cutting surface

Sturdy support you can tie around

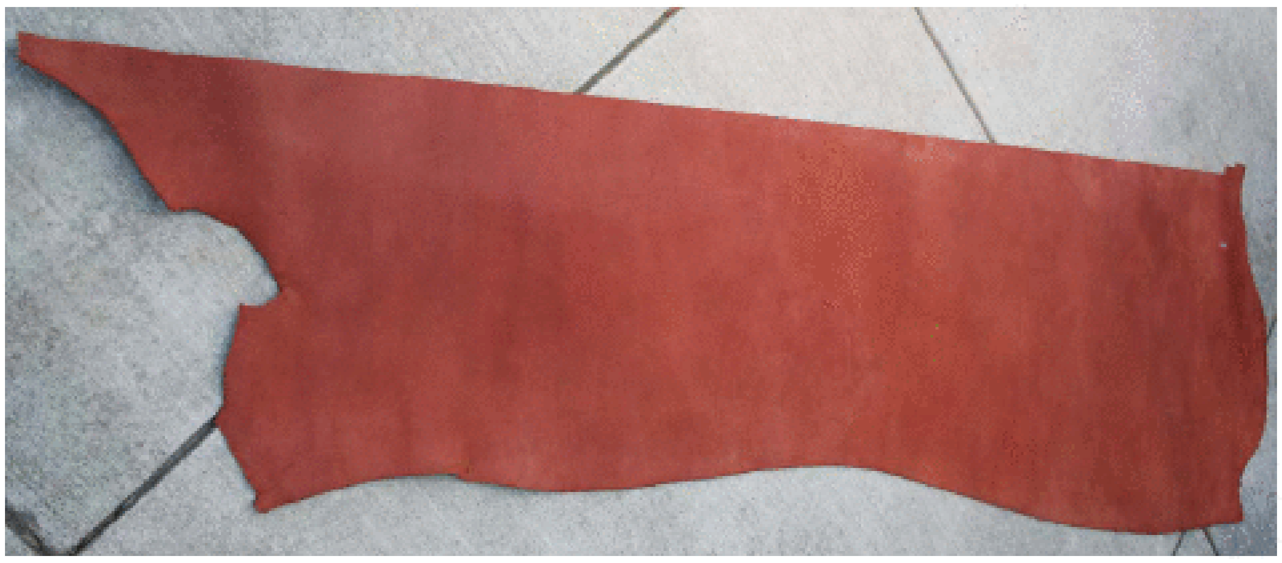
MAKE IT.

CRAFT YOUR BULLWHIP

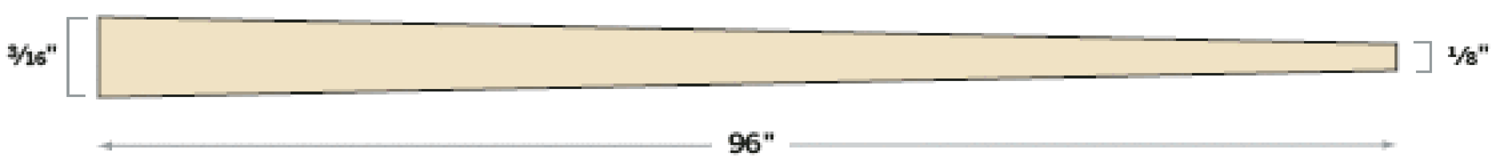
START **Time:** 4–8 Hours **Complexity:** Medium Easy

1. CUT THE LONG PIECES

1a. Cut the belly. Mark and cut a leather strip at least 8' long, that tapers evenly and symmetrically from 3⁄16" at one end to 1⁄8", as shown in the Belly Cutting Diagram (below). This will be the whip's belly, around which the thong plaits are laid. The plaits form a hollow tube through which the belly runs. If your hide is longer or shorter than 8', adjust your layout accordingly. With a longer hide, you can make a longer whip.

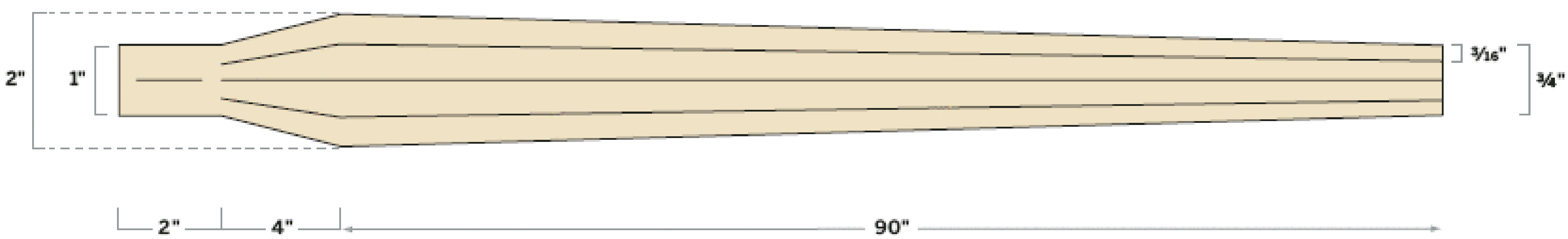


Belly Cutting Diagram (not to scale)

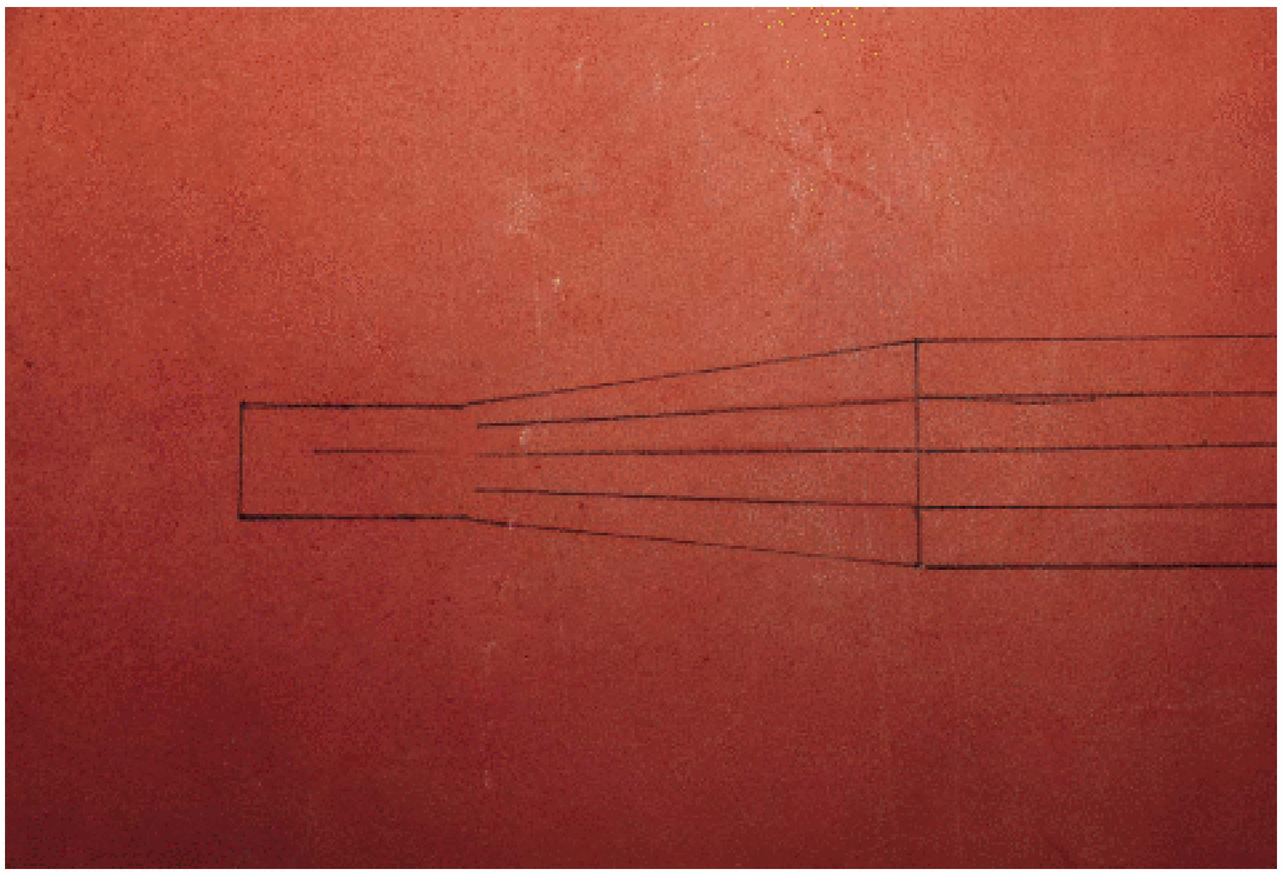


1b. Lay out the thong. The thong consists of connected strips of leather that are woven or plaited together to form the main body of the whip. Thong layout is the most critical portion of the entire whip-making procedure, so take time to do this accurately. Adjust the length of the thong to match the length of the belly if it's different from 8'.

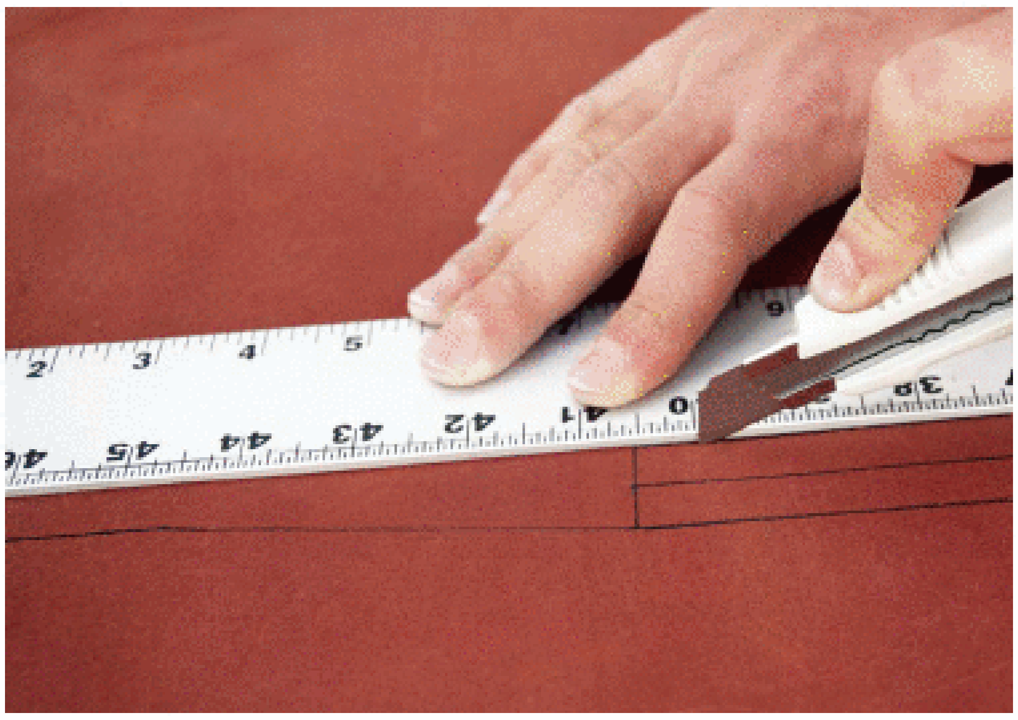
Thong Cutting Diagram (not to scale)



Use a soft-leaded but sharp pencil to draw the outline of the thong on the leather hide, 2" wide at the widest point, following the Thong Cutting Diagram at the bottom of the previous page. The main concern is to keep the width of all 4 strips equal to one another at every point along the thong's length.



1c. Cut the thong. Use a very sharp knife and a straightedge to guide your hand as you cut through the leather, following the layout.



2. PLAIT THE THONG

This is the most time-consuming portion of the project. Study the plaiting sequence photos carefully. The first time you plait your thong into a whip, it might be somewhat confusing, but keep trying, and before long the process will be not only easy, but also quite a bit of fun.

2a. Hang the belly and the thong. Secure the wide end of both the belly and the thong together, with the belly centered on top, with a C-clamp, vise, or other sturdy support. Tie the other end of the belly to another support, so that it's stretched tight and will hold steady while you plait around it.

2b. Dress the leather. This prepares the thong to make it easier to pull tightly into good, even plaits. I apply saddle soap to the leather with my fingers and then work it into the leather, warming and softening it. Some serious whip makers use their own special dressings concocted from beef fat, beeswax, oils, and other stuff, although these will also make the whip more attractive for dogs to chew on.

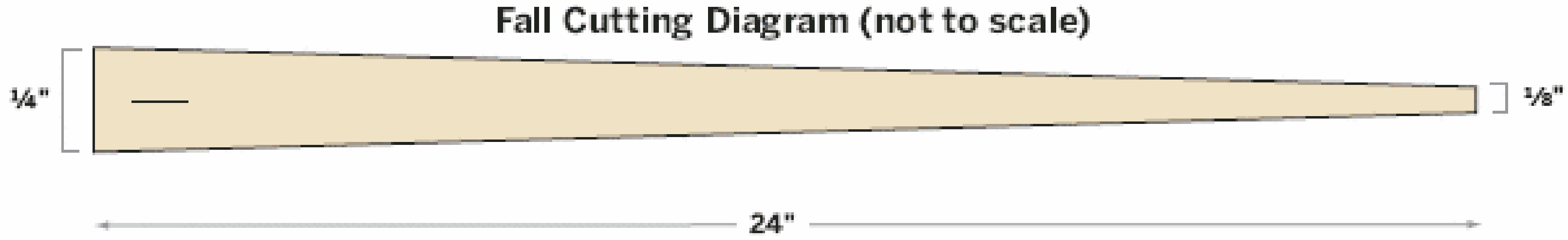
2c. Do the actual plaiting. This takes a while to accomplish, but it's pretty easy once you get the hang of it. Every wrap goes around the belly, which is the thinner strap shown in the background. Repeat the process, pulling the thongs tight after every step, until there is about 4" of unplaited thong left at the bottom. The belly will be longer than the plaited whip, and will extend out of the bottom. Tie off the plaited thong temporarily with a rubber band to keep it from unraveling.

3. ATTACH THE FALL AND CRACKER

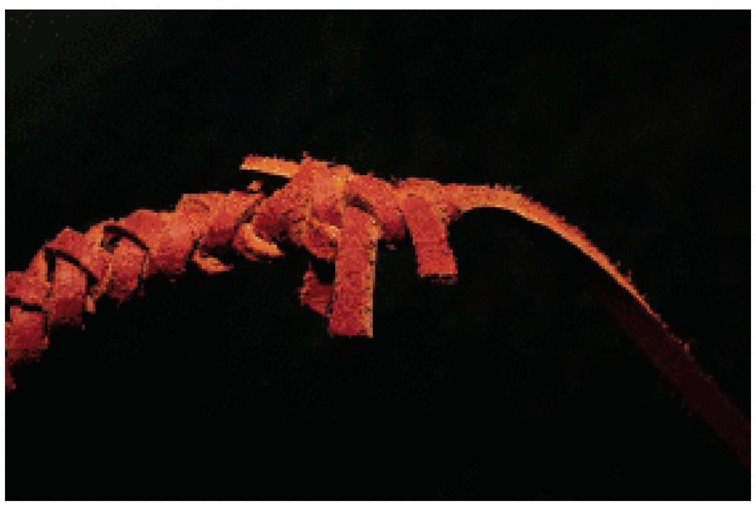
The fall is a thin strip of easily replaceable leather attached to the end of the whip. Since the whip tip moves at supersonic speed, the end gets worn fairly quickly. The replaceable fall protects the plaits in the whip.

3a. Cut a 2' strip from the hide, as shown in this Fall Cutting Diagram. Cut a 1" slit near the wide end.

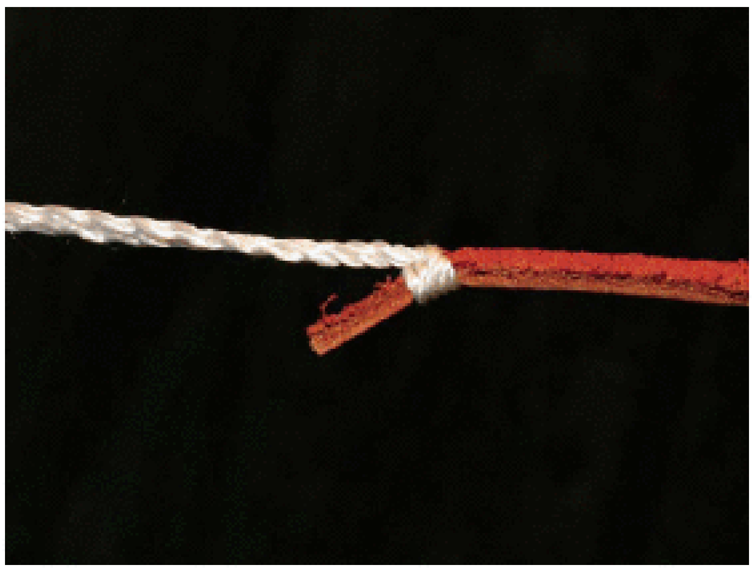
Fall Cutting Diagram (not to scale)



3b. Attach the fall to the whip by placing the whip's tip through the slit in the fall. Then tie 4 single overhand knots in each of the strands of the thong. Pull the knots tight and cut off the excess.



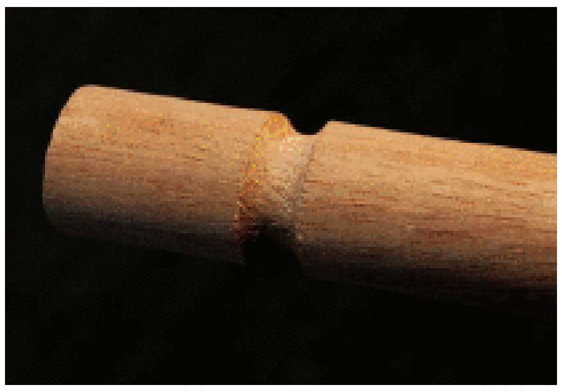
3c. Make the cracker by cutting an 8" length of light cotton or nylon cord (or horsehair) and tying it securely to the fall with a sheet bend knot (wikipedia.org/wiki/sheet_bend). Unwind a bit of the other end into individual fibers.

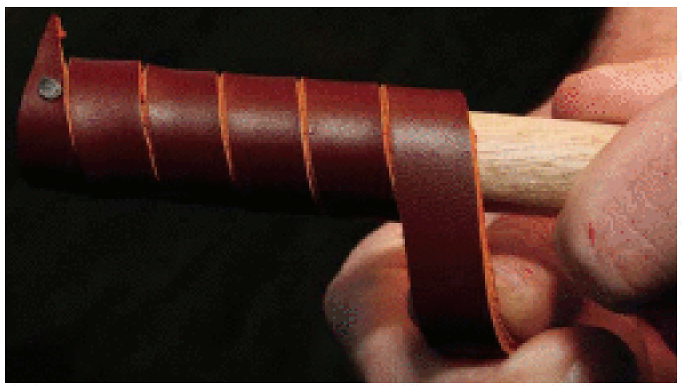


4. MAKE AND ATTACH THE HANDLE

4a. Cut the dowel down to handle size (I find 7" convenient), and cut a shallow groove in the handle 1" from one end.

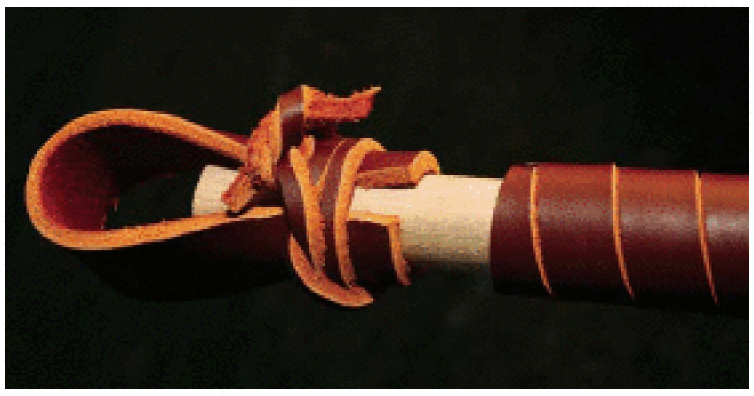
4b. Cut an even leather strip ½"–¾" wide by 2'–3' long, with gradually angled cuts at both ends. Use a nail or heavy staple to tack the strip to the top of the handle, opposite the groove. Wind the leather around the groove. Wind the leather around the handle and tack again at the bottom end of the strip.





4c. Cut a 1"×7" leather strip from the hide. This will be the keeper, the piece that connects the whip plaits and belly to the handle.

4d. Cut a very thin leather strip, about ⅛"×15", from the hide. Bind the keeper to the handle with this thin strip, using the groove to anchor it firmly in place. First, tie the thin strip directly into the groove with a clove hitch (wikipedia.org/wiki/clove_hitch), then wind the leather strip several times around the keeper, and tie it off. Pull hard on the keeper to test it for strength. If necessary, retie or use a second thin strip to bind it on.



4e. Attach the plaited thong to the handle by first passing the handle through the slit in the thong, then pulling the thin end through the keeper. The whip is now ready for use!

FINISH X

NOW GO USE IT »

USE IT.

LET'S GET CRACKING

SAFETY

Until you get a feel for how to handle a whip, expect to endure a few accidental welts. Things to remember:

• Eye protection is absolutely required. A hat that covers your ears is also a smart precaution.

• Wearing gloves, a jacket, boots, and heavy pants will reduce your chances of getting a whip-lash.

• Keep people, animals, and things you don't want broken clear of your practice area.

PRACTICE

There are many methods of whip cracking. All require practice to obtain consistent results. Practice makes perfect, and builds arm strength too!

The Forward Crack Start with the whip laid out on the ground in front of you. Bring your arm up and back. Then with a sharp motion, bring your hand forward, similar to a baseball pitcher's arm motion. Done correctly with a well-made whip, this results in a nice, sharp crack. Try various arm speeds to see what works best for your whip.

The Overhead Crack Begin by twirling the whip overhead to gain velocity. When the fast-moving whip tip is just behind and to your right (assuming a right-handed user), bring your hand forward smartly, and quickly snap your wrist. Done correctly, this will reward you with a brisant crack.

CRACKER CARE

Cracking a whip subjects the popper end to a lot of punishment, and they don't generally last too long. I like to experiment with different cracker materials to see what gives the best report. To begin, try soft, thin cotton or nylon twine with one end unwound into its individual fibers. In my experience, different cracker constructions give widely different results. Experiment with various materials and lengths to see what works best with your particular whip.

Photograph above by Corbis; photograph below by Sam Murphy

RESOURCES

For more family-friendly whipping tips and resources see makezine.com/09/bullwhip.

LASH PROGRAMMING

Photograph: Corbis

Whips evolved as herding and cattle-driving tools. A good whip handler can produce a cracking sound that bursts from any location within the whip's reach. Cattle instinctively turn away from the loud sound's source, so the ability to precisely place these small sonic booms anywhere in midair lets cattle drivers steer their herds.

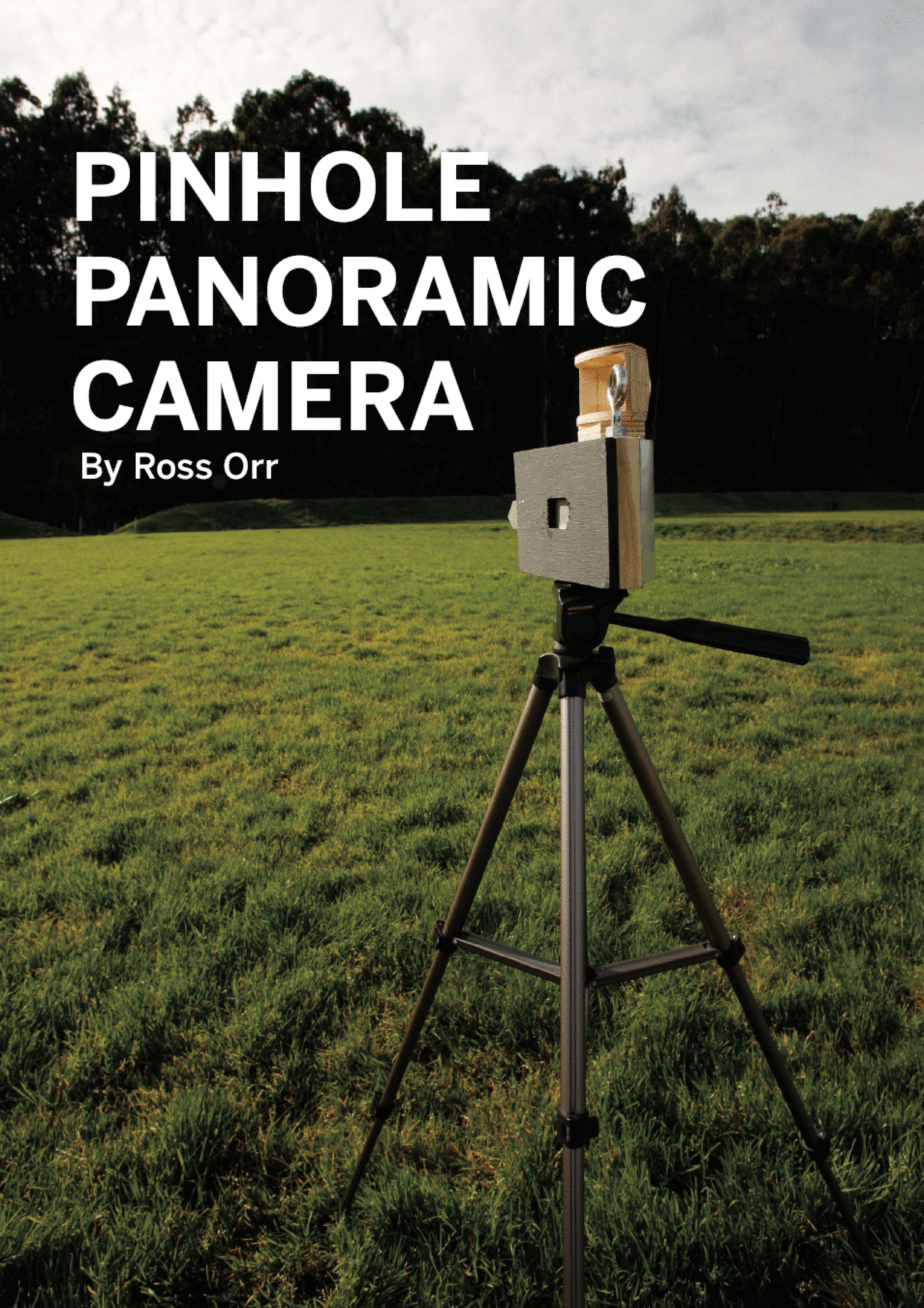
Crafting a whip that cracks well requires time-tested methods. A well-designed whip is a lesson in supersonic fluid mechanics. It must taper gradually from base to end in a specific fashion, and it must be made of materials that gracefully and easily transfer the energy and momentum of the moving internal coil along its length.

Alain Goriely, professor of mathematics at the University of Arizona, has published several research papers on the way whips work, and has come up with several fascinating conclusions about how waves propagate through these flexible devices. His research describes how a loop moving down the length of a whip accelerates as the whip tapers, and he developed a series of equations that accurately model the curvature, boundary conditions, tension, and speed of the whip. Goriely's computer analysis of whip dynamics confirms that the cracking sound results from hypersonic movement, and he has measured tip speeds in well-made whips that exceed Mach 3 — three times the speed of sound.

Goriely divides the world of whips into two categories: pain-making whips and noise-making whips. The pain-makers, such as the infamous cat-o'-nine-tails, are short, bulky, and made up of several strands that hang separately. They don't crack. Noise-making whips are long and tapered, consisting of a braided single strand. Despite their frightening appearance, the noise-making whips are not used as weapons or torture devices; their purpose is to produce and aim incredibly high tip velocities.

PINHOLE PANORAMIC CAMERA

By Ross Orr



PIN-O-RAMA

Lensless and low-tech, pinhole cameras have always been maker-friendly. But forget the Quaker Oats carton, and go wide with this roll-film, panorama design.

I bought a new scanner recently, and soon found myself spelunking through drawers of old photos from my many misspent years in photography. Some of the most interesting shots were the pinhole camera experiments I had done as a teenager. With ghostly outlines from multi-minute exposures, and shapes warped into boomerangs by curved film, these otherworldly images got me dreaming about pinhole cameras again.

So I headed to the workshop to build a new one. And then another, and another. I eventually made more than a dozen, and this "Pin-o-rama" design is my favorite. Unlike simpler pinholes, it uses standard 120mm roll film, which means you don't have to open the camera and reload after each exposure, and you don't need a darkroom to process the results — just take the rolls to a photo lab. Also, it's built entirely from scratch, rather than hijacking the film-transport from an existing camera.

Photograph by Sam Murphy

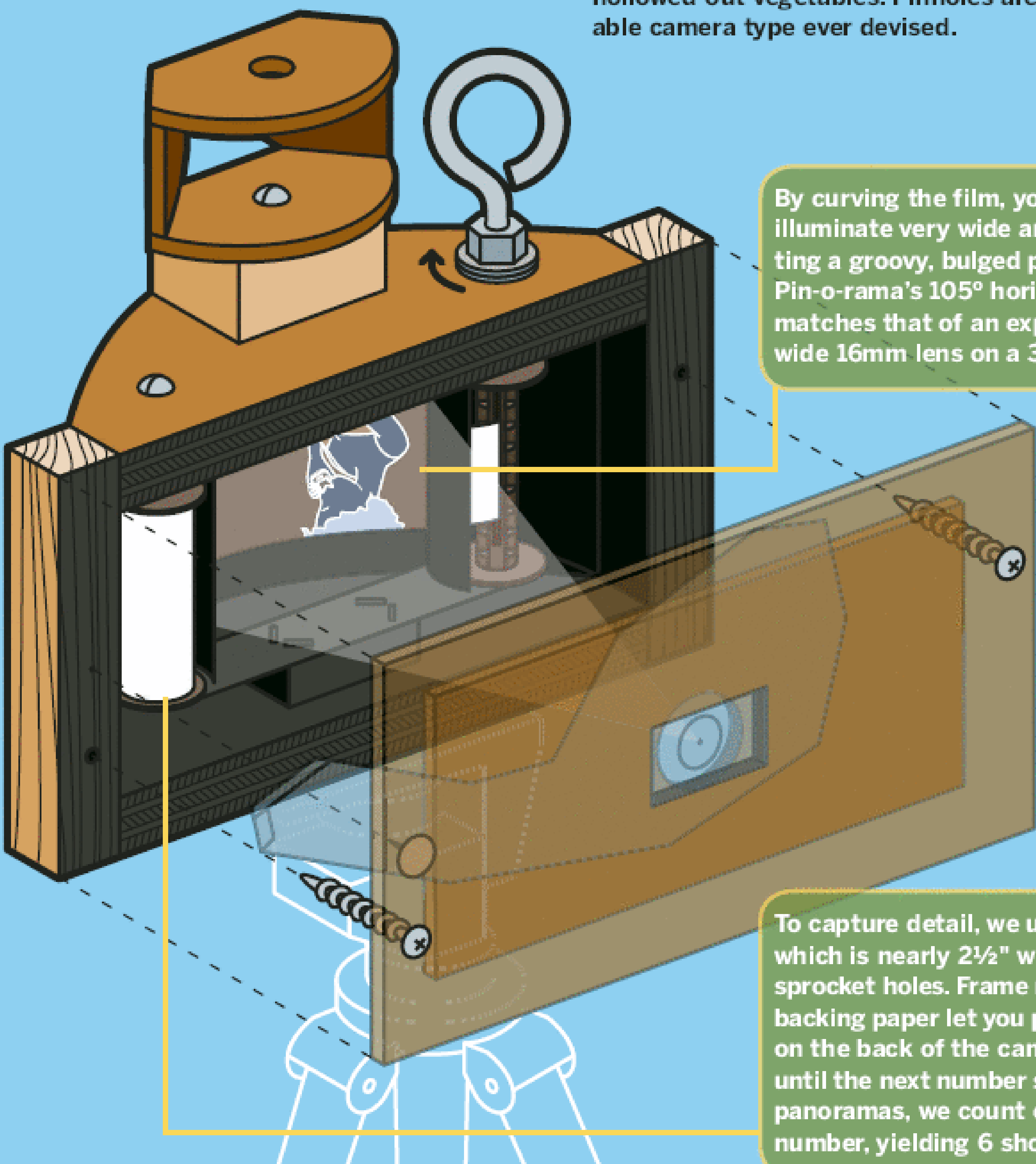
Set up: p.95 **Make it: p.96** **Use it: p.101**

Ross Orr keeps the analog alive in Ann Arbor, Mich. A frequent contributor to MAKE, Ross hacks low-tech gadgets and invasive plants in his spare time.

THE HOLE PICTURE

A pinhole camera is a light-tight box with a piece of film (or photo paper) on one side and a tiny hole in the other. An image forms because each point on the film can only "see" the one patch of the outside world that's lined up with the pinhole, whether it's light, dark, blue, red, etc. Because the pinhole does not focus light like a lens, the film can be any shape and a flexible distance from the hole, and the enclosure can be made from any lightproof material.

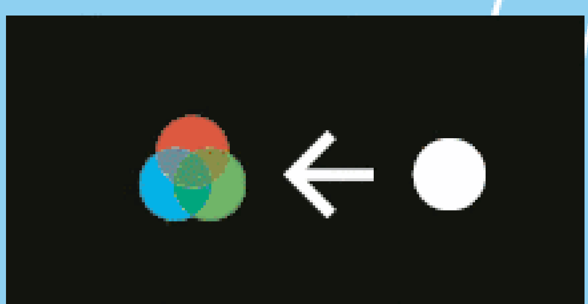
With construction so forgiving, pinhole tinkerers have produced a riot of camera creations, from mint tins to airplane hangars — even animal skulls and hollowed-out vegetables. Pinholes are the most hackable camera type ever devised.



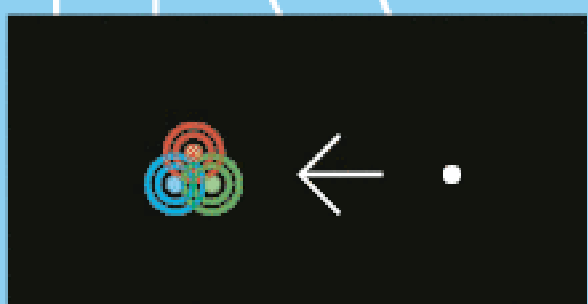
By curving the film, you can uniformly illuminate very wide angles, while getting a groovy, bulged perspective. The Pin-o-rama's 105° horizontal coverage matches that of an expensive, super-wide 16mm lens on a 35mm camera.

To capture detail, we use 120mm film, which is nearly 2½" wide and has no sprocket holes. Frame numbers on the backing paper let you put a peep sight on the back of the camera, and wind until the next number shows. To shoot panoramas, we count off every other number, yielding 6 shots per roll.

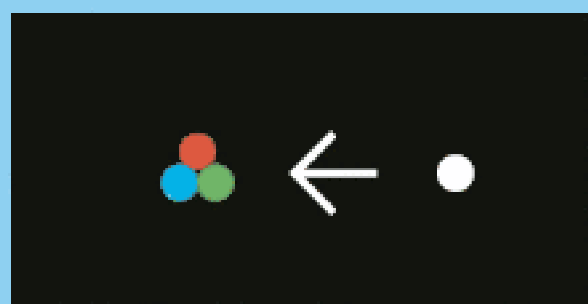
PROPER PINHOLE SIZE



TOO LARGE: The pinhole's image comes from overlapping pinhole-sized blobs of light. A large pinhole loses all detail smaller than its own diameter.



TOO SMALL: With a too-small pinhole, light diffraction smears the image. A smaller hole also decreases brightness, requiring longer exposures.



JUST RIGHT: Calculating proper pinhole size has absorbed much scholarly brainpower. For cameras with typical focal lengths, it's 0.2mm to 0.5mm.

Illustration by Nik Schulz

SET UP.

MATERIALS

[A] Scrap piece of ½" MDO plywood at least 6" square. Medium density overlay (MDO) has a smooth finish that looks nice.

[B] ½"×¾" pine strips (2) about 6" long each

[C] Aluminum sheet 0.01-0.02" thick (e.g. roof flashing), about 1' square

[D] Tinsnips

[E] Sewing needle

[F] Utility knife

[G] Jigsaw or scroll saw or band saw

[H] Drill and assorted bits

[I] Drawing compass

[J] English and metric ruler or calipers

[K] Flat black spray paint

[L] Roll of 120mm film and cheap, expired film rolls for testing (2) or one old roll and a spool

[M] Light meter or camera with a built-in meter (optional)

[N] Slide projector or slide scanner

[O] Tuna can or other source of springy steel

[P] Black silicone sealant

[Q] Pop rivet tool and pop rivets (rivets not pictured)

[R] Ball-peen hammer

[S] ⅜" threaded eye bolt (or thumbscrew) with matching nuts (2) and washers (2)

[T] #10×1" bolt with assorted matching nuts and washers

[U] ¼" #20 nut

[NOT SHOWN]
Epoxy or wood glue

Scrap piece of ¼" plywood at least 9" square

5⁄16" fender washer

¾" round-head wood screws (4) and 1½" round-head wood screws (4)

Cereal box cardboard

Staples or tacks

Electrical tape

320-grit sandpaper

Carpenter's square

Hacksaw

Metal file

Screwdriver any type

Block of scrap wood

Photography by Ross Orr

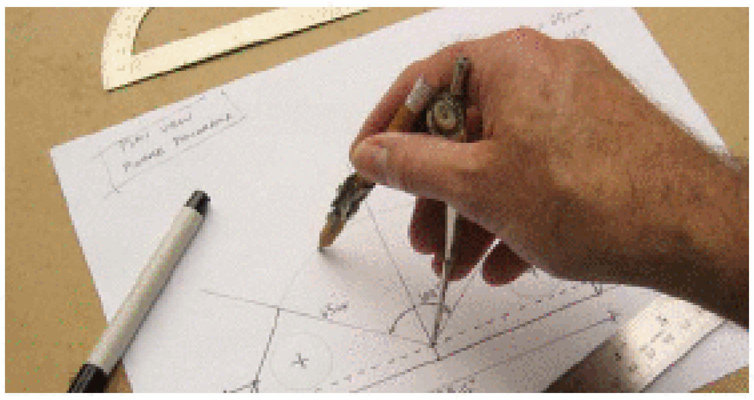
MAKE IT.

BUILD YOUR PINHOLE PANORAMA CAMERA

START **Time:** A Day or Two **Complexity:** Medium

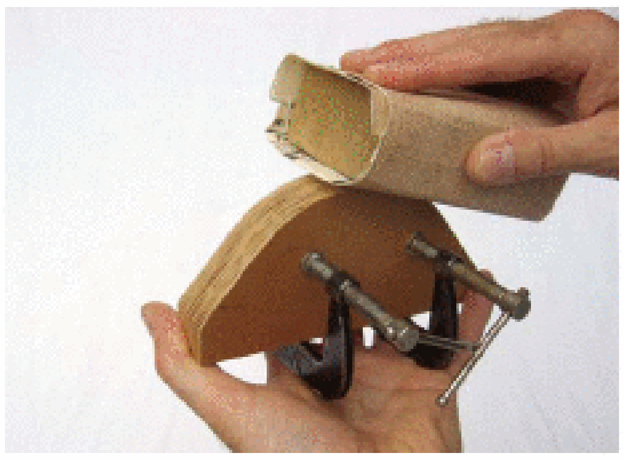
1. MAKE THE BODY AND WINDER

1a. Draw a paper template for the top and bottom pieces. We're going to cut 2 identical D-shaped pieces of plywood; the curved side is a 105° chord of a circle with radius 65mm (about 2.56"), which continues along tangent flat planes to form 2 corners that extend ¼" past the circle's center. Download the template I used at makezine.com/09/pinhole.



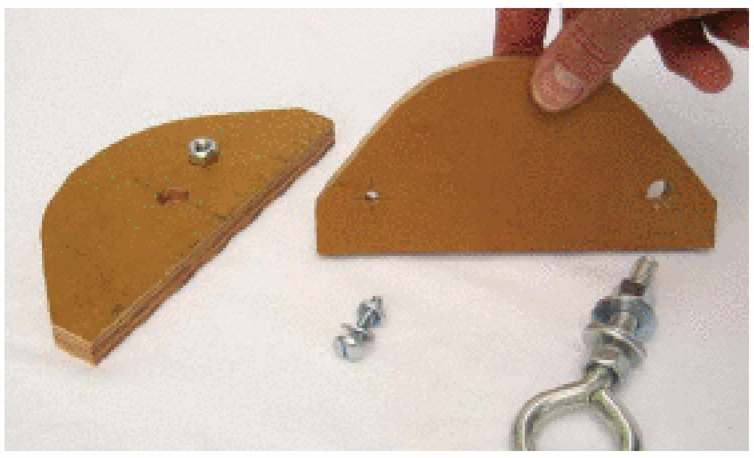
1b. Use a jigsaw or band saw to cut the ½" plywood into 2 D-shaped pieces, following your template.

1c. Clamp the 2 Ds together, and sand until the cut perimeters are smooth and matching.

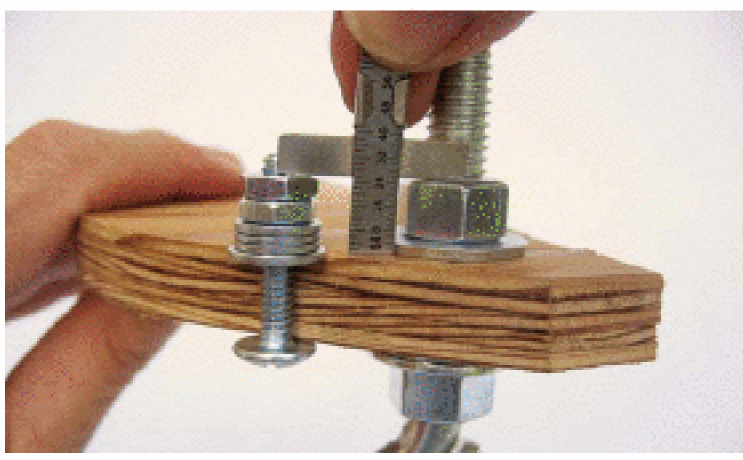


1d. Use the template to mark the spool centers on the top piece. Drill a ⅜" hole for the film take-up spool, which will be on the left as you face the camera's curved back. Drill a 3⁄16" hole for the supply spool on the right. In the center of the bottom piece, on the underside, drill a ½" hole partway through.

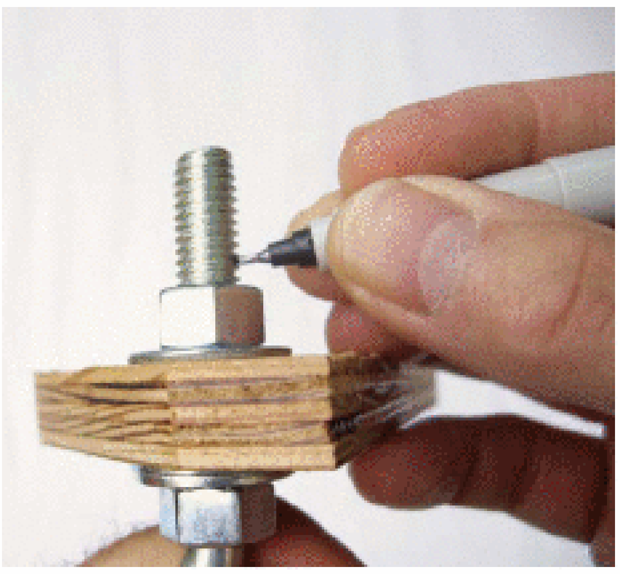
1e. Epoxy a ¼" #20 nut into the partial hole in the bottom piece, to make the camera's tripod mount.

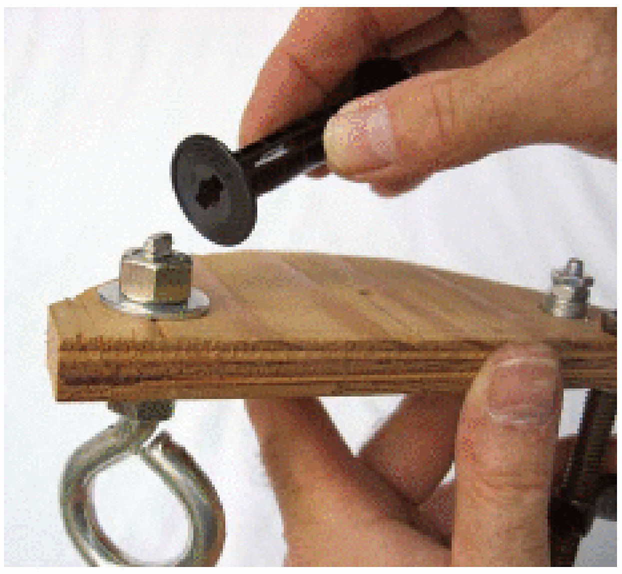


1f. Fit the ⅜" eye bolt through the top piece with nuts and washers on each side, then measure the distance that the nut opposite the winder eyelet will stick into the camera. Find a combination of washers and nuts that fits onto the #10 bolt (for the supply reel) and matches this height.



1g. Cut both bolt ends so each protrudes ⅛" beyond the nut face. Get an empty 120mm film spool from a friendly camera lab, or untape one from a cheap, expired roll of 120mm film; this will be our take-up spool. File the ends of each bolt flat on 2 sides, so that they engage the slot of the spool.

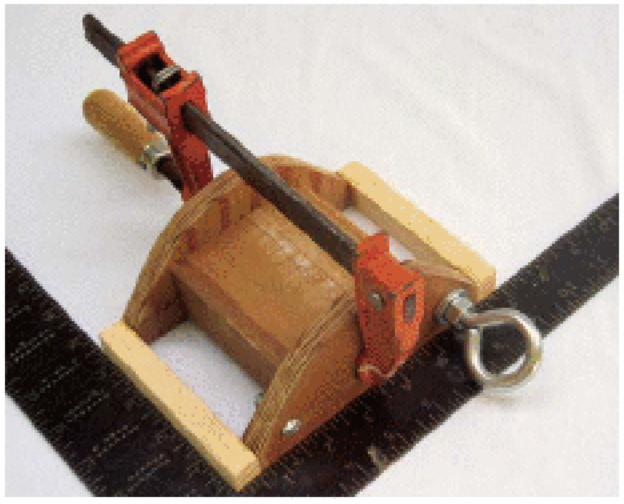


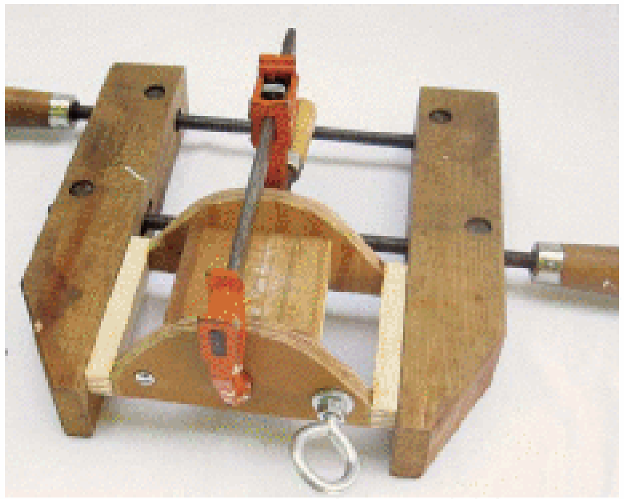


1h. Use thread-locking compound or mash the bolt's threads slightly to keep the nuts in place, so that the bolt assembly spins easily through the wood without loosening or tightening.

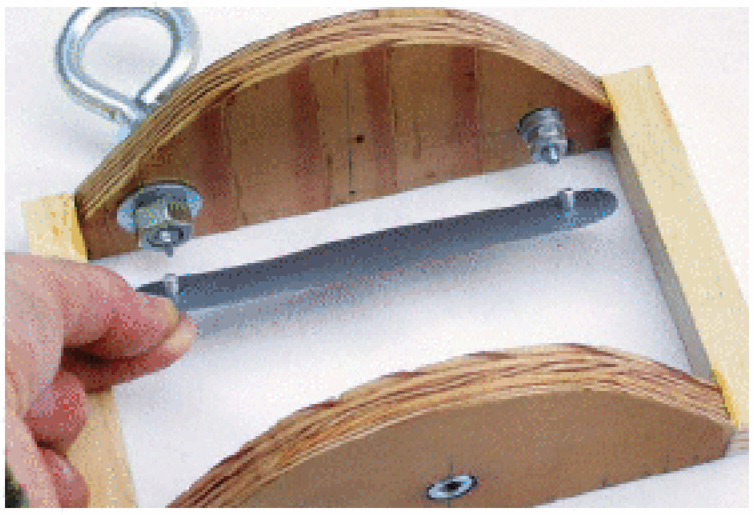
1i. Calculate the inside height of the camera by measuring the spool height and adding twice the height of the nut stacks; using this dimension will center the film vertically. Cut a scrap block of wood down to this dimension.

1j. Calculate the outside height by adding 1" (twice the plywood thickness) to the inside height, and cut 2 side rails to this length from the ½"×¾" wood. Clamp the top and bottom pieces around the scrap block, and glue on the side rails after making sure that all 4 pieces fit together evenly and are perfectly square.

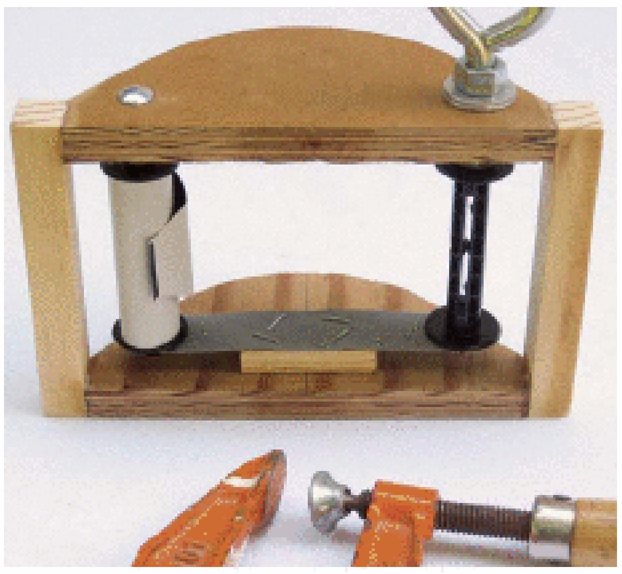




1k. After the glue has set, cut a 1"×5" strip of springy steel — I used the sidewall of a tuna-fish can. Drill ⅛" holes that exactly match the spacing of the bolts on the top, and then attach pop rivets through these holes. The rivet nubs will catch the bottoms of the film spools.

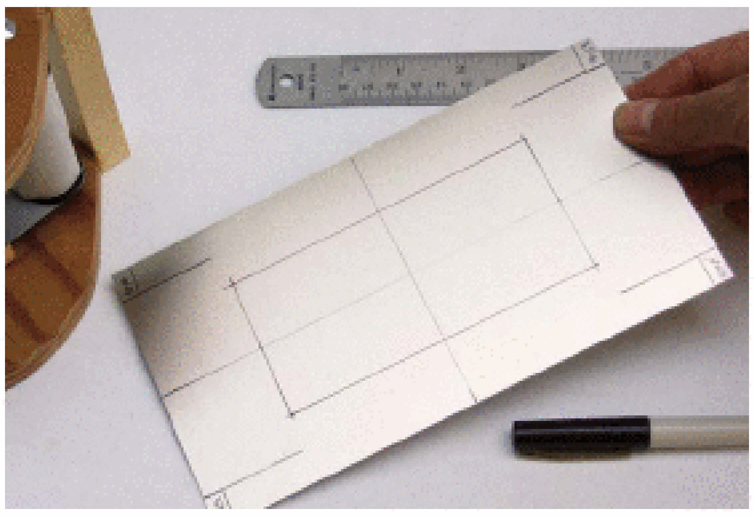


1l. Cut a small wooden block the same thickness as the nut stacks, and staple or tack the spring to it, centered. My block was ⅜"×1"×1½". Apply glue to the block and position it on the floor of the camera. Load the film and take-up spools between the spring nubs and the bolts, and slide the spring block around until the film spools are exactly vertical. Clamp, and let the glue set.



2. MAKE THE FILM GATE

2a. Cut aluminum flashing to the height of the camera body, and 8" wide. Draw a 2¼"×4¾" rectangle in the center. At each corner, draw lines that parallel the top and bottom edges, ½" in (to match the plywood thickness), and extending to the same longitudes as the sides of the rectangle. Measure the camera's curved plywood edge, and symmetrically mark the corners of the aluminum where the edge overlaps this distance. For example, my camera back measured 7¾" around, so I marked in ⅛" from each side.

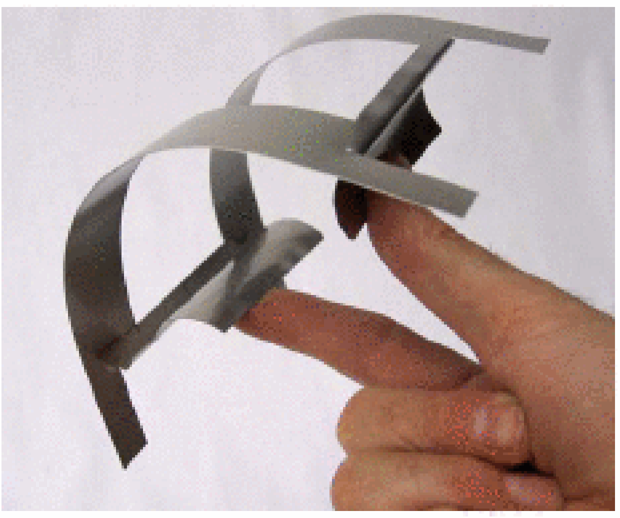


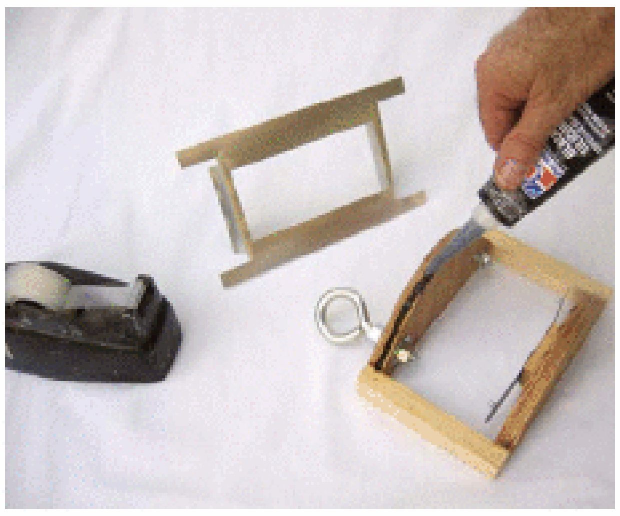
2b. Use tinsnips to cut along the 4 lines that extend in from the sides, and then cut the excess-overlap corners off of each piece, as marked. Then score the center rectangle lines with a sharp utility knife, and flex along the score lines to snap through the aluminum.

2c. Fold the 2 center flaps inward from each side, using a screwdriver shaft as a brake to form smooth, 90-degree bends. Sand any rough edges, especially around the opening in the center.

2d. Fit the gate around the back of the camera. Cut notches in the flaps so that they clear the spring strip, and carefully curl them around so they fit around the film spools.

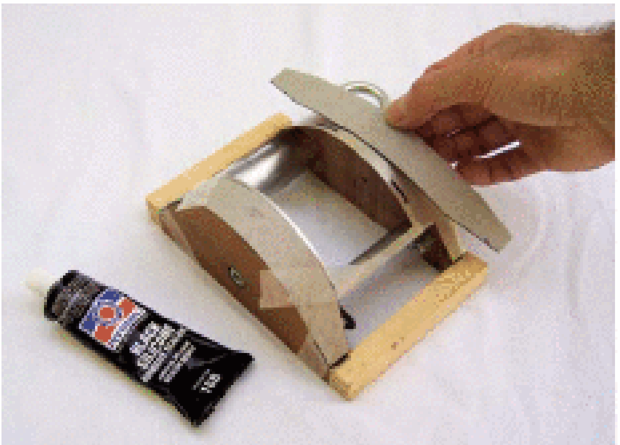
2e. Spread a thin bead of black silicone sealant along the plywood edges, position the film gate onto the back, and tape it into position until it cures.

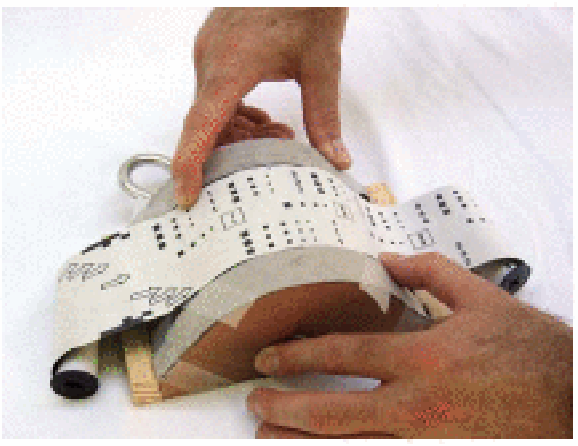




2f. Wrap your test film in position around the back of the gate (if it isn't centered, add or remove washers on the film-winder bolts). Mark the edges of the film on the gate.

2g. Cut 2 straight strips of cardboard from a cereal box, to use as guide rails for the film. Glue them in place along your marks on the gate with a thin layer of silicone. The film should easily slide between these guides with a little wiggle room.



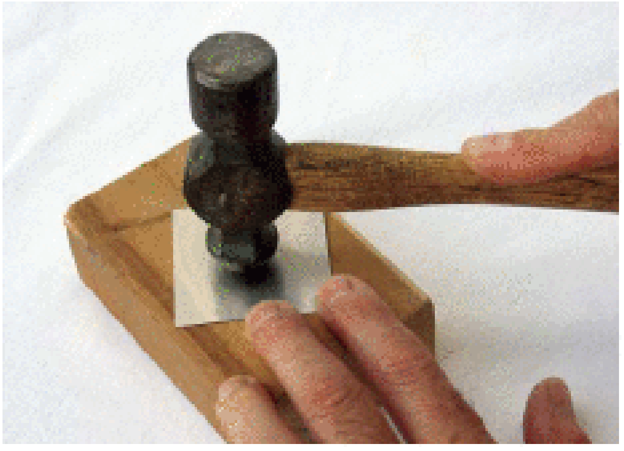


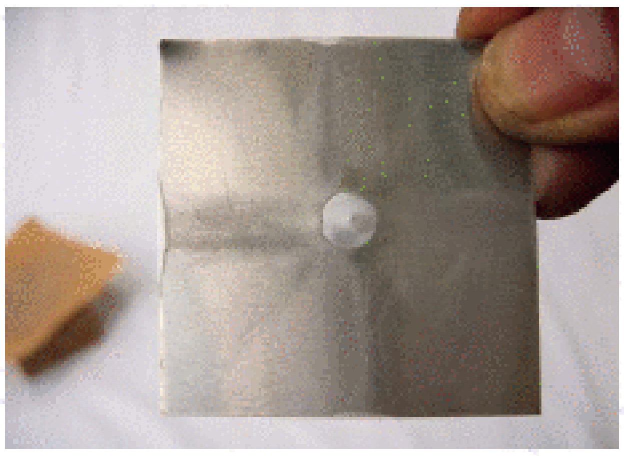
3. MAKE THE PINHOLE

3a. Cut several 1⅞" squares of sheet metal; we'll put a pinhole in each of these, and load them into a 35mm slide projector or slide scanner later to choose the best ones.

3b. For each square, use a ball-peen hammer to tap a small bump into the center of the metal.

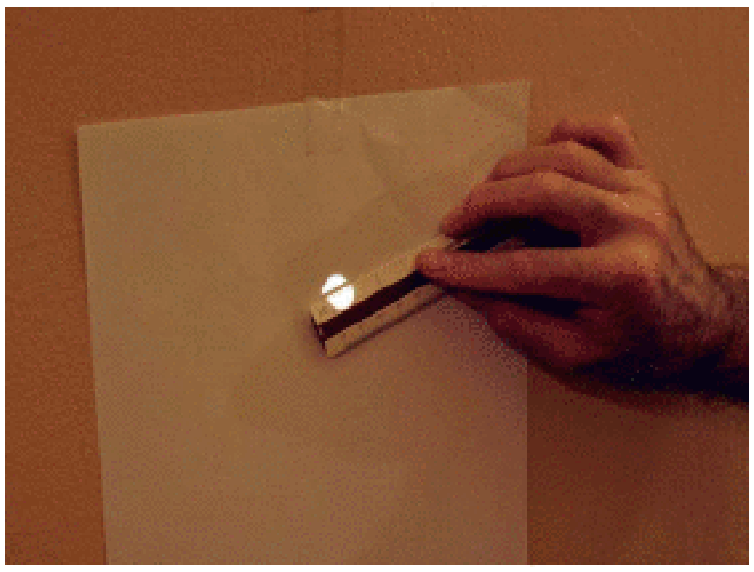
3c. Thin the bump with #320 sandpaper. Stop sanding when light pressure with a needle telegraphs a tiny dent through the other side.





3d. Back the bump against a phone book, and lightly press the needle until a hole shows through. Sand away any raised burr, blow through the hole to remove gunk, and check the diameter.

3e. Use a slide scanner or projector to check each hole's diameter and roundness. For our camera's 65mm focal length, we want a pinhole diameter of 0.33mm, plus or minus 20%. Focal length divided by hole diameter yields the equivalent f-stop, and we're aiming for about f/200.



With a scanner: Set the scanner to its highest resolution, scan the hole, and read its size by setting your image software's units to millimeters.

With a projector: Set the projector up so that a full 35mm slide image measures 52"×35". Load the pinhole into the projector, and look for the light spot to measure about ½" in diameter.

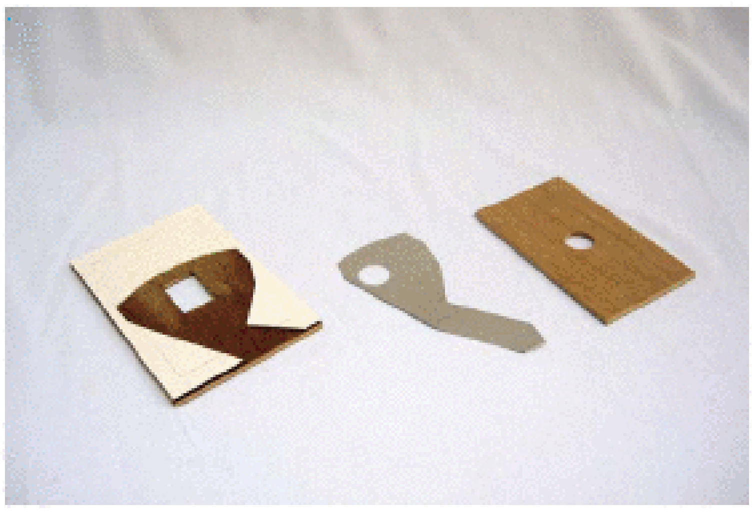
4. MAKE THE FRONT AND SHUTTER

With long exposure times, pinhole shutters can be very low-tech — a piece of black gaffer's tape will work fine but I like this simple "cigar cutter" design. The lip that's formed by the inner and outer panel edges deflects any light that leaks through the sides, making it disappear before it gets a direct line to the film.

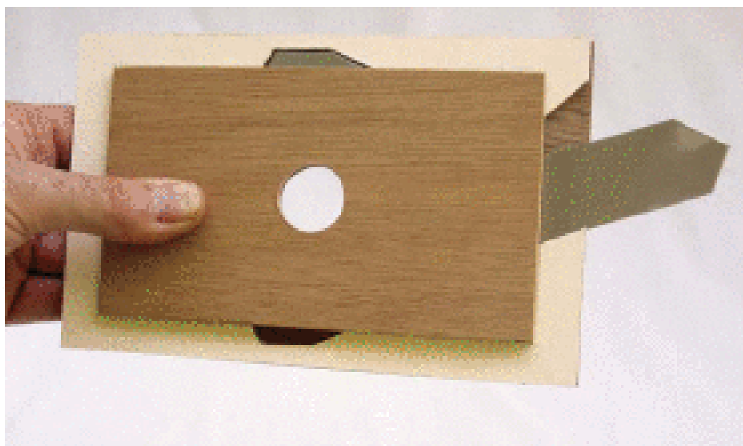
4a. Cut 2 rectangles of ¼" plywood, one to the camera front's inside dimensions and one to its outside dimensions. Mine measured about 4"×5¾" and 3½"×5¼".

4b. Drill a ⅞" diameter hole in the exact center of the smaller (inner) piece, and cut a 1"×1½" rectangle in the center of the larger (outer) piece. If you want to use a simple piece of tape as a shutter, glue these pieces together and skip ahead to step 4e.

4c. Use paper and a thumbtack to make templates for a pivoting shutter and the chamber it moves within. The pivot point will sit at the right edge of the front panel (if you're right-handed). pinhole by about 2"; this will be the shutter's inside edge. The chamber should limit the shutter's travel so that its hole swings between fully visible to fully tucked away. When you have shapes that work, cut the shutter out of aluminum flashing and the chamber out of cardboard.

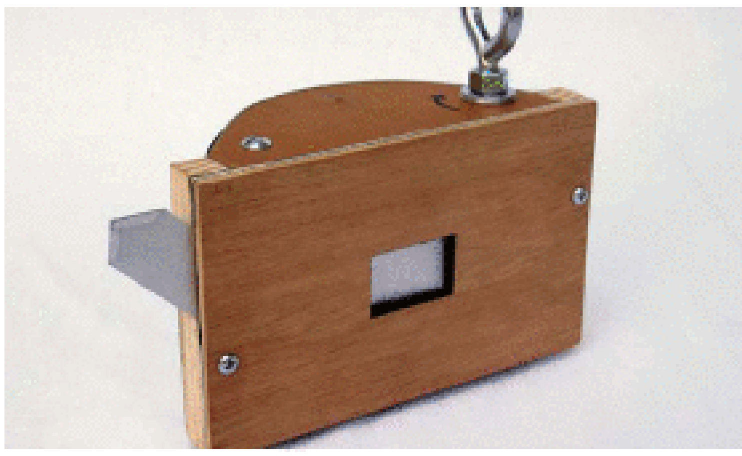


4d. Glue the cardboard chamber to the outer panel, thumbtack the metal shutter into place at the pivot point, and position the small panel in back. Test the shutter to make sure the alignment works.



4e. Disassemble the pieces, and spray-paint black both sides of the inner panel, and the back sides of the shutter and outer panel. Reattach the shutter and glue everything back together.

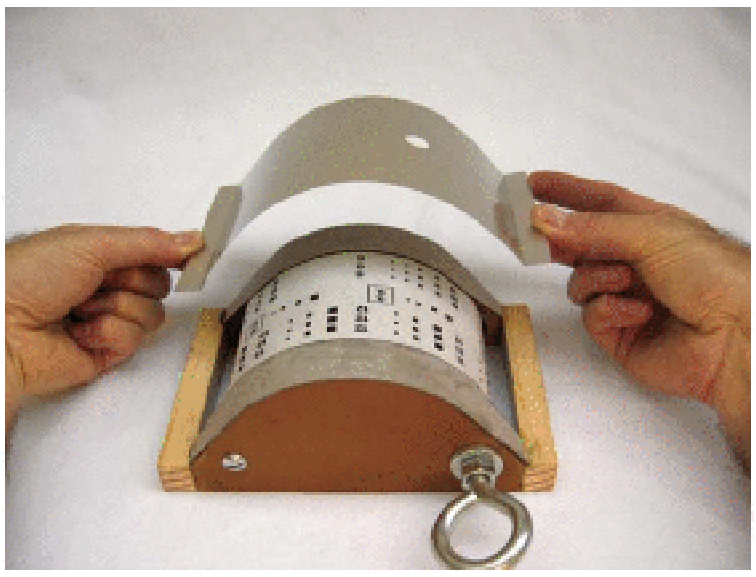
4f. Center the pinhole behind the rear opening and tape it in place. Hold the panel against the camera, point the pinhole toward some light, and sight along the edges of the film gate to check for any obstructions. The plywood shouldn't block any light from reaching the corners of the film.



4g. Drill clearance and pilot holes, and use two ¾" wood screws to attach the front panel to the side rails, in place.

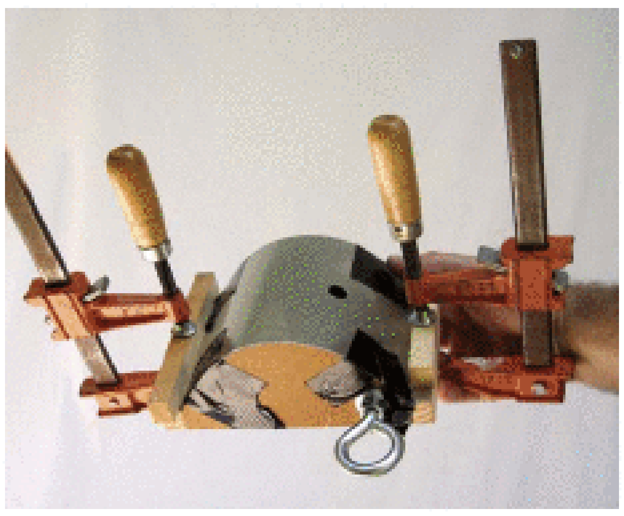
5. MAKE THE BACK

5a. Cut a piece of flashing to match the height and width of the camera back, bending ½" flanges for the side rails. Drill a ½"-diameter peep sight for the frame counter, offset 1¼" left of center. Put a small square of black tape over this hole; you'll keep it there to cover the hole whenever you aren't winding the film.



5b. Spray-paint black the inside of the back piece you just cut, and the interior of the camera itself. But don't paint the wooden side rails, which you'll be gluing, or the gate where it touches the film. Mask these areas with tape before spraying.

5c. Glue down the back with a sparing amount of silicone, to avoid squeeze-out into the film path. Tack and clamp the side flanges to the wood rails, and hold the back against the D's with tape until the silicone cures.



5d. That's it! Your camera is now ready to use.

NOTE: The finished camera shown above includes an optional viewfinder. To see the step-by-step process for making the viewfinder, please go to makezine.com/09/pinhole.

FINISH X

NOW GO USE IT »

USE IT.

JOIN THE PINHOLE PAPARAZZI

120MM FILM

Once you remove 120mm film from its foil pouch, the only thing that keeps ambient light from exposing it is the backing paper at each end of the roll, and the fact that it's wrapped so tightly around the spool. So be careful, and don't reload in the sun.

Choose 100- or 200-speed negative film. Anything faster makes sunny-day exposures too brief to time accurately. I recommend Fuji's Superia color and Acros black-and-white films.

LOADING THE CAMERA

When the roll is done, you don't rewind; instead, wind it all onto the take-up spool. The original inner spool becomes the take-up for your next roll.

1. Unscrew the front of the camera, unspool a few inches of backing paper, and use your (moistened) fingertips to fish the paper through the film gate.

2. Tape the paper onto the take-up spool, wind it one turn, and then close up the camera.

3. Wind until the "1" shows in the peep sight. You're on a roll, and ready to shoot! (After each winding, stick the black tape back down over the hole.)

TAKING PHOTOS

With the viewfinder, you will need to move your eye around to see all the edges of the frame.

After every shot, wind to the next odd number, so you don't accidentally double-expose. This yields 6 double-width panoramas per roll.

With 100-speed film, try 2-second exposures in sun, or 10 seconds in bright shade. At this slow shutter speed and camera height, you'll need a tripod to keep your images sharp. In a pinch, resting the camera on a flat surface will work, too, but be careful not to jiggle the camera while exposing the film. For other light conditions, use a light meter or another camera to get exposure times. Your Pin-o-rama has an f-stop of about f/200. Few light meters give readings for f-stops this high, but you can take the shutter speed indicated for f/16 and

multiply the time by 150. Don't hesitate to double or triple the calculated time. Negative films are tolerant of overexposure. To time exposures without looking away from the subject, hold a watch to your ear and count ticks.

FINISHING A ROLL

After exposing shot #11 (the sixth and final shot), keep winding until the paper backing disappears from the peep sight. Open the camera in dim light, and use the adhesive band to tape the roll tight. (If you find the take-up reel has wound too loosely, add more spring pressure on the supply spool.)

Any lab or camera shop that caters to professionals can develop your 120mm negatives for about $5. The 6×12 format is nonstandard, so they should develop the negatives only, and return them uncut. Then you can scan them yourself with a flatbed film scanner. The generous negative size means that even a budget scanner will do a decent job — resolution is a non-issue given the softness of pinhole images. (Darkroom prints are possible too, using a 4×5 format enlarger.)

For pinhole photography resources and additional information go to makezine.com/09/pinhole.

PIN-O-RAMA PHOTO GALLERY

The Pin-o-rama camera design was a brainwave from early 2006. Since then, I've loved exploring how it transforms familiar scenes from my hometown into fresh and surprising images.

Big Boy The limitless depth of field of a pinhole lets you move as close as you want to your subject, while leaving distant details sharp — making all kinds of playful juxtapositions possible. The Pin-o-rama's curved perspective, so obvious when manmade straight lines are in the frame, is much less noticeable when they're absent. With this camera's wide, cinematic framing, I like compositions where the subject is strongly off-center.

Cafe Scene This one is a sentimental favorite from my first test roll with the Pin-o-rama prototype. During the 9-minute exposure, people got up and sat down, unaware that the strange object resting on my table was taking a photograph. The clock's minute hand also has blurred into nothingness. At the time, I had no idea what this camera's images would look like, but after pulling the film out of my developing tank, I was delighted.

PINHOLE PORTFOLIOS

See more of Ross Orr's pinhole photographs at flickr.com/photos/vox/tags/pinorama

Homemade Pinhole Flickr Group: flickr.com/groups/homemadepinhole

Liberty Plaza Tree Lights
I started this 15-minute exposure just as daylight was fading from the sky — slightly self-conscious about loitering in a darkened park with my unidentifiable apparatus. I was surprised that on the negative, it's quite noticeable that the pinpoints of light shatter into tiny ripples, from the diffraction of light waves passing through the pinhole. In the background, the taillights of cars creeping by in stop-and-go traffic add their own sparkle to the scene.

Liberty Block Darting into the street between passing cars, I set down my tripod to make this exposure of a nice old commercial block in downtown Ann Arbor, Mich. The couple waiting at the crosswalk stood motionless enough during the 3-second exposure to register on film, but another shopper walking through the scene dematerialized completely. The glint off the window was pure serendipity; pinhole photography seems to invite fun surprises and accidents.

Peaches Pinhole photos can evoke mysterious, even somber moods. But I enjoy working against that stereotype, seeking out subjects that are vibrant and colorful. Strong crossing light can provide extra punch and contrast. I also sometimes use Photoshop's Unsharp Mask filter in an unconventional way: with a very large radius and the amount set to about 12%, to lift the "fog" from pinhole images and regain the brilliance of the original scene.

Yellow Bakery Vertical I've always enjoyed how the afternoon sun lights up this brightly painted neighborhood bakery. This was shot using a Kodak pro film 3 years past its expiration date; any minor color shifts are easily corrected when scanning. Historically, the biggest users of 120 film were wedding photographers and other professionals. But these shooters migrated to digital so abruptly that camera stores often have excess out-of-date rolls for sale, at half price or lower.

THE $5 CRACKER BOX AMPLIFIER

By Ed Vogel & Blind Lightnin' Pete

BIG SOUNDS FROM A SMALL PACKAGE

In MAKE, Volume 04, I presented my version of the venerable cigar box guitar. The instructions for the project included adding an electric pickup so you could play the guitar through an amplifier.

People from around the world emailed me to tell me they'd built cigar box guitars based on my instructions. I struck up a conversation with one gentleman from Europe who goes by the moniker Blind Lightnin' Pete. He made a couple of beautiful cigar box guitars, including one he calls the Vintage Blues Texas Rattlesnake Special model. He then went one step further, and built a cracker box guitar amplifier. This outstanding little amp cost all of $5 to build (depending on where you get the parts). Pete kindly allowed me to modify his design and present it as a project for you to build. (See page 111 for a word from Pete about the origins of the cracker box amp.)

My amp differs a little from Pete's because I wanted to make a workable little practice amp with parts and tools that could be purchased "one-stop shop" at RadioShack and built in an hour.

Photograph by Sam Murphy

Set up: p.107   Make it: p.108   Use it: p.111

Ed Vogel lives in Minneapolis and believes that nothing may just be the next big thing.
Blind Lightnin' Pete is the online pseudonym of Howlin' Mississippi Slim.

THIS BOX ROCKS

Hi-Carb Sound

The heart of this surprisingly loud, clear-sounding, battery-powered guitar amp is National Semiconductor's LM386 series low-voltage op-amp IC. Two potentiometers in the circuit control the gain and the volume. For the cleanest sound, turn down the gain knob all the way and turn up the volume knob to the maximum. Then slowly turn up the gain. For a raunchier, distorted sound, start with the volume knob all the way down, and the gain knob at maximum. Then crank up the volume. You can achieve lots of different sounds by playing with the knobs. Experiment!

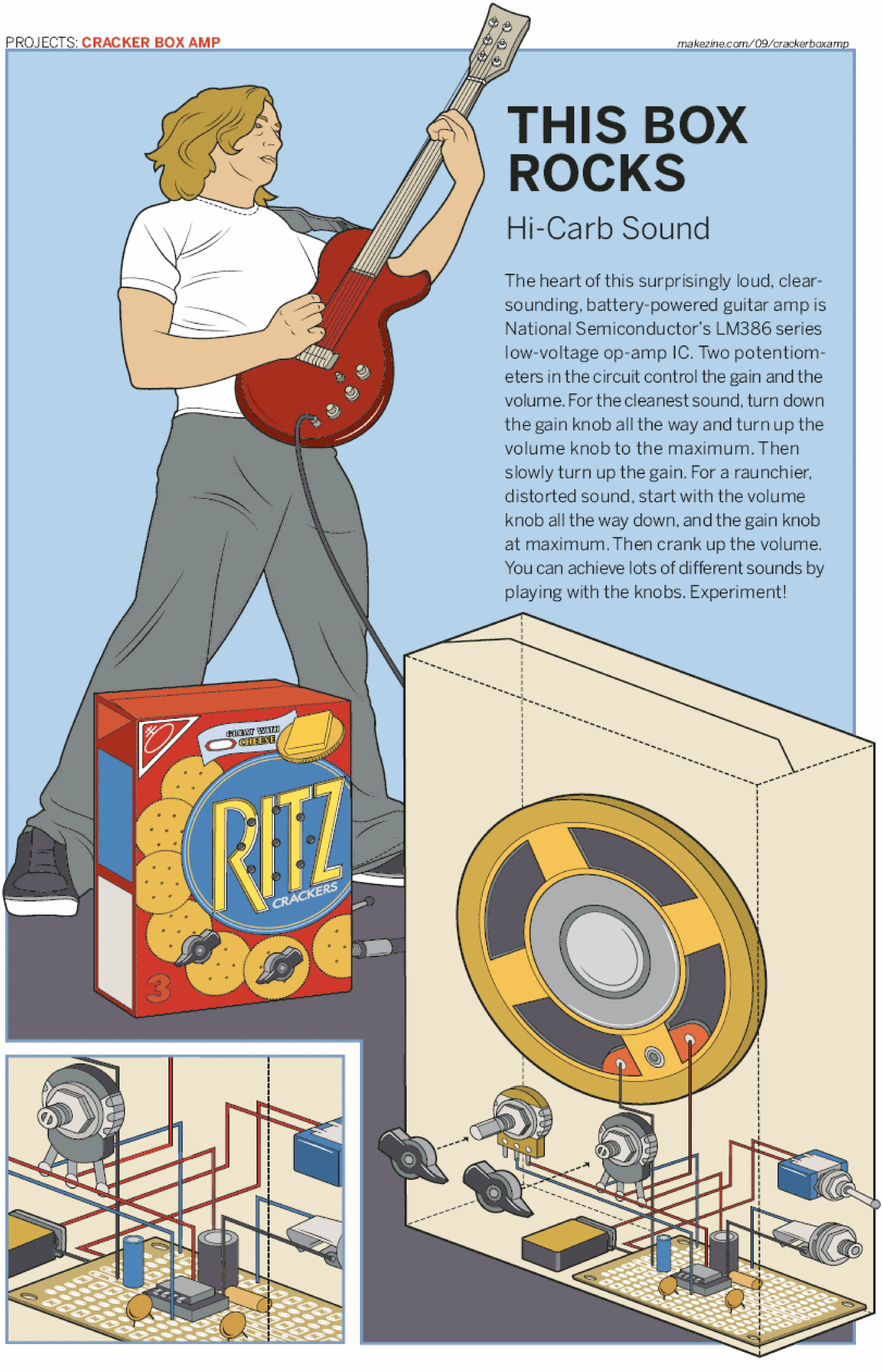


Illustration by Timmy Kucynda

SET UP.

MATERIALS

[A] A box of some sort or another (cracker box shown)

[B] Toggle switch, single pole single throw

[C] 9V battery

[D] Battery connector

[E] 0.047μF capacitor

[F] 220μF capacitor (biggest)

[G] 0.01μf capacitor

[H] 100μf capacitor

[I] Hookup wire, 20 or 22 gauge AWG solid core is best.

[J] 5KΩ potentiometer (audio or log taper)

[K] 25-ohm (25Ω) rheostat

[L] LM386N audio amplifier

[M] 8-pin DIP IC socket

[N] Chicken head knobs (2)

[O] Prototyping PC board

[P] Soldering iron

[Q] Solder

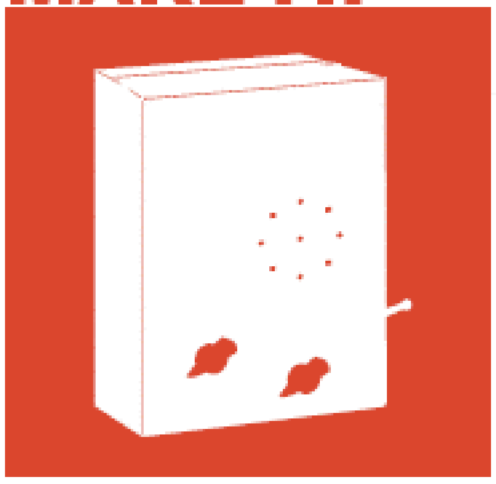
[R] Speaker, 8Ω impedance

[S] 10Ω resistor

[T] ¼" mono phone jack

[NOT SHOWN]
Speaker grill (optional)
Glue gun

MAKE IT.



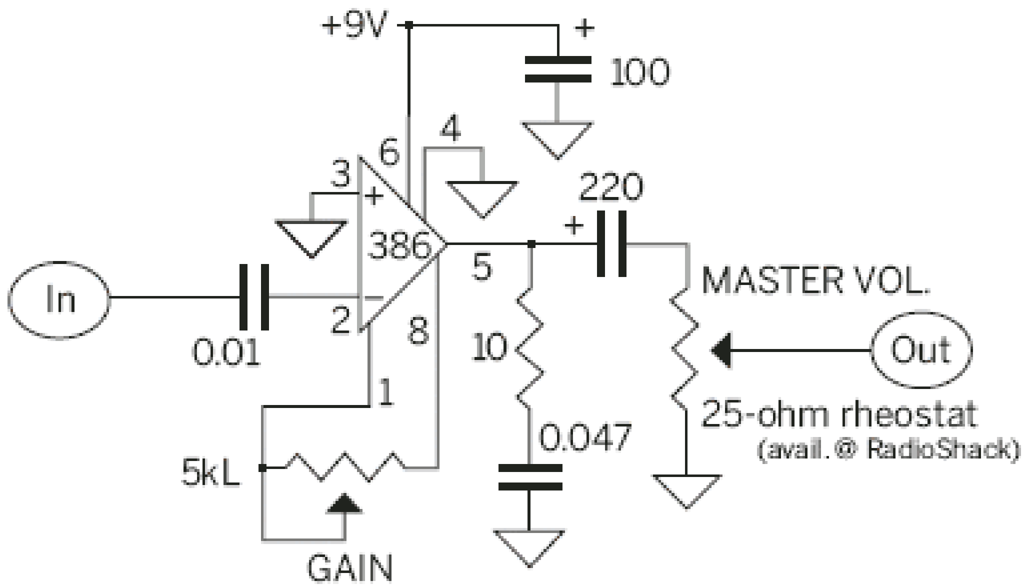
BUILDING THE CRACKER BOX AMP

START

Time: An Afternoon Complexity: Medium

1. MAKE THE CIRCUIT

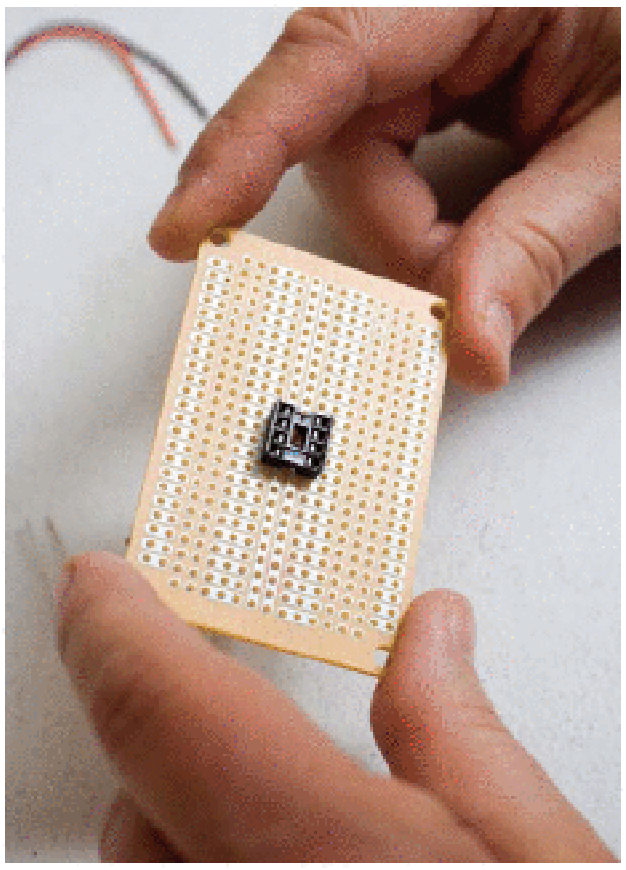
1a. Make a copy of this schematic, or download the PDF at makezine.com/09/crackerboxamp and print it out.

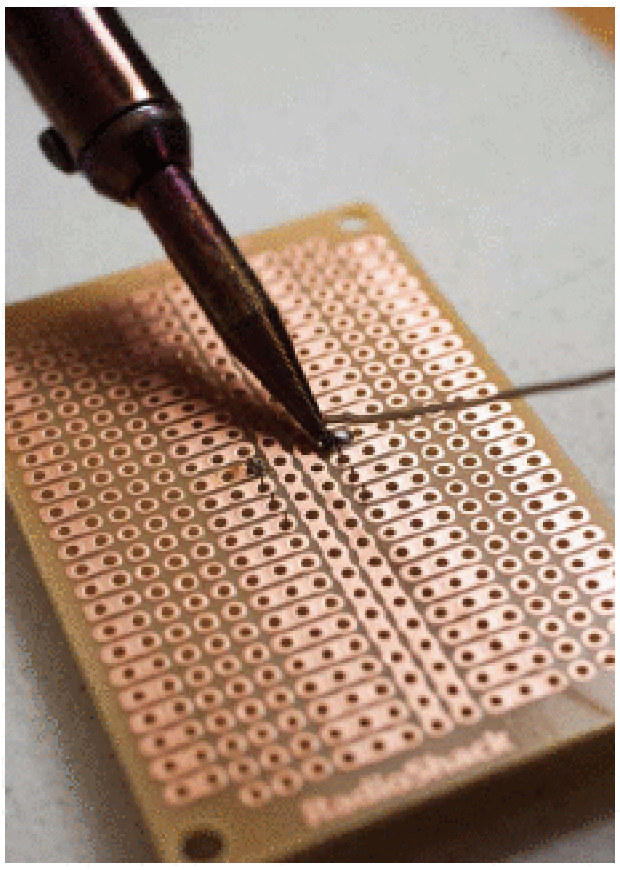


1b. Install the socket in the printed circuit board.

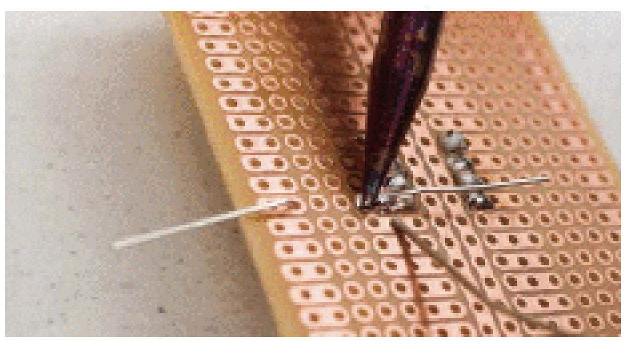
1c. Solder it down.

1d. Install the chip. I like having the chip in the printed circuit board while I build because there can be no doubt as to where pin 1 is. This is also why I install parts and make wire connections on the top of the printed circuit board.



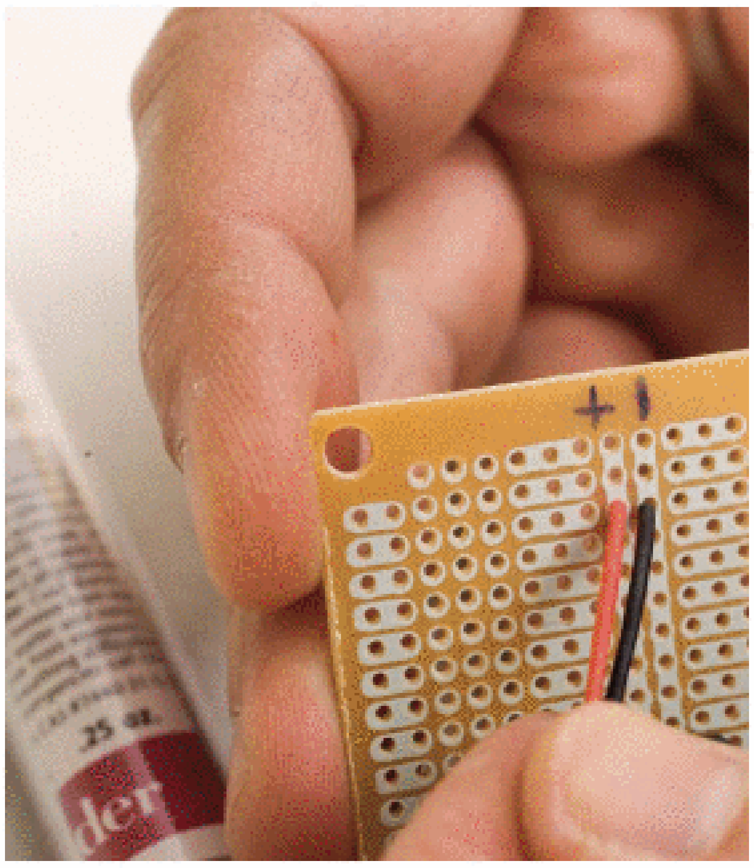


1e. Install the 0.01µF capacitor so one leg connects to pin 2 of the chip and one leg is in a "proto row." Flip it over and solder it.



Photography by Ed Vogel

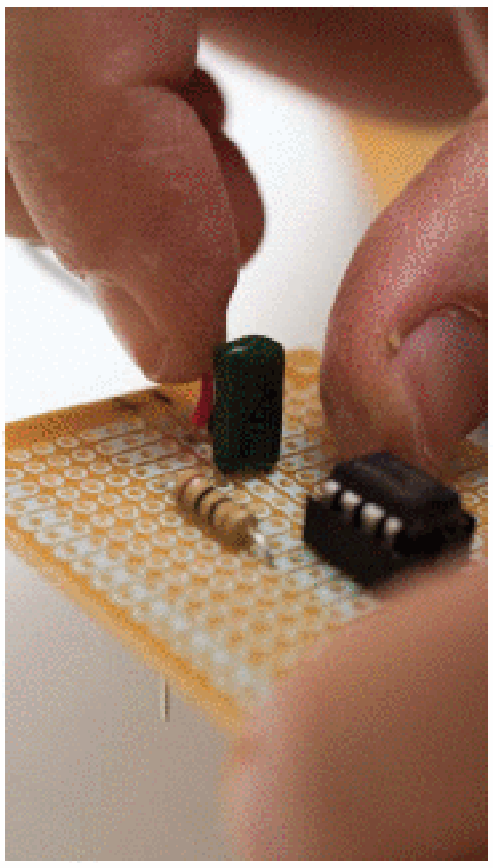
1f. Install the 9V battery clip and mark a plus sign for the red wire and a minus sign for the black wire.



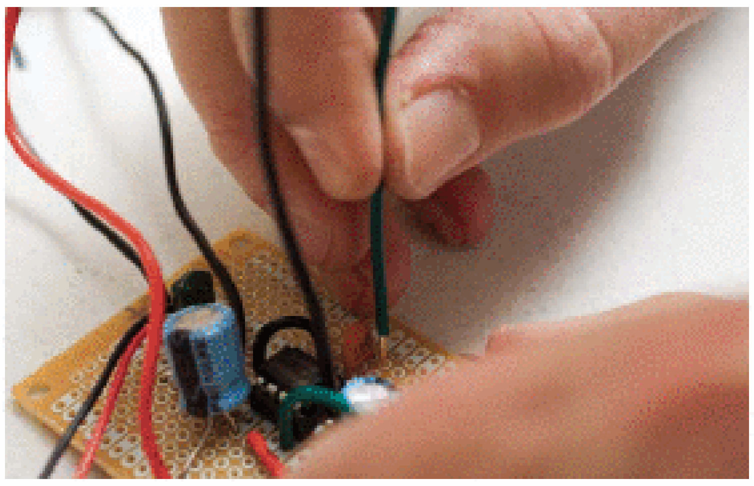
1g. Install the 10Ω resistor and the 0.047μF capacitor. Take advantage of the "proto rows" to make the connections:

- Chip pin 5 to one leg of the 10Ω resistor.
- The other leg of the 10Ω resistor to one leg of the 0.047μF capacitor.
- The other leg of the 0.047μF capacitor to "ground."

For our purposes "ground," which is shown on the schematic as a triangle with the point down, is the long "proto row" we marked with a minus sign.

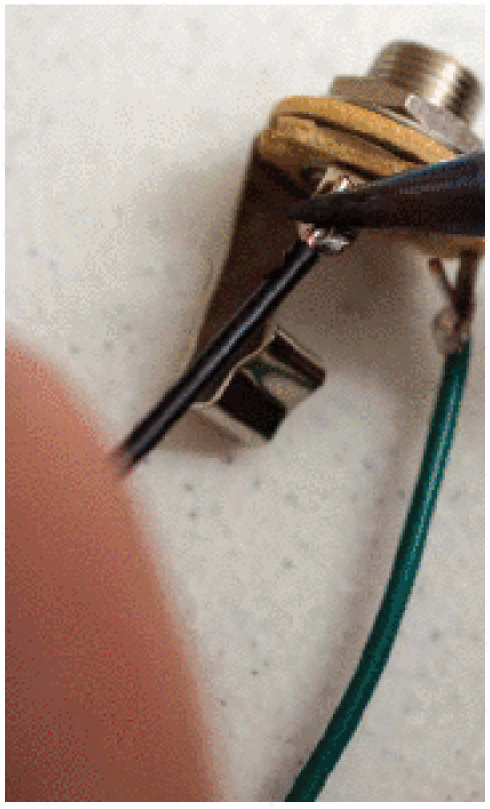


1h. Use this same technique to install and make connections.

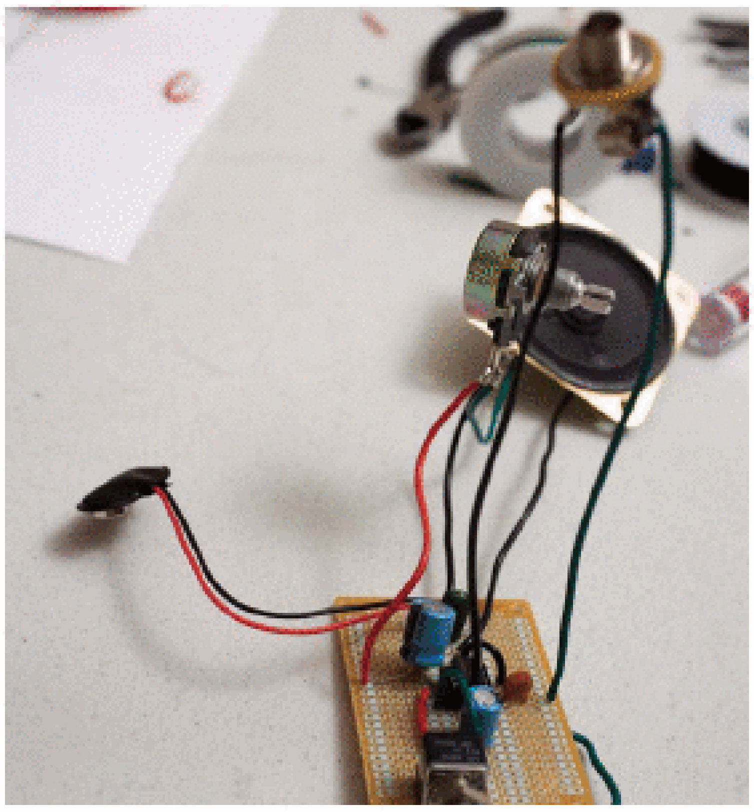


TIP: Every time you install a part or make a connection, mark it off on the schematic ("Little Gem" schematic courtesy of runoffgroove.com/littlegem.html).

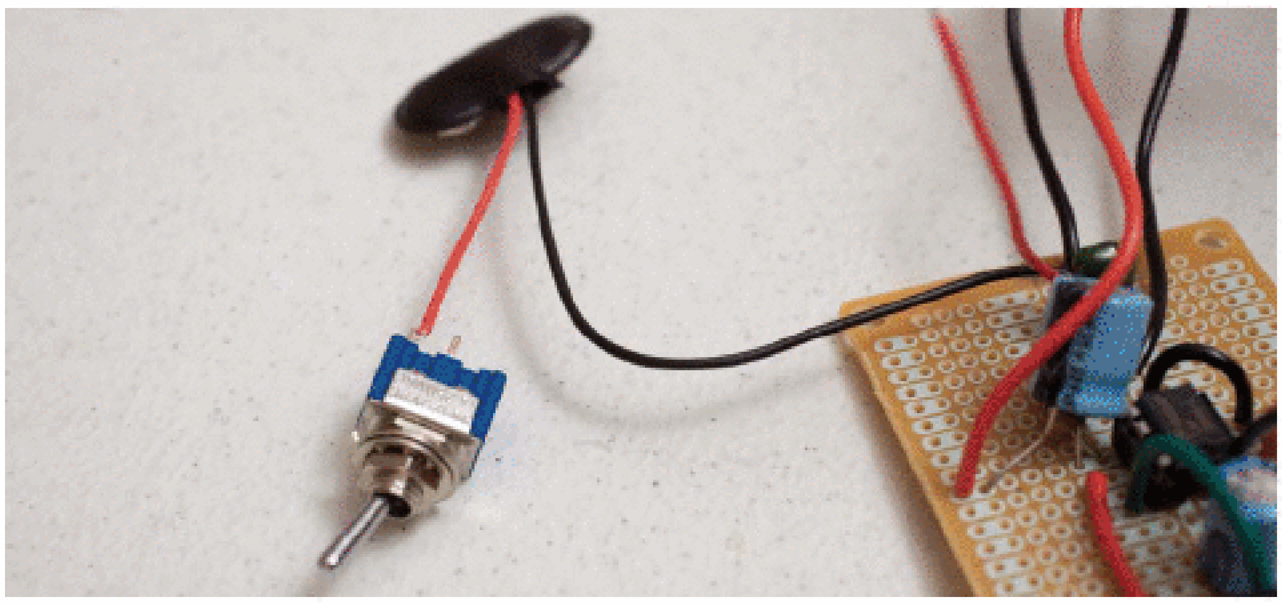
1i. Solder the wires to the phone jack. Use green for signal and black for ground.



1j. Install the wired phone jack to the circuit. You should end up with something that looks like the photo to the far right here.



1k. Cut the red lead and install the switch.



2. BUILD THE ENCLOSURE

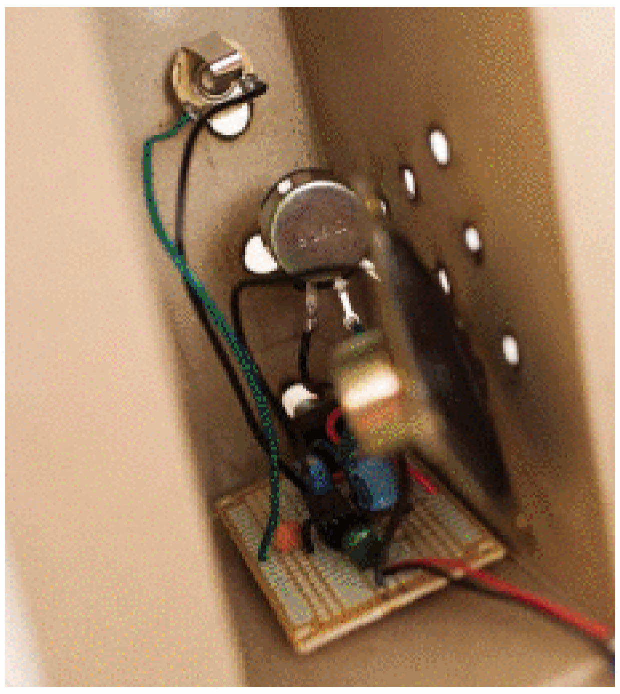
2a. Make holes in the side of your box to fit the potentiometer, rheostat, and phone jack.

TIP: Why bother with drills and X-Acto knives when you can use your soldering iron to make holes?

2b. Make holes for the "speaker grill." You are going to find some hanging chads on the inside of the box. Reach in there with the soldering iron and burn them off.

2c. Make a hole for the switch.

2d. Pop your circuit into the box.



2e. Mount the speaker. Make some big glops of hot glue to act as "standoffs" on the speaker.

2f. Mount the switch.

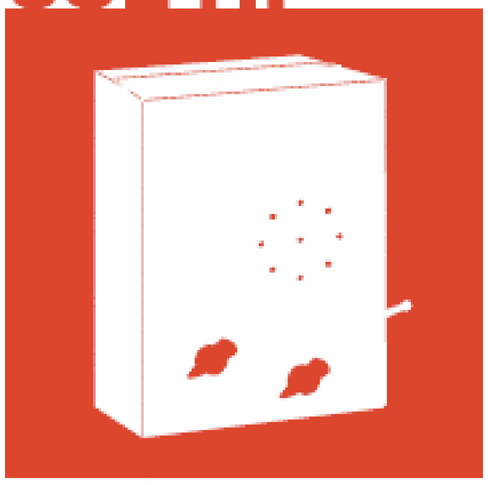
2g. Install the chicken head knobs.

NOTE: It's a proven fact that chicken head knobs greatly enhance the vintage sound of an amplifier. Use them liberally.

FINISH X

NOW INSTALL A BATTERY AND GO USE IT! »

USE IT.



THE ORIGINS OF THE CRACKER BOX AMP

Blind Lightnin' Pete's cracker box amp.

A FEW WORDS FROM BLIND LIGHTNIN' PETE

The cracker box amp I built cost $5. It uses an 8-pin National Semiconductor LM386 series low-voltage op-amp IC. The amp circuit unleashes the full potential of this beast and creates ¼ watt of arena-shaking power. Think of it as sort of a silicon shrunken head of the Marshall stack that Jimi Hendrix played at Monterey.

This integrated circuit has provided the basis for low-power solid-state amplifiers in recent years, including the famous Smokey Amp and a few of the designs at runoffgroove.com.

You can buy an LM386 for under a buck; it's a standard RadioShack item, the same one that was used in the MAKE project for turning your old computer mouse into a robot (*see MAKE, Volume 02, page 96, "Mousey the Junkbot"*). Our favorite hobbyist robot supply source, Solarbotics (solarbotics.com), sells them for 75¢ a piece.

I added a couple of capacitors, a couple of resistors, an LED, a ¼" jack, a potentiometer, and a $2 speaker, wrapped it all in a big blob of solder, crammed it in whatever empty box was laying around, and voilà!

The pot controls the gain, and it goes from California clean vintage Fender to Santana Mesa Boogie crunch to Hendrix Marshall. It runs off any combination of batteries — I usually use a 9V, but it's possible to get a cleaner tone with 12V (8 AA batteries in series). I have used it to drive a 4×12 Marshall cabinet, and it gets pretty loud. Not loud enough to compete with a rock drummer, but loud enough for me not to hear my wife screaming "turn it down," which I guess is enough for household use. If we had any neighbors, I could raise some complaints from it. Let's just say that even with a 2" speaker it's plenty loud enough for most apartment dwellers.

Interested in learning a bit more about the LM386? A great place to start is National Semiconductor's website (national.com) where you can download the data sheet. Even better, if you take the time to register on the site, they will generously send you a few samples for free!

Ask for the LM386N-4 series, as these are rated to handle up to 18V. Although any of the LM386 chips will work wonderfully for our hi-gain design, several experimenters and makers have found that cleaner tones with more headroom are achievable by running the circuit with a few extra volts.

OTHER OP-AMP 386 PROJECTS

Home-built bat detector:
bertrik.sikken.nl/bat/my_div.htm
Mini bench amp to test audio circuits:
makezine.com/go/minibench
Headphone amplifier:
radiowrench.com/sonic/so02144.html

See videos of Blind Lightnin' Pete playing his cigar box guitar through his cracker box amp at makezine.com/09/crackerboxamp.

Photography by Blind Lightnin' Pete

PROTOTYPE THAT

When Kevin Binkert moved into the old Standard Metal Products (SMP) building in San Francisco's South-of-Market neighborhood 15 years ago, all that remained of the 1920s metal foundry was a metal plaque. In homage, Binkert revived the name and built out an atelier that melds the most modern Computer Numeric Control machines with traditional hand tools.

As a maker-for-hire, Binkert has prototyped a handheld blaster for brain tumors, engineered hydrant valves for San Francisco's fire department, produced custom parts for the city's Italian streetcars, and restored two historic clock towers.

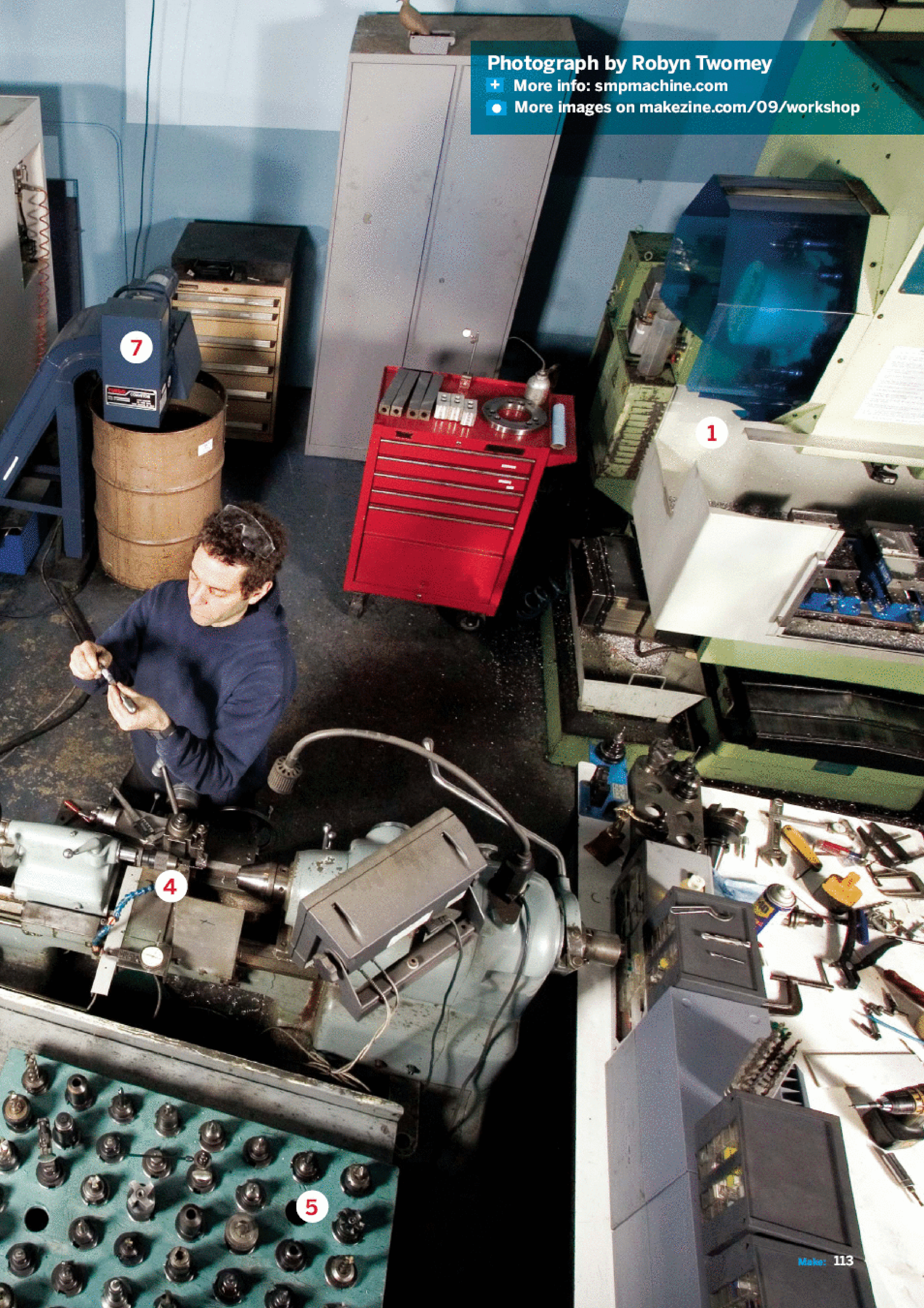
In between commercial jobs, he worked on the Spirit of America, a 45,000-horsepower jet vehicle that tore through the desert at an unofficial record speed of 675 mph; built The Spinner, a Ford V8-driven machine that whips braided cables to deafening supersonic speeds; and unleashed the Flame Tornado, a gas-powered sculpture that spews a 40-foot-tall vortex of fire.

These days, he's taking his talent to the small screen for *Prototype This!*, a forthcoming Discovery Channel TV show produced by *MythBusters* creators Beyond Productions. Binkert and MAKE contributor Joe Grand are among the five hosts.

Binkert's DIY career began in post-college jobs at movie special-effect houses. His defining maker moment came when he joined machine performance provocateurs Survival Research Laboratories (*see MAKE, Volume 07*) in 1989.

"I think that around retirement a lot of machinists start realizing they can make art with their tools," Binkert says. "I got into this the opposite way." —*David Pescovitz*

1. Okuma three-axis milling machine, known for its reliability and accuracy. 2. Mori Seiki CNC lathe used by its previous owner to machine parts for high-speed centrifuges. 3. Marvel cut-off band saw. 4. Monarch Model EE lathe, arguably the best manual lathe ever. 5. Cat-40 tools for the Okuma. 6. Wheel balancer machined for an SF streetcar. 7. Chip conveyor catches the scraps from the CNC and drops them in the steel drum. Periodically, a man named Luther retrieves the material for recycling. 8. Dentures left by dentists who commissioned a custom denture-cutting tool. 9. Arbor press for installing bearings and pins.



Photograph by Robyn Twomey

+ More info: smpmachine.com

● More images on makezine.com/09/workshop

1+2+3

Curie Engine

By John Iovine

Changing the temperature of nickel wire turns heat into motion.

You will need: A bit of low-Curie nickel alloy wire, 1" or larger neodymium "super magnet," copper wire, birthday candle, brass screw and nut, small steel plate, glue or wood screws, 4"×¾" wooden slat, 2"×1¼"×½" wood block. Nickel wire and magnet, or a full kit, are available for purchase at makezine.com/go/heatengine.

1. Put it together.

Glue or screw the steel plate and 4" slat to the wood block base as shown below. Drill a pilot hole, and screw the brass screw at the top of the slat. Drill a ¼" hole in the base about 7⁄16" from the steel plate end. For complete measurements, go to the website listed above.

Wrap about 1" of nickel alloy wire around a pencil to make a coil. Take 4" of copper wire, and twist the coil onto one end. Make a 90° bend in the copper wire 1½" down from the end with the coil, and cut the other end so there's 1" after the bend. Hook the wire bend onto the brass screw, with the coil on the side nearer the steel plate.

2. Test the wire and magnet.

Place the neodymium magnet onto the metal plate. The wire should swing up to meet the magnet, pulled by the nickel alloy coil. Push down and release the wire, and it should swing back up. Insert a birthday candle in the base, and adjust the magnet position and wire so the coil is suspended above the wick.

3. Light the candle.

Light the candle. The wire should swing down and up repeatedly, out of and back into the candle flame. Like ordinary iron or steel, the nickel-iron alloy is magnetic, but it has a much lower Curie point — the temperature above which it loses its magnetic properties. (The copper wire and brass screw are not magnetic.) When the coil heats up to this point, it is no longer attracted to the magnet, so it falls away and out of the flame. As it cools, it becomes magnetic again and swings back up, over and over again, until the flame burns too low to touch the coil.

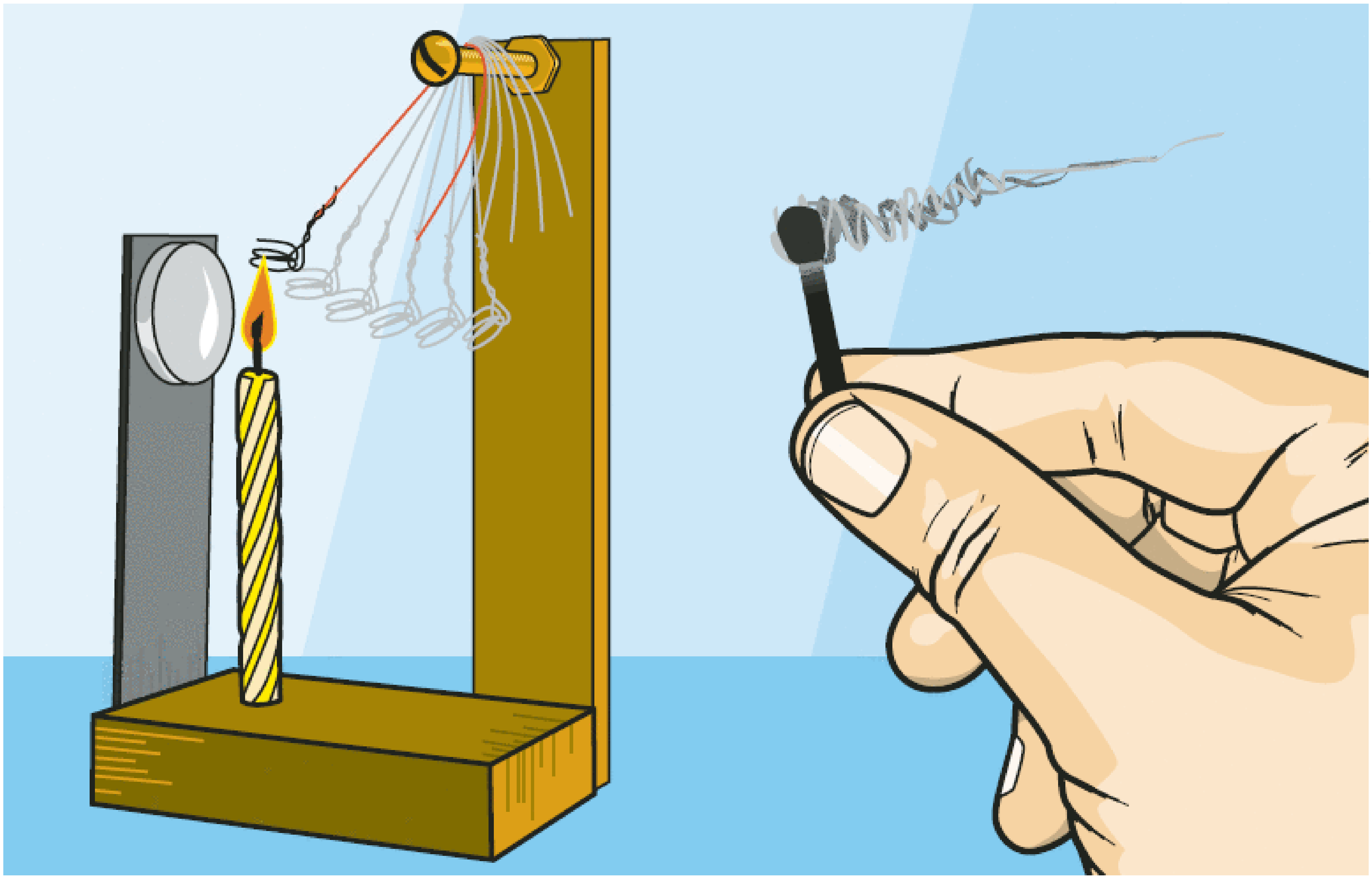


Illustration by Dustin Hostetler

John Iovine wrote the Kirlian Photography article on page 66.

STRUNG OUT

Make a one-string electric guitar from plastic tubing. By Tom Zimmerman

Photograph by Sam Murphy

This project will show you how to build an amazingly inexpensive and rad-looking one-string electric guitar out of pine wood and PVC pipe. A single string purposely keeps the design simple. (*For a 3-string cigar box model, see MAKE, Volume 04.*)

But first, we need to establish the names and functions of the various parts of a guitar. Please refer to the diagram and materials list on the following page before starting.

1. Get your parts together.

Do you want a lead or bass guitar? A lead guitar has a thinner string and is used for playing melody. A bass has a thicker string and plays lower notes. Get the cheapest tuning machine and metal low E string you can find. If the tuning machines come in a strip, cut them apart with a hacksaw, preserving a mounting hole for each tuning machine.

2. Make the body.

The sound of the vibrating string is picked up by a piezo element, so you can design the body any way you please. Look at pictures of guitars to get ideas, or trace a real guitar.

Draw the pattern on the wood and cut it out using a jigsaw, scroll saw, or band saw. It helps to first make release cuts (cuts going from the edge of the wood to the pattern) that fall away, providing turning room for the blade.

Next, sand and round the edges to give it a finished look, and then hold it like you are playing it. This is your last chance to modify any curves for comfort. When you're happy with your design, clean off the dust with a damp rag and paint the body. Several thin layers of paint are better than one thick layer. Refer to the photo at the bottom of the next page to see the process of making the body.

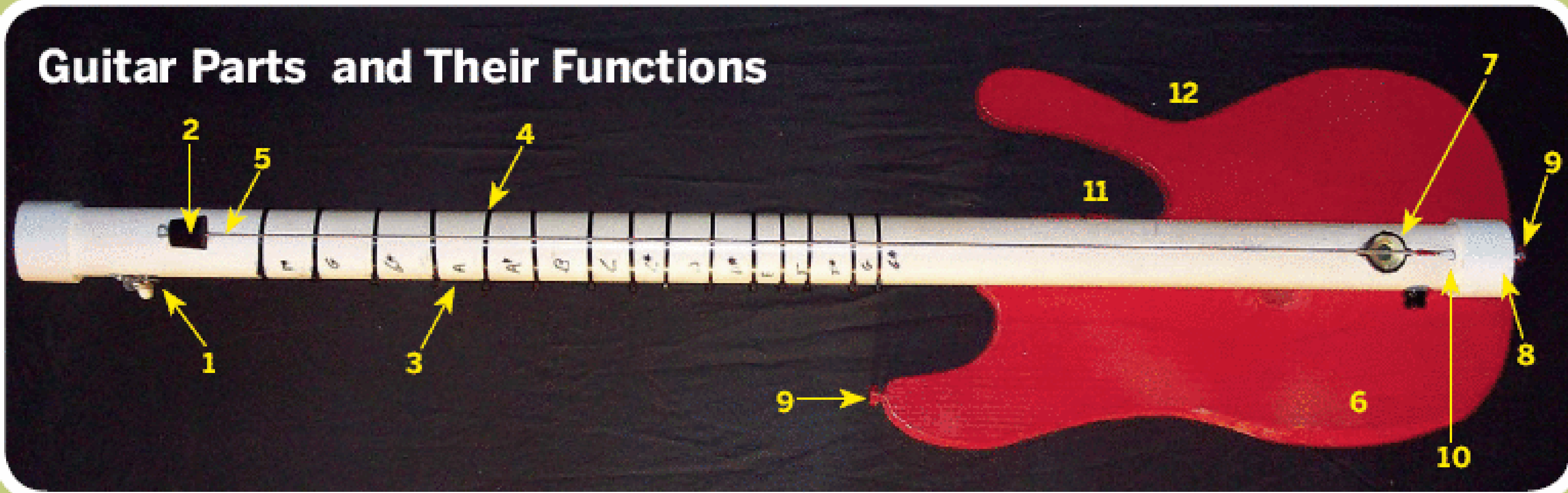
MATERIALS

- Guitar (or bass) string
- Guitar (or bass) machine tuner
- PVC pipe 4' long
  1" dia. for guitar, or 1½" dia. for bass
- PVC end caps (2)
  To fit pipe
- Pine board
  1"×12"×2' long
- Spray paint
  For coloring the body
- Silicone sealer glue
- ⅛" extender cable (RadioShack #42-2562)
- Piezo element (RadioShack #273-073)
- Rubber stopper
- Rubber feet
- Cable ties
- 1½" hex lag screws (6)
- Black tape

TOOLS

- Jigsaw or band saw
- Drill
- Sander
- ¾" wood boring bit
- ⅛" twist bit
- ¼" twist bit
- Clamps (2)
- Thin flat file
- Razor knife
- Wire stripper
- Wire cutter
- Adjustable wrench
- ¼" socket
- Soldering iron and solder

Guitar Parts and Their Functions

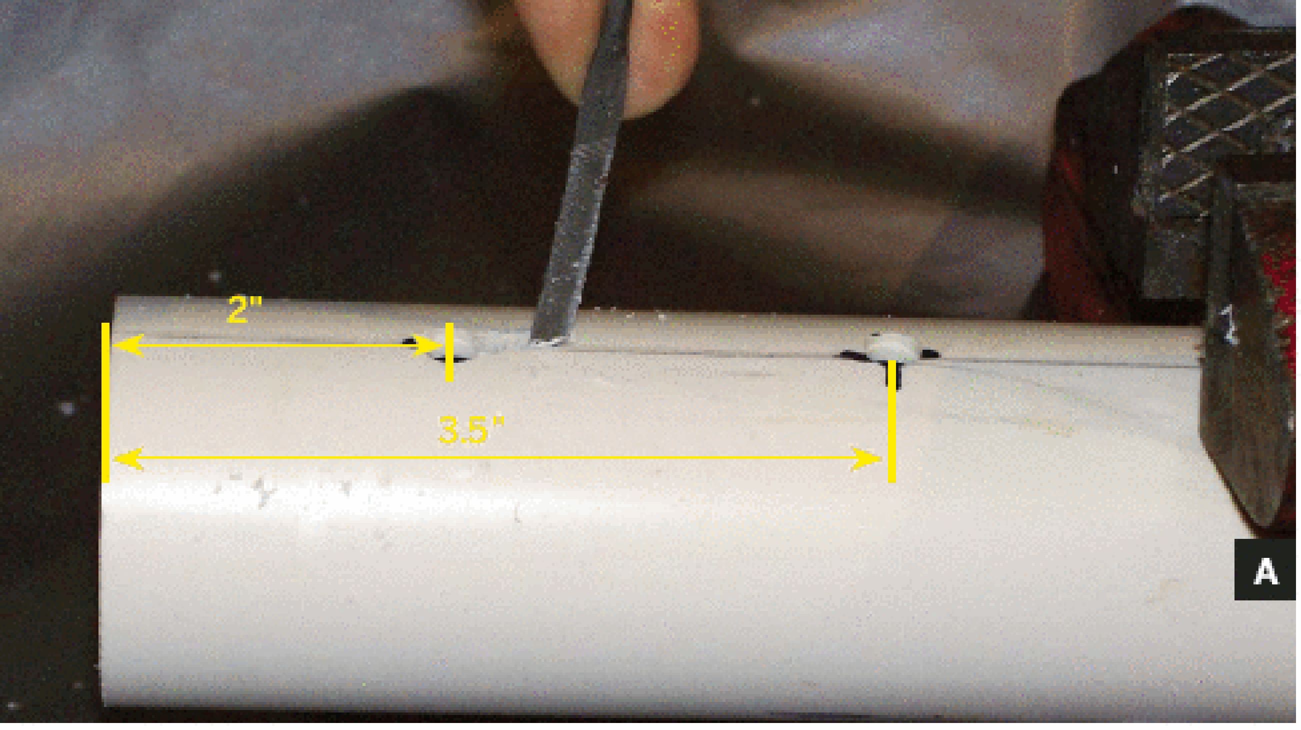


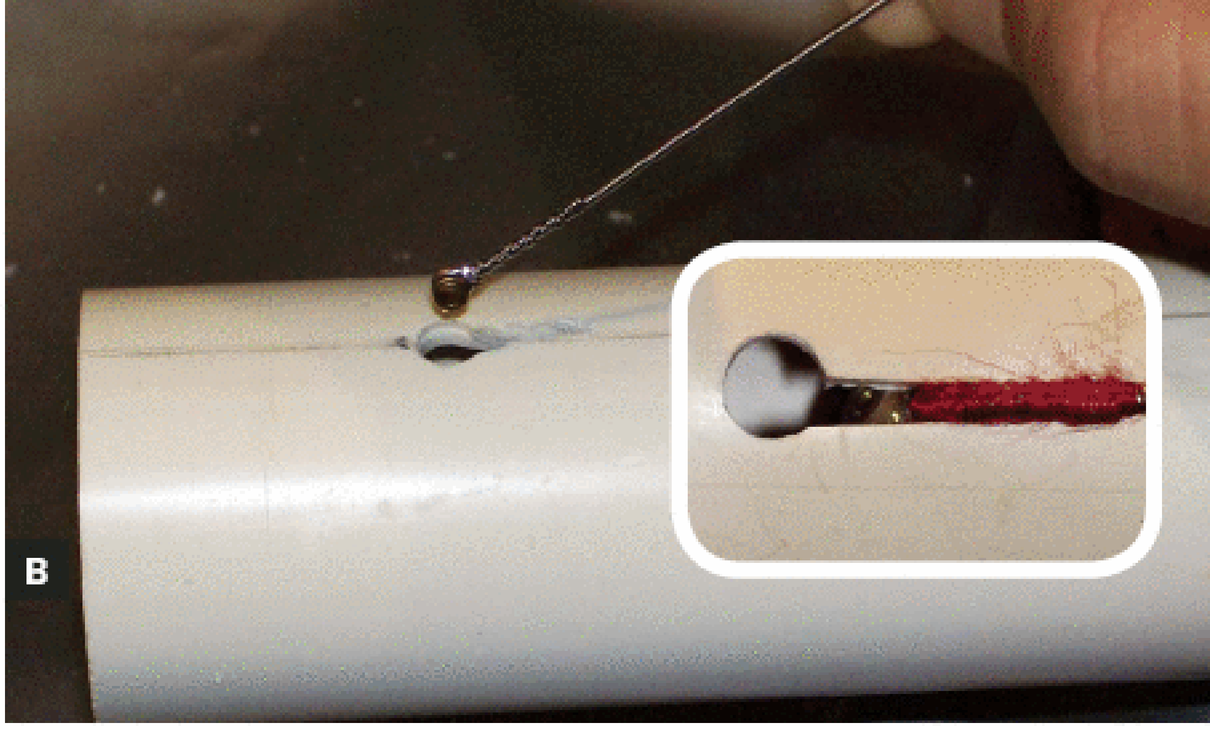
1. **Tuning machine** Pulls the string tight so it will produce sound.
2. **Nut (stopper)** Establishes the lowest note when the string is played open (no fingers).
3. **Neck** Supports the string and frets.
4. **Frets** Stop the string at precise lengths to produce notes.
5. **String** A metal wound wire that vibrates when plucked to produce sound.
6. **Body** Keeps the neck from rotating.
7. **Pickup** Converts string vibrations into electricity.
8. **Input jack** Connects pickup to amplifier cable.
9. **Strap buttons** Stubs to attach shoulder strap to the body.
10. **String anchor** Holds the end of the string.
11. **Neck cutout** Provides hand access to play high notes.
12. **Leg cutout** Contoured to fit the leg when playing in the sitting position.

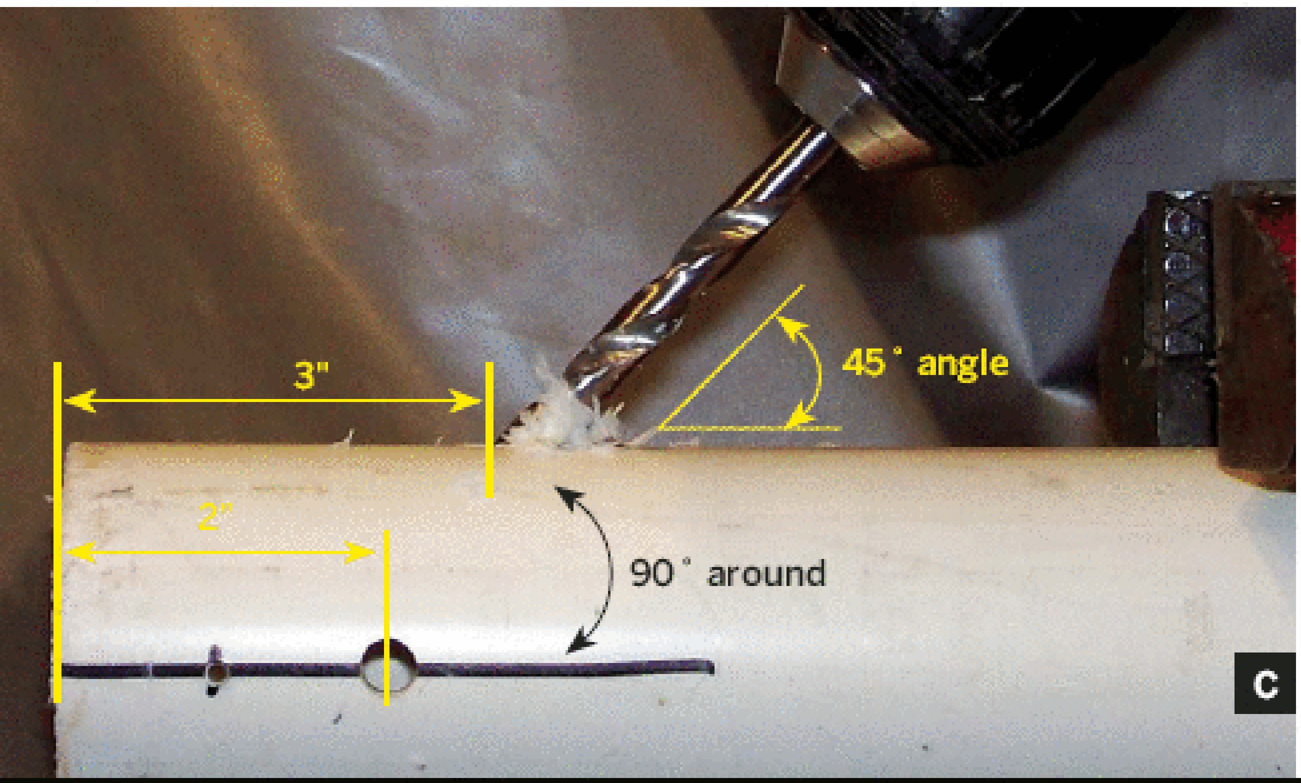
You may notice a black knob sticking out of the PVC pipe below the pickup. I installed a potentiometer to adjust the volume, but I don't recommend it. It adds noise to the circuit. Instead, adjust the volume on the amplifier.

Make the Body

Photography by Tom Zimmerman







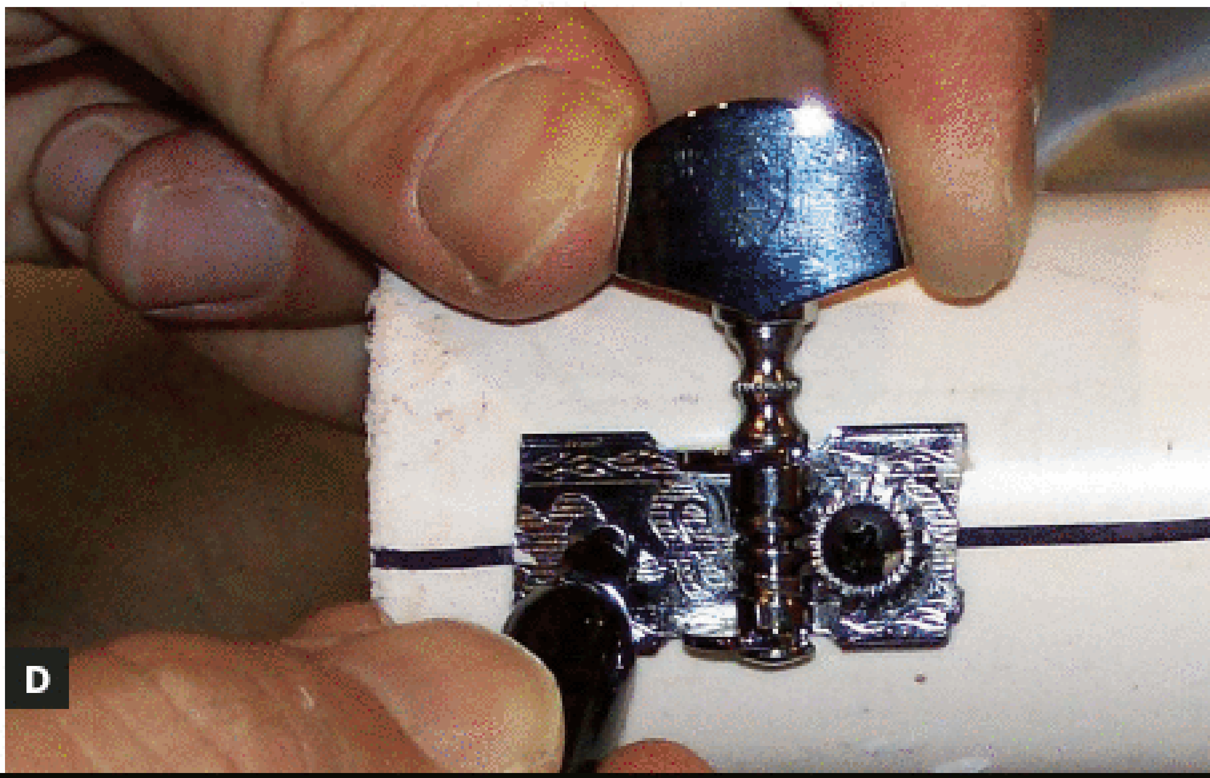


Fig. A: File the notch.
Fig. B: Insert the string ball (with close-up of the installed string).

Fig. C: Drill holes for the tuner.
Fig. D: Mark the tuner mounting screw hole.

3. Prepare the string anchor.

If you're making a lead guitar, cut the 1" PVC pipe to 39" using a hacksaw. For the bass guitar, cut the 1½" PVC pipe to 44". Clamp the string tightly to the PVC pipe and use it as a guide to draw a straight line down the pipe. Remove the string and drill two ¼" holes 2" and 3½" from the end of the PVC pipe along the line. In the hole closest to the pipe end, use a small flat file to carve a ½"-long notch toward the center of the pipe (Figure A). Test to see that the ball of the string fits in the hole and is grabbed by the notch when the string is pulled tight (Figure B).

4. Install the machine tuner.

Drill a ¼" hole 3" from the other end of the PVC pipe, on the line you drew. While the bit is turning, slowly tilt the drill toward the center of the pipe about 45 degrees (Figure C). This will create a slanted ledge for the string to rest on. Drill a ¼" hole 2" from the end of the pipe, 90 degrees around from the first hole.

Put the shaft of the machine tuner into the second hole and mark the location of the mounting screw (Figure D). Remove the machine tuner and drill a ¹⁄₁₆" pilot hole. (Careful: Keep the bit straight or it will snap). Put the machine tuner back into the hole and screw it in with the wood screw that came with the machine tuner.

5. Attach the neck to the body.

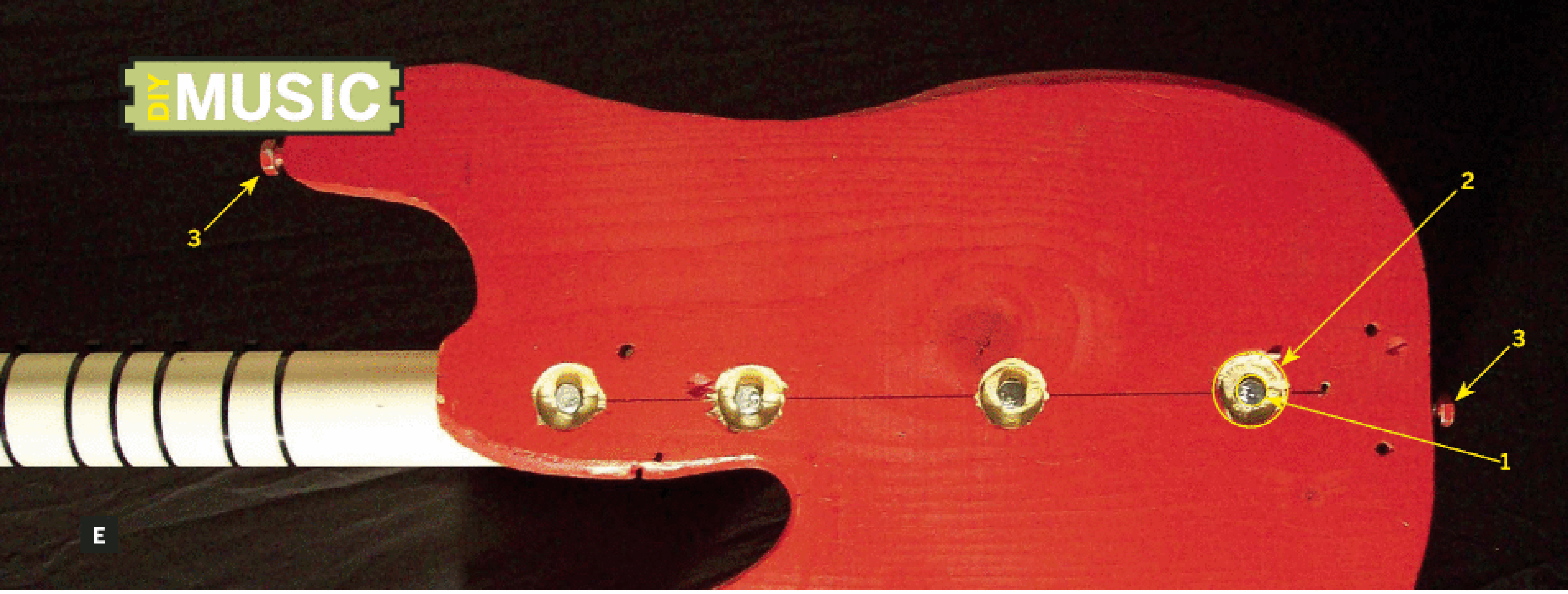
Draw a centerline down the back of the body and drill 4 evenly spaced ⅛" pilot holes. Countersink each hole halfway through the wood from the back with the ¾" wood bore bit.

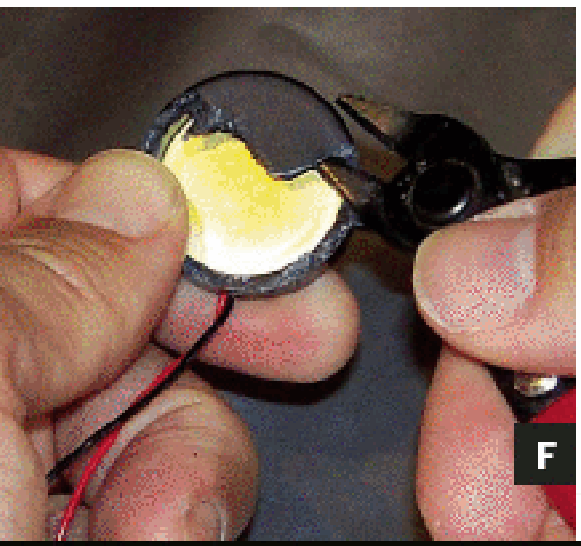
Lay the PVC pipe on a table, string side down. Clamp the body on top of the PVC pipe along the centerline with the ends of the PVC pipe and body flush. Make sure the machine tuner is away from the body. Use the 4 pilot holes as a guide to drill ⅛" holes through the PVC pipe. From the back of the body, screw the lag bolts through the wood and into the PVC pipe with an adjustable wrench.

See Figure E on the following page for reference.

6. Install the strap buttons.

Hold the guitar against your body and find 2 comfortable anchor points for the strap. Drill ⅛" pilot holes and screw in the lag screws, leaving a ¼" gap between the screw head and the body for the strap to fit into.





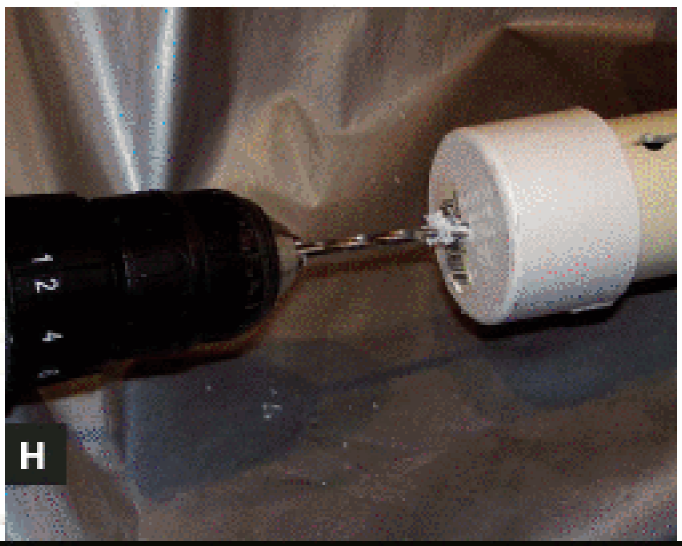


Fig. E: Attach the neck to the body. (1) Hex lag screws pass through wooden body into PVC pipe. (2) Countersink holes provide clearance for wrench and allow the screw heads to be flush with the body. (3) Lag screws are used as strap buttons. Fig. F: Prepare the pickup by cutting away the top of the plastic case. Fig. G: Attach a rubber foot in the disk center. Fig. H: Drill the cap. Fig. I: Sand one side flat.

7. Prepare the pickup.

Cut away the top of the piezo element's plastic case, starting at the hole in the center. Don't insert the cutters too far into the hole — you don't want to damage the piezo element. Cut away the plastic until you get to the side of the case, then start cutting around the side until the whole top comes off (Figure F).

Attach a ½" self-adhesive rubber foot onto the center of the piezo element (the brass shiny surface) or slice ¼" off the bottom of a rubber stopper and glue it to the piezo element with a dab of silicone sealer. The diameter of the rubber stopper must be small enough so it does not touch the plastic case (Figure G).

8. Install the pickup.

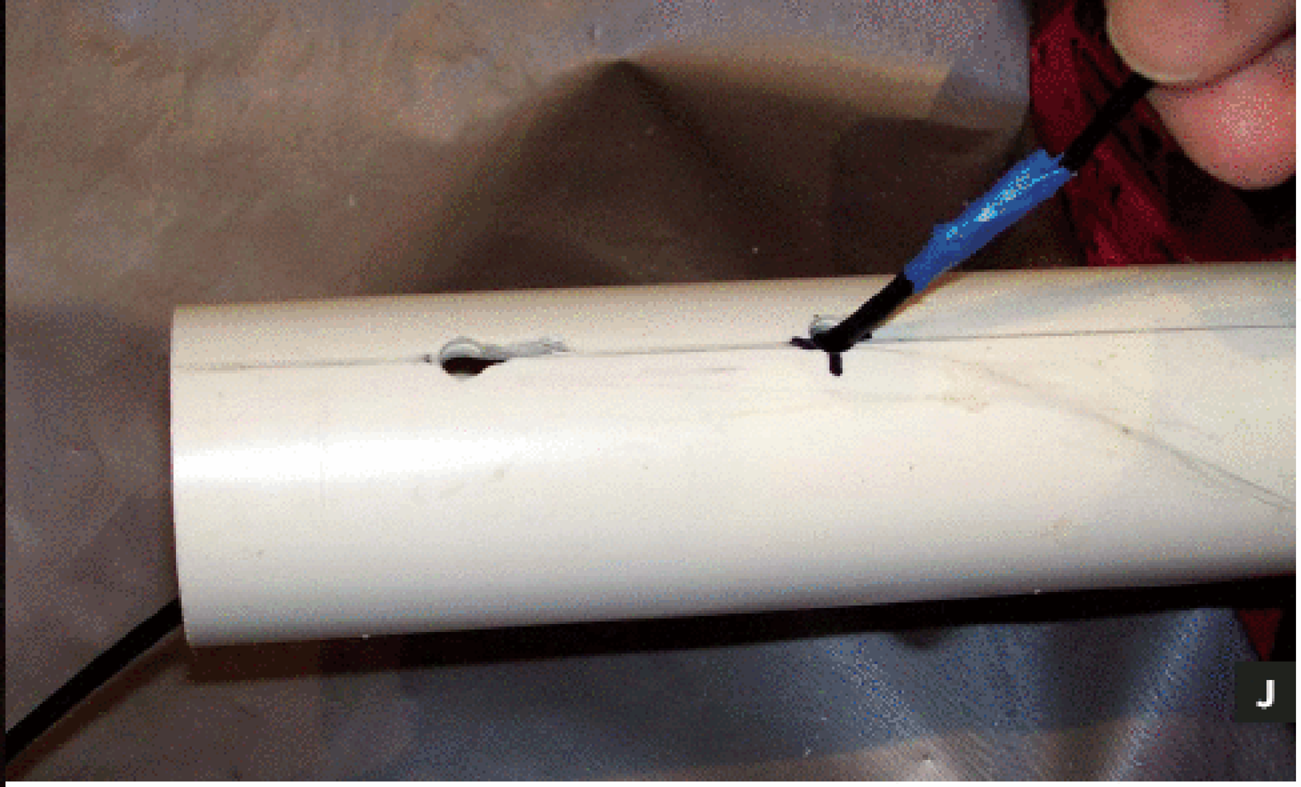
Drill a ⅛" hole in the center of one PVC end cap (Figure H) and sand one side flat so the pipe will rest against the body (Figure I). Cut the plug off the audio extender cable and feed it through the hole in the PVC cap. Tie a knot in the cable 1' from the end so it won't pull through the end cap. Feed a cable tie through the non-notched ¼" hole out the bottom of the pipe. Tape the cut end of the extender cable to the cable tie and pull it back through the non-notched hole (Figure J).

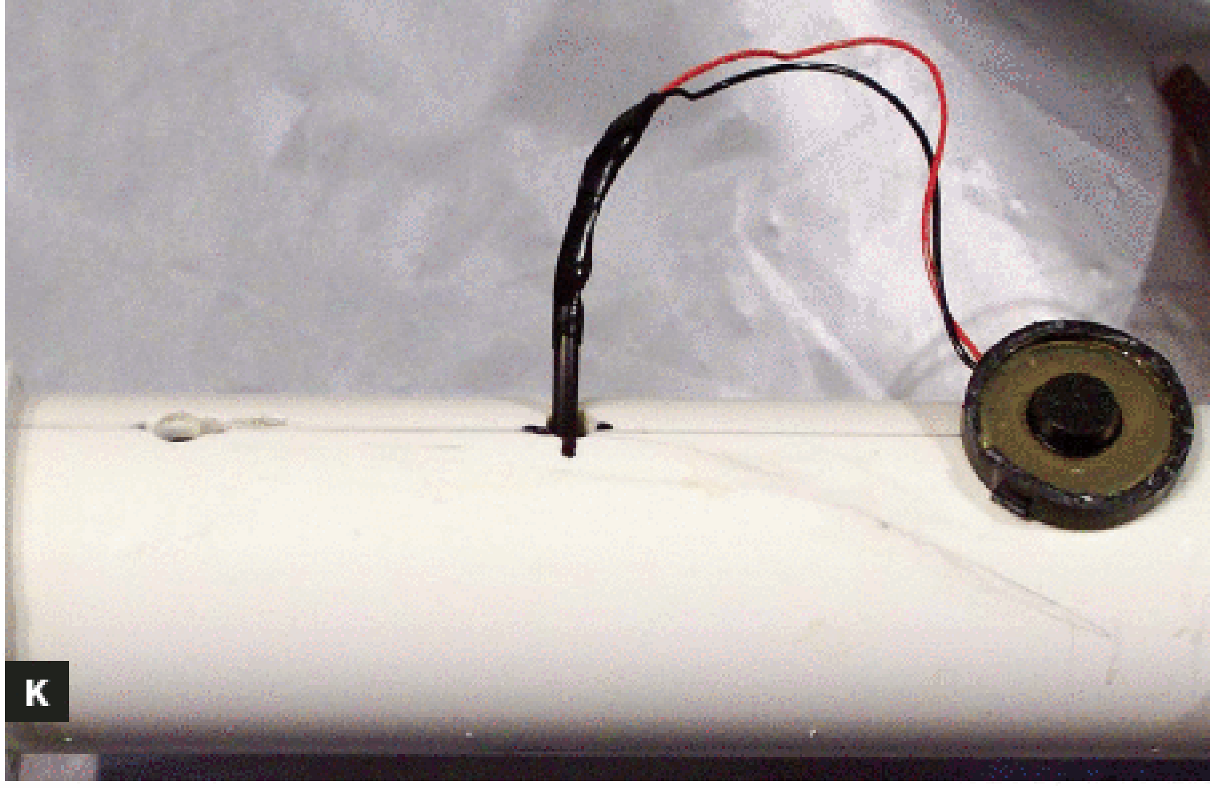
Cut and strip the cut end of the extender cable. The piezo has 2 wires: ground (black) and signal (red). The extender cable has 3 wires: ground (bare copper), left and right (both insulated). To confirm which is which, plug the extender cable into multimedia speakers and crank up the volume. When you touch the left channel wire, you'll hear a buzzing out of the left speaker. When you touch the right channel wire, you'll hear a buzzing out of the right speaker. When you touch the ground, you won't hear anything.

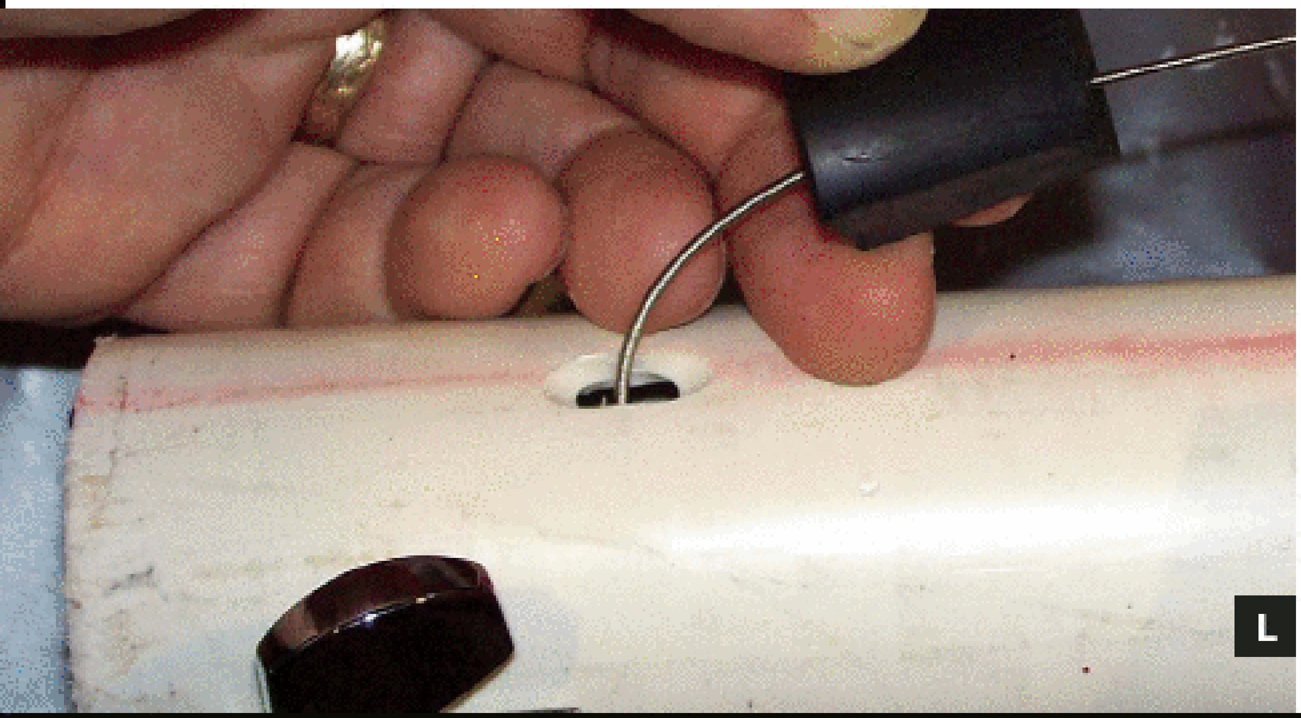
Solder the piezo ground (black) to the extender cable ground. Solder the right and left channels together to the piezo signal (red). Tape up the connections individually and gently pull them through the ¼" hole (Figure K).

9. Install the string.

Slice a wedge off the side of a single-hole rubber stopper. Push the ball end of the string through the notched hole and pull the string so the ball locks securely under the notch. While holding tension on the string, feed the other end through the wedged rubber stopper and into the hole of the tuning machine shaft (Figure L). Rotate the







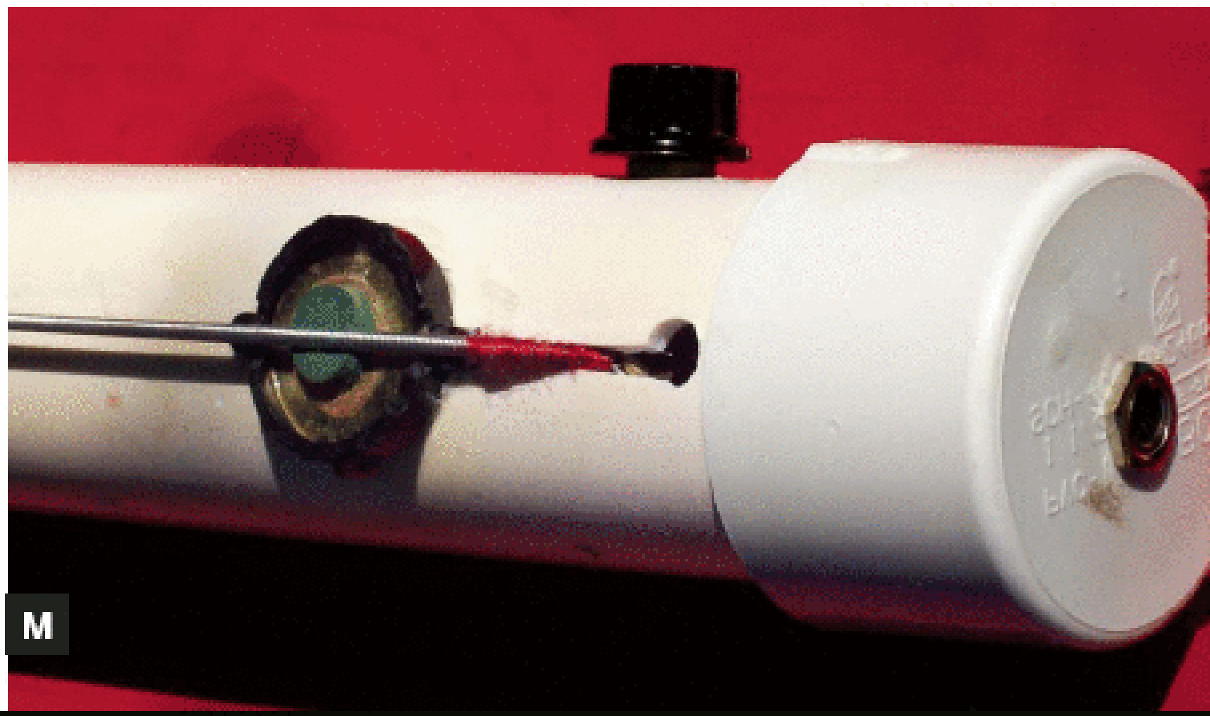


Fig. J: Feed the cable through the non-notched hole.
Fig. K: Wire the pickup and gently pull the connecting wires through.

Fig. L: Install the wedged rubber-stopper nut.
Fig. M: Make sure the guitar string rests on the center of the pickup's rubber foot.

tuning machine until the string is tight enough to stay in place, making sure the string rests on the center of the pickup rubber (Figure M).

Notice that we haven't glued the piezo element to the PVC pipe. The free-floating pickup guarantees that it is lined up with the string, preventing sideways forces that cause the pickup to distort. You now have a fretless guitar.

The gap between the string and PVC pipe should be uniform along the neck. If the string hits the PVC pipe when you pluck it, increase the size of the nut (wedged rubber stopper) and pickup rubber.

10. Add the frets.

Frets stop the string at fixed distances to produce discrete notes. If you want to add frets, tighten about 12 cable ties evenly spaced along the length of the neck. If you have a good musical ear, slide each of them to produce a chromatic scale (E, F, F#, G, etc.).

If you have no idea what this means, borrow a guitar tuner from a musician friend and turn the machine tuner so it produces an E note when the string is open (no fingers on the string). Press behind the first cable tie (closest to the machine tuner) and move the cable tie until an F note is produced. Move the next cable tie to produce an F# note, etc. Alternately, you could slide the frets to produce a major scale ("do, re, mi") or any scale you like, just like a sitar!

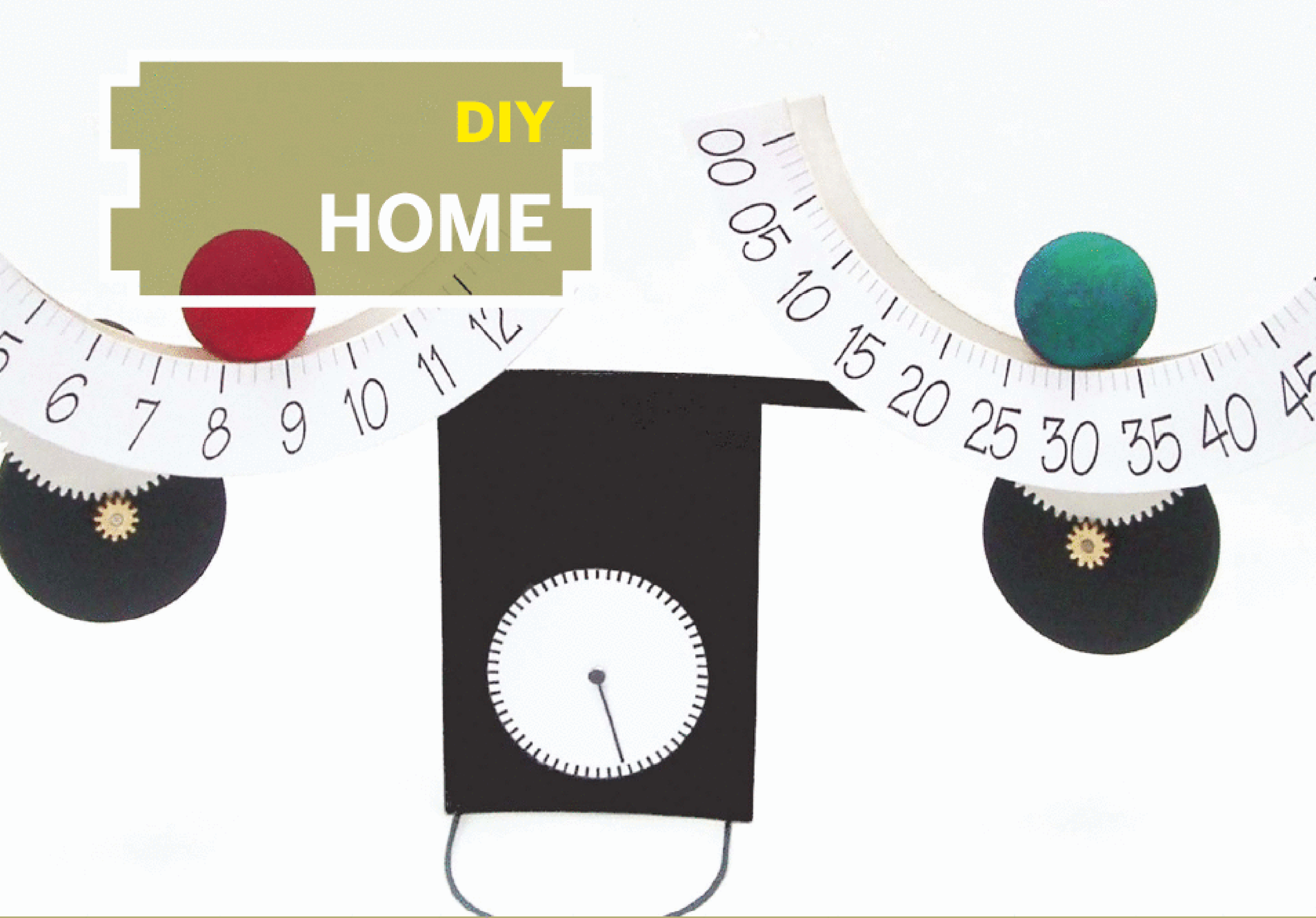
11. Learn to play.

Now that you have a guitar, it's time to play. Put on your favorite song and try and play notes that sound like the chords the band is playing.

Or get together with a musician friend and have him or her teach you scales and some basic riffs (series of notes). If nothing else, crank up the music, pluck away, and look cool. It works for music videos and it can work for you.

Tom Zimmerman is an inventor, educator, and researcher at the IBM Almaden Research Center who loves gadgets, LEDs, synthesizers, and hooking people up to computers.

DIY
HOME



TIME-BASED DEVICES

Transplant a heartbeat from cheap alarm clocks.

By Larry Cotton

Some projects need a nice, steady, low-voltage pulse at a constant rate. This is relatively easy to do with the ubiquitous 555 IC, but what's not so easy is keeping a 555-based circuit accurate to within a few seconds a month. For that, you're better off just gutting a cheap travel clock. This will give you an easy module that generates ultra-accurate pulses at 1Hz — something which, in my opinion, is more valuable than telling time.

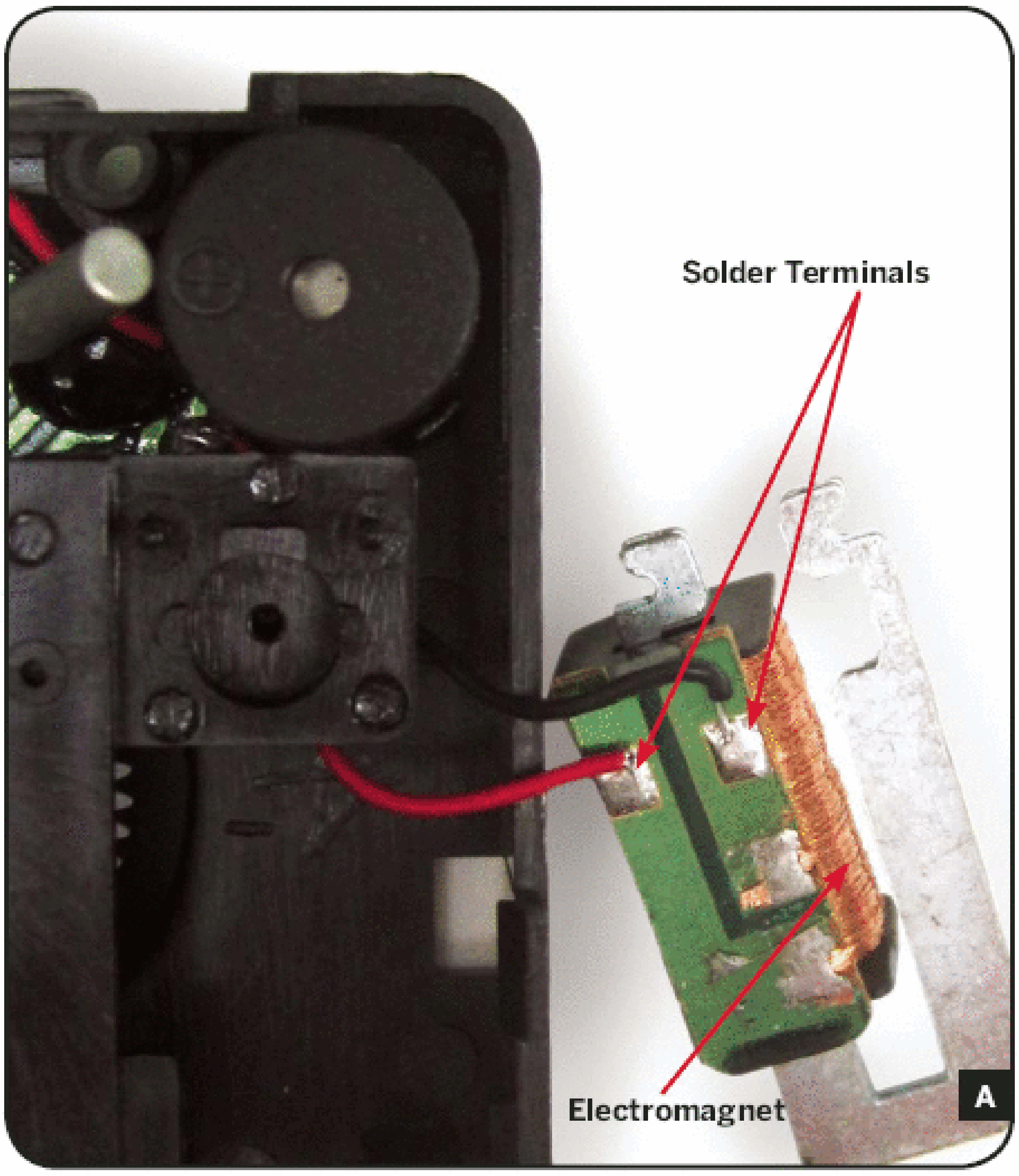
Not just any clock will do, however: it should run on one battery (usually AA size) and have hands, not an LED readout. If it has a second hand, it must jerk forward every second (most do), rather than sweep. Clocks like this are easy to disassemble and cost less than $5 at some retailers. They all use the same basic mechanism: a 32,768Hz quartz-crystal oscillator, along with the electronic and mechanical parts that convert its oscillations to clock ticks.

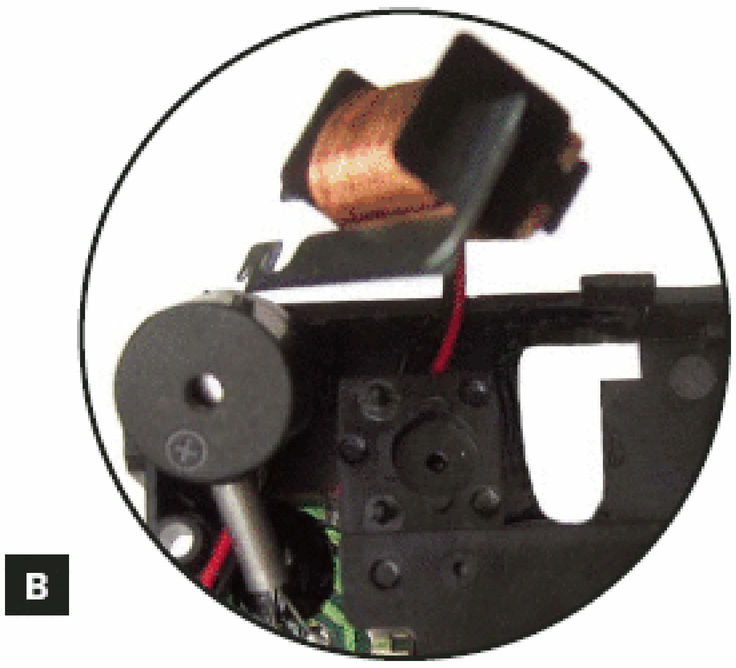
Disassembly demands a bit of finesse. Although you're not tinkering with a fine Swiss watch, you are filleting some fairly delicate clock guts. What you're looking for is the electromagnet (solenoid), which turns the first gear in the gear train.

Your surgical procedure will depend on whether your project just needs the electronic pulse generator, or a clock with working hands that continues to tell time. If you just need the clock's ticker, you can disassemble without worrying about reassembly, and throw away the gears, hands, and even the electromagnet.

Here are the steps I followed with my clock. Yours may differ depending on its age. I've also successfully used wall clocks, which also come

Photography by Larry Cotton





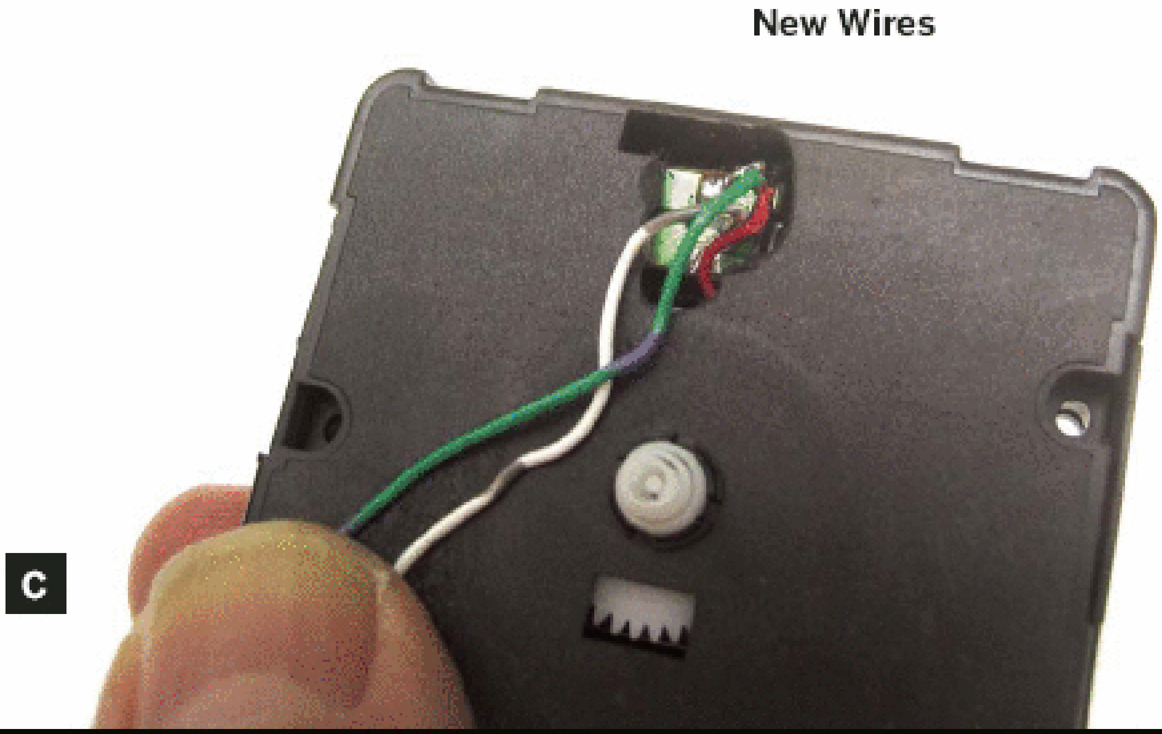


Fig. A: Lifting out the electromagnet reveals the two wires you need to splice into. Fig. B: Clearance hole cut through clock's front panel.

Fig. C: New wires to your own circuit connect to the electromagnet through the clearance hole in the now-bare clock face.

apart easily. The electromagnet in a wall clock may not be as readily removable, but it's a piece of cake to solder new wires to, and it will work fine with the electromagnet in place.

1. Remove the battery cover.

2. Remove the battery.

3. Remove the clear face cover.

4. Pull off the hands.

5. Remove a shaft nut and washer. This depends somewhat on the quality of the clock, and may not need to be done.

6. Pull off any setting knobs that attach to rear protrusions.

7. Remove clock face and mechanism. You may have to release the boxy little clock mechanism (roughly 2"×2"×½") from the main body of the clock; you may also need to remove a printed clock face in order to access parts, and make a wire-clearance hole. Read the remaining instructions to help you decide what to do.

8. Pry off the back. It's usually just snap-fitted together. Otherwise, carefully Dremel (is that a verb?) the case open. In some cases, the back piece holds tiny plastic gears in place, so they may fly out if you're not careful. But if you don't need the hands, don't sweat the flying gears.

9. Carefully lift out the little gear and the electromagnet. The electromagnet has fine copper wire wound on it, and the first gear in the train is surrounded by steel fingers. Two wires are attached to the magnet, usually red and black.

10. Discard the electromagnet. If you don't need the hands, you can do this by clipping or unsoldering its wires.

11. Pry the face off if you haven't already done so. Mine was attached with tape. You may have to route 2 new wires through the front of the clock.

12. With a Dremel and small bit, make a small hole in the plastic housing. You want to do this just below where the 2 solder terminals for the electromagnet's wires were. This will clear the new wires you will install. Alternately, if you have room, you may be able to route the wires around the circuit board and out the back.

13. Carefully solder 2 new thin, flexible, insulated wires in place. You can do this to either the electromagnet or just to the 2 wires. Polarity isn't important. You may have to mechanically attach your new wires with tiny loops before soldering.

14. Route the wires away from the clock. Go through the hole in the housing, if necessary. If you need the clock's hands, reinstall the first gear

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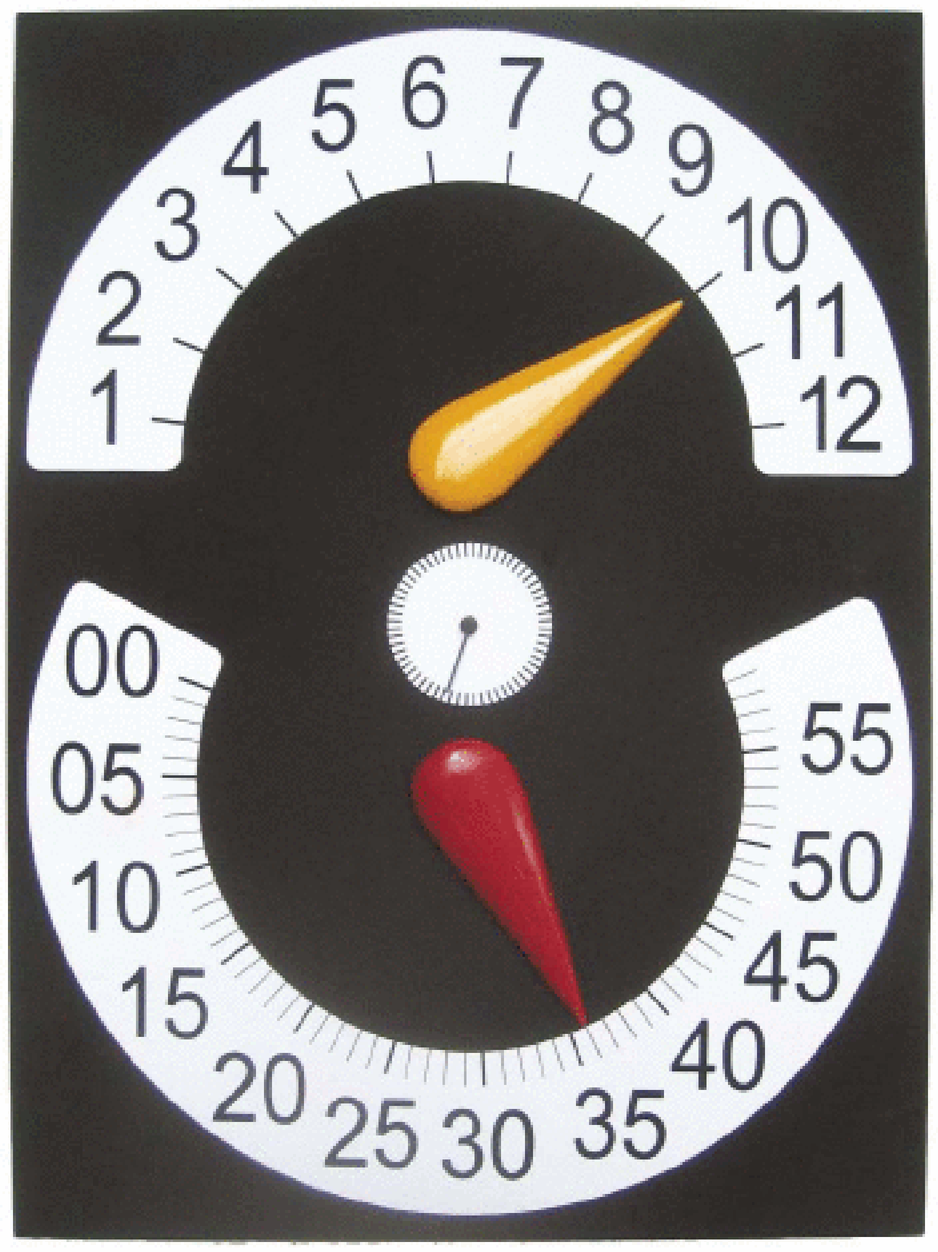

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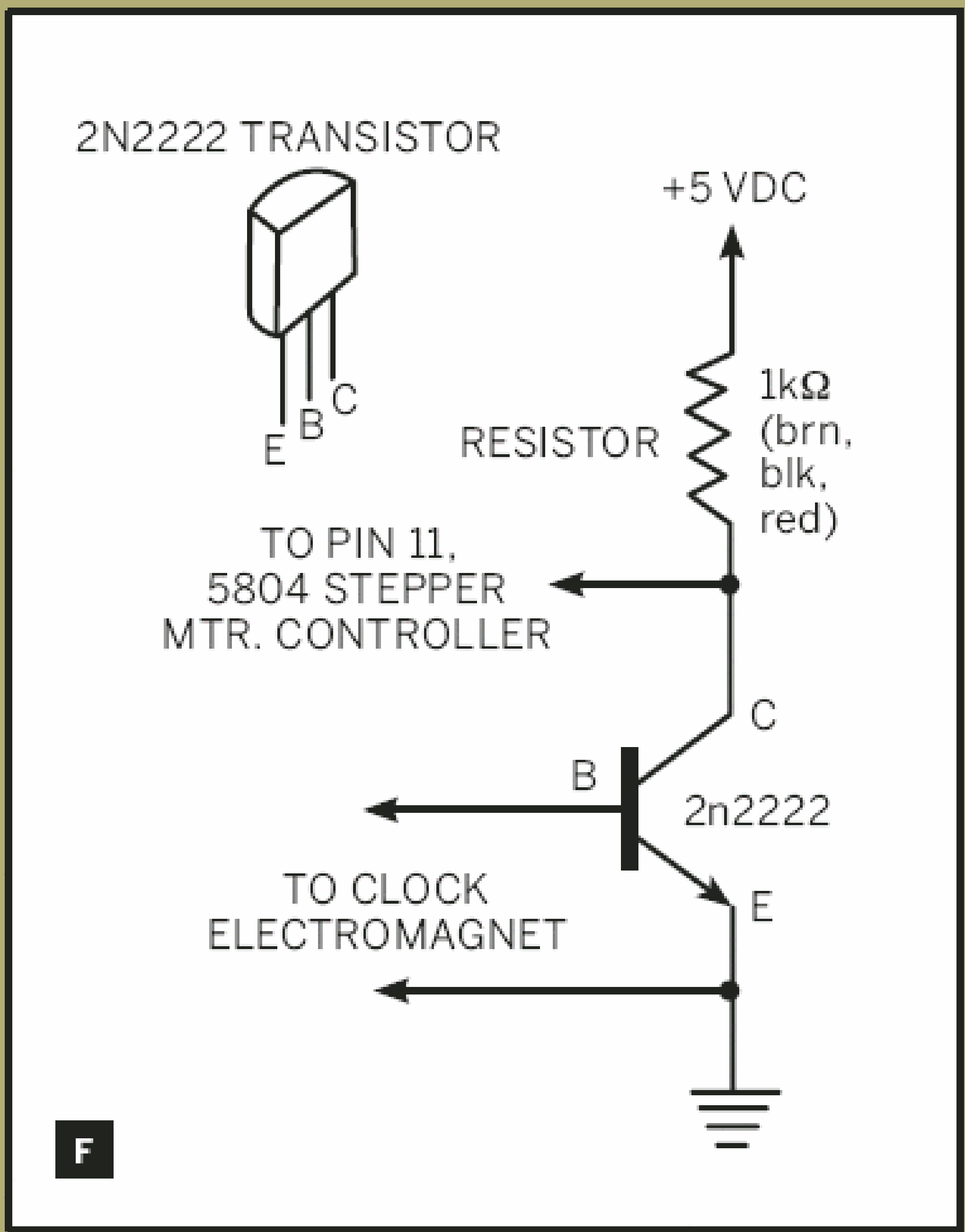
Fig. D: Moebius clock advances a single-sided paper loop with printed times. Fig. E: Dual-dial clock shows hours above and minutes below; hands swing back at the ends of their arcs.

Fig. F: Simple transistor circuit boosts clock pulse up to 5V, for driving a stepper motor or interfacing with other 5V-based electronics.

out, and reverse your disassembly.

The 2 wires you connected to the clock will put out a very short electrical pulse every second. Some clocks alternate a strong every-other-second pulse with a weak and less usable one. You can use a cheap NPN transistor such as a 2N2222 to amplify this pulse, to interface with the next stage of electronics. You can also add divider ICs, such as a 4017, to increase time between pulses to almost any length you wish.

I've transplanted tickers successfully into several alterna-clocks I've built. For my Moebius clock, I sent the amplified pulse into a stepper motor which advances a Moebius strip tape with times printed on it. For my dual-dial and arc clocks, I send the pulse to the motor through a BASIC Stamp microprocessor, which keeps track of the time. When it becomes 12:59:59, the code triggers a subroutine that quickly runs the hands (or arcs) backward and resets the time to 1:00 — which is always fun to wait for and watch.



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Larry Cotton is a retired power-tool engineer, musician, and part-time math teacher who just happens to have a bit of extra time on his hands in New Bern, N.C.

METAL ETCHING

Chemically carve detailed text or line art onto brass or copper. By Tom Jennings

Photography by Tom Jennings

I make forged, obsolete laboratory instruments as art pieces. To render intricate line art and text onto metal panels, I use the same chemical etching process that creates printed circuit boards. The etched areas are only a few thousandths of an inch deep, but they give a clear image that you can fill in with paint or enamel. If you're building the panels into an object, you should etch them before bending them or drilling any holes. This process only works on flat, solid metal surfaces.

Be warned: This is a highly variable process. I've done immaculately perfect panels with smooth 10-micron lines, but most often there are flaws in the materials, rough areas, loss of resolution, or other problems. Cleanliness and care get better results, but the trick is to go with the flow, and work with what you get.

Create the Transparency

You can create your artwork by hand or digitally, but it needs to be rendered as a mirror-image of your final image, in solid black on transparent film. Use black ink only, and print on the coated side, not the shiny side.

Illustrator, the GIMP, Photoshop, and other graphical utilities let you threshold any images into pure black-and-white, to make them suitable for etching. Then use Reverse to produce a printable mirror-image. You want the printed image to read correctly when you're looking at it with the ink-and-coating side down.

I do my artwork in Adobe Illustrator, and print it on HP transparency film in my Epson 777 inkjet. When my art is ready, I load the transparency film, hit Save, reverse the image, Print, then Undo.

MATERIALS

Artwork
Transparency film
Printer or copier to render your artwork onto the transparency film
Copper or brass plate Zinc will probably also work, but don't use iron or steel, and definitely not aluminum, which is dangerously incompatible with the etchant.
Lamp with 500W photoflood lamp bulb (3200° Kelvin) and reflector on improvised stand over work surface
Dishwashing liquid
Sandpaper and fine abrasives of varying grits up to 600 or finer You can also use red and white auto polish, cheap from any auto parts store.
Nitrile or other chemical-protective gloves
Protective eyewear
Pane of glass big enough to cover metal plate
Pyrex dishes (2) big enough to hold the metal plate
Piece of clean wood or other "carrier" for the metal plate so you can move it without touching it
A drawer or other clean, dry, and absolutely dark place to put the plate
Photo timer or stopwatch that's easy to read in the dark

CHEMICALS

All are available from GC Electronics (gcwaldom.com) or Minute Man Electronics (minute-man.com)
ER-71 negative acting photo resist liquid in a spray bottle
ER-8 photo etch developer
Ferric chloride etchant
Electroless tin plating solution (optional)

WARNING: The light-sensitive chemicals are flammable, and the ferric chloride etchant is extremely dangerous — it burns and stains skin, fabric, wood, and reacts violently with aluminum.

Polish the Metal Plate

To receive the photo-resist coating, the metal must be absolutely smooth and grease-free; a single fingerprint can ruin the surface.

1. Sand the surface with increasingly fine sandpaper, ending up with 600 or 1500 grit. Follow up with red and white automotive polishing compounds.

2. Wash the entire plate spotlessly clean with hand dishwashing soap, and dry with paper towels. Don't touch the surface!

3. Place the plate on a wood block or other carrier, bring it to a protected place, and let it dry. Be sure to handle the plate by the edges only. You can dry it in a clean, non-greasy oven at 120-150°F for 20 minutes, or leave it in a drawer for a few hours.

Set Up Your Work Area

The coating, exposure, and development steps need to be performed in a darkened room or under a red darkroom light, so it's important to find a good spot and set up ahead of time. And because solvents are involved, the area also needs decent ventilation. A kitchen sink by a back door at night would work.

1. In an area that's well-ventilated and can be made dark, set up the 3200° Kelvin photoflood lamp in the reflector, such that it shines straight down onto a flat tabletop, 18" from the table surface, plus or minus an inch. The lamp has a very short life (6 hours) and it generates a lot of heat. It exceeds the ratings of most cheap aluminum reflectors, but that was not a problem for me. It's not left on for long enough to do any harm that I noticed.

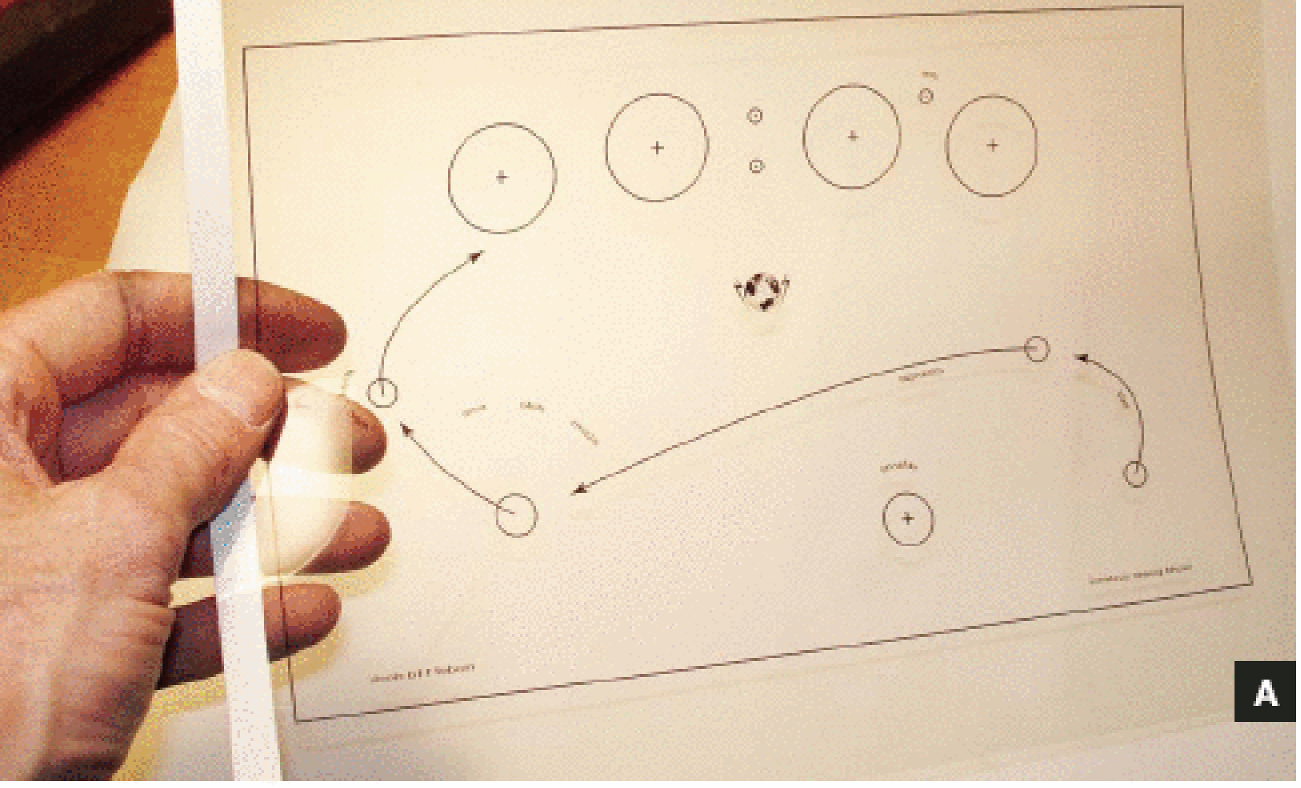
2. Put your photo timer or stopwatch someplace accessible and visible.

3. Clean and dry the sheet of window glass so that it's spotless on both sides.

Coat the Plate with Emulsion

This step coats the plate with a very thin light-sensitive film, and you need to do it in the dark. Be sure to keep the ER-71 liquid in its box when not in use.

1. Holding the prepared metal only by the carrier, tilt it, and pump-spray the surface with ER-71 photo resist liquid until it is soaking wet and excess liquid drips off one corner.



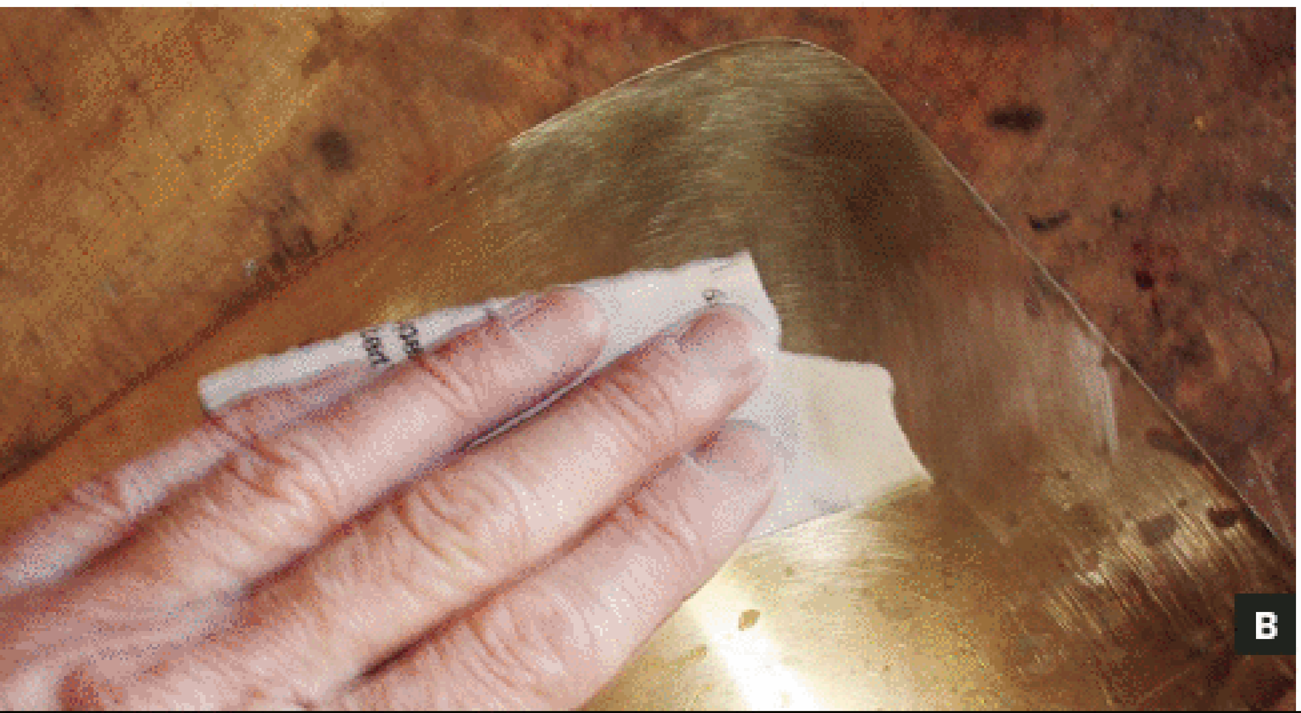


Fig. A: Print the etch image backwards onto a sheet of transparency film. Fig. B: Clean and polish the metal (copper or brass) surface. A single fingerprint can ruin the transfer.

Fig. C: Sensitize the metal by coating it with photo emulsion liquid. Keep the spray bottle out of the light when not in use.

2. Let the excess drip for 12 seconds, then hold it flat and look for 100% perfect wet coverage. If you see fisheyes, or the liquid pulls away from the metal, it wasn't clean enough. In this case, wipe off what you can, and finish cleaning with some ER-8 developer on a rag. Clean thoroughly and try again.

3. Put the plate in a dark, dry, flat, and level storage space, like a drawer. As the coating dries, it will level out and harden. Let it dry for 30 minutes.

4. A second coat isn't usually needed, but I've occasionally used one when the coating seemed too thin or etching didn't work the first time. Wait at least 1 hour before applying a second coat.

Expose the Plate to Light

This step also needs to be performed in the dark or under dim red light.

1. Place the metal plate on the table, photo-coating side up. If your carrier is very thick, raise the lamp to compensate, so that it's 18" above the object.

2. Place and carefully align your artwork onto the plate so that the image is righted. Because we printed the image reversed, the inked image now lies right up against the coated metal. That's good. If it were printed the other way, the transparency film would lie between the ink and the metal, which greatly lowers resolution.

3. Carefully place the cleaned sheet of glass over the transparency to hold it flat against the coated metal. Recheck image alignment.

4. Turn the 3200°K photoflood lamp on for 4 minutes, then switch it off. You may need to experiment with exposure time if you use a different lamp or height.

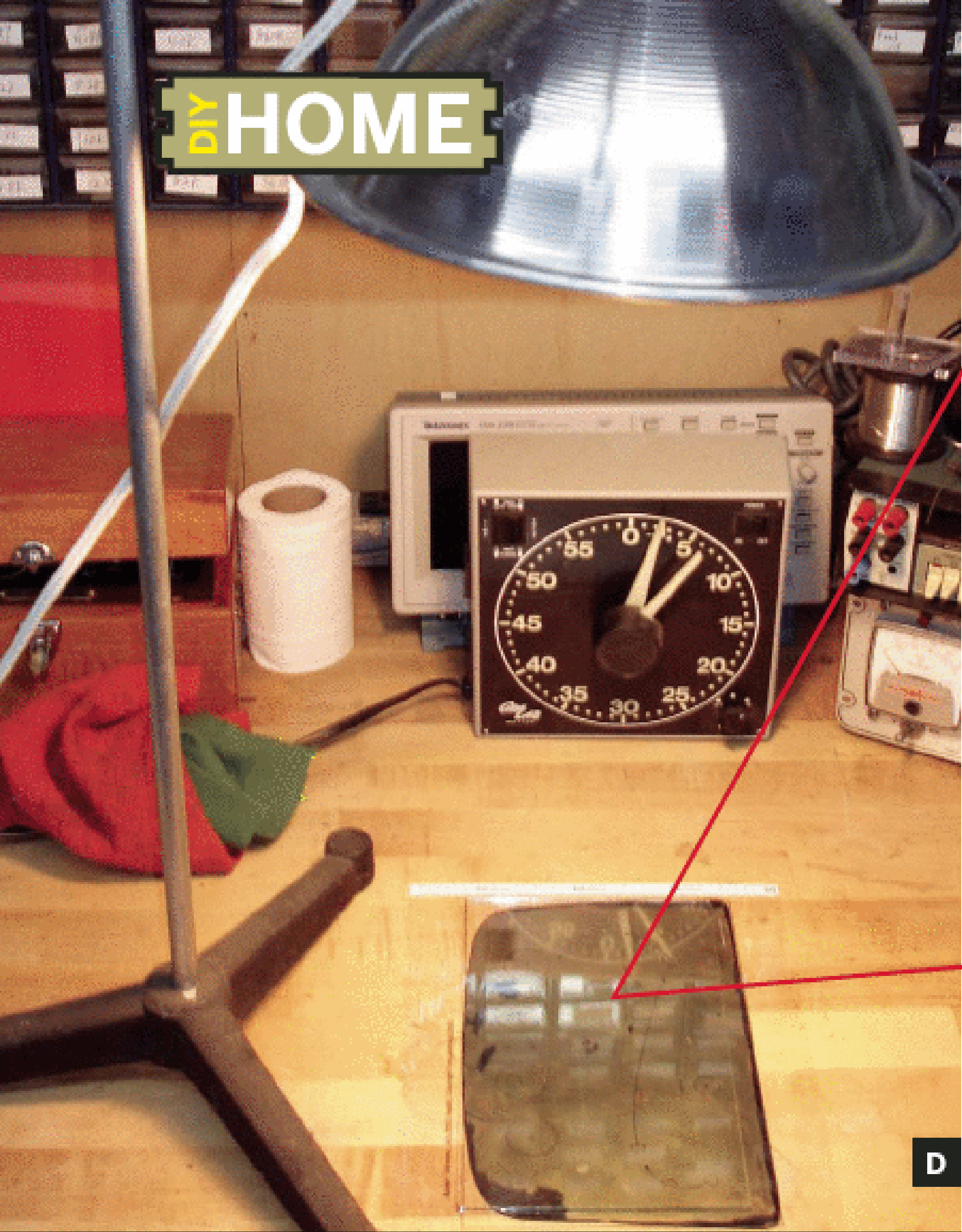
5. Keep the exposed plate in the dark until it's in the developer bath (next step).

Develop the Image

Developing the plate causes the parts that were exposed to the light to harden into a resist coating, and the parts that were directly under the black ink to wash away, leaving bare, exposed metal. You need to continue working in the dark until the plate is in the developer bath.

1. Place the exposed object in Pyrex dish #1, coated side up, and pour on enough ER-8 developer to cover it. Used ER-8 is fine for this step. Once the plate is covered, you can turn the lights on.

2. Rock the dish gently so that the ER-8 sloshes



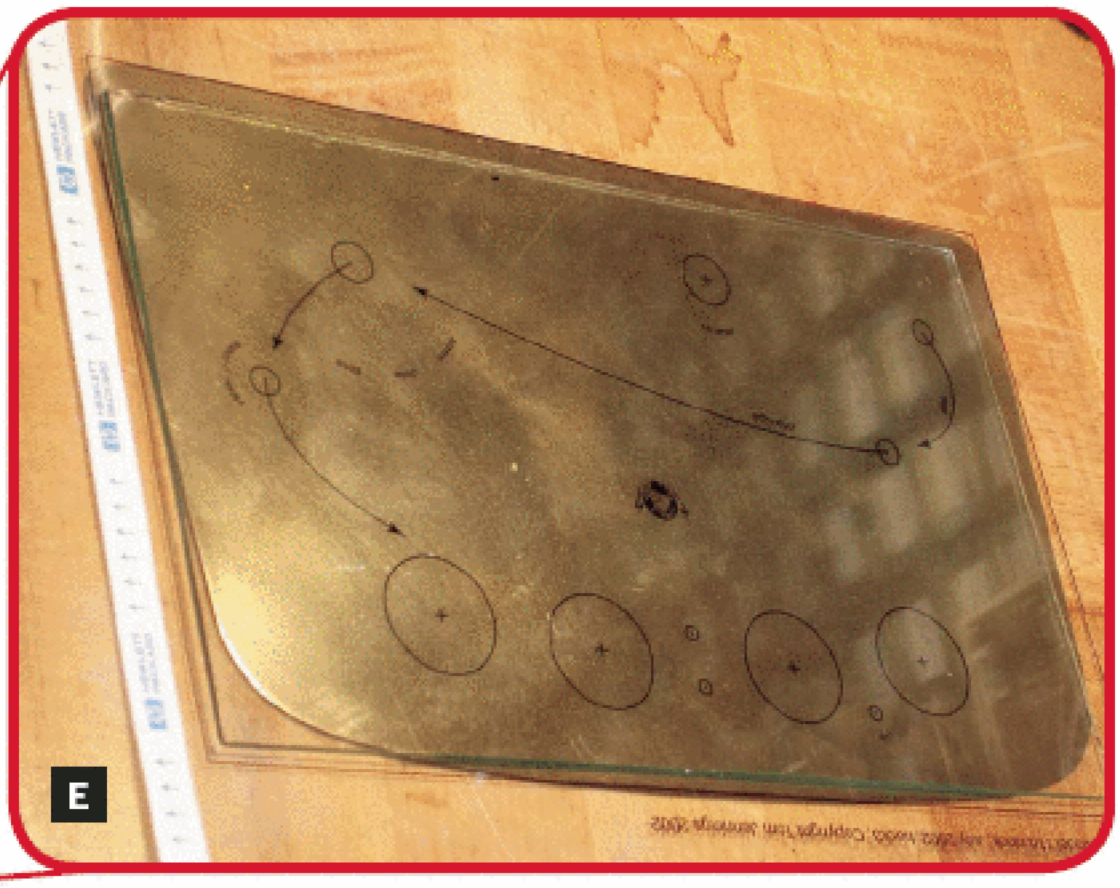


Fig. D: Expose the coated metal plate for 4 minutes under a 500W photoflood lamp, with the reflector positioned 18" above. Don't worry if the reflector isn't rated for a bulb that hot; it isn't on for long enough to matter.

Fig. E: During exposure, the transparency should be positioned with its inked side directly against the metal, pressed down with a plate of glass.

over the coated surface for 45 seconds.

3. Remove the object from the dish, draining developer back into the dish.

4. Place the object into Pyrex dish #2, and pour in enough new, fresh ER-8 to just cover the surface. The exposed coating is very soft and delicate at this point.

5. Very gently rock the dish for 10 seconds. Lift the object out of the dish and let it drain, handling it only by the edges.

6. The coating is now no longer light-sensitive, but it is invisible and extremely delicate until it's dry. Do not touch! Set the object aside to dry fully, for 1 hour.

NOTE: ER-8 developer is reusable an unknown number of times, probably a dozen or more. The second brief dip in fresh ER-8 just rinses off any crud that was in the used ER-8 from the main step. This stretches the life of the developer. I keep my used ER-8 in a clean glass jar.

Find and Fix Flaws in the Coating

If the exposure process failed, etching will just roughen the plate's surface and you'll have to sand it all off and start over. Here's how to make the coating pattern visible; then check it and correct any flaws before etching.

1. Fill a Pyrex dish with water and add just a few drops of etchant.

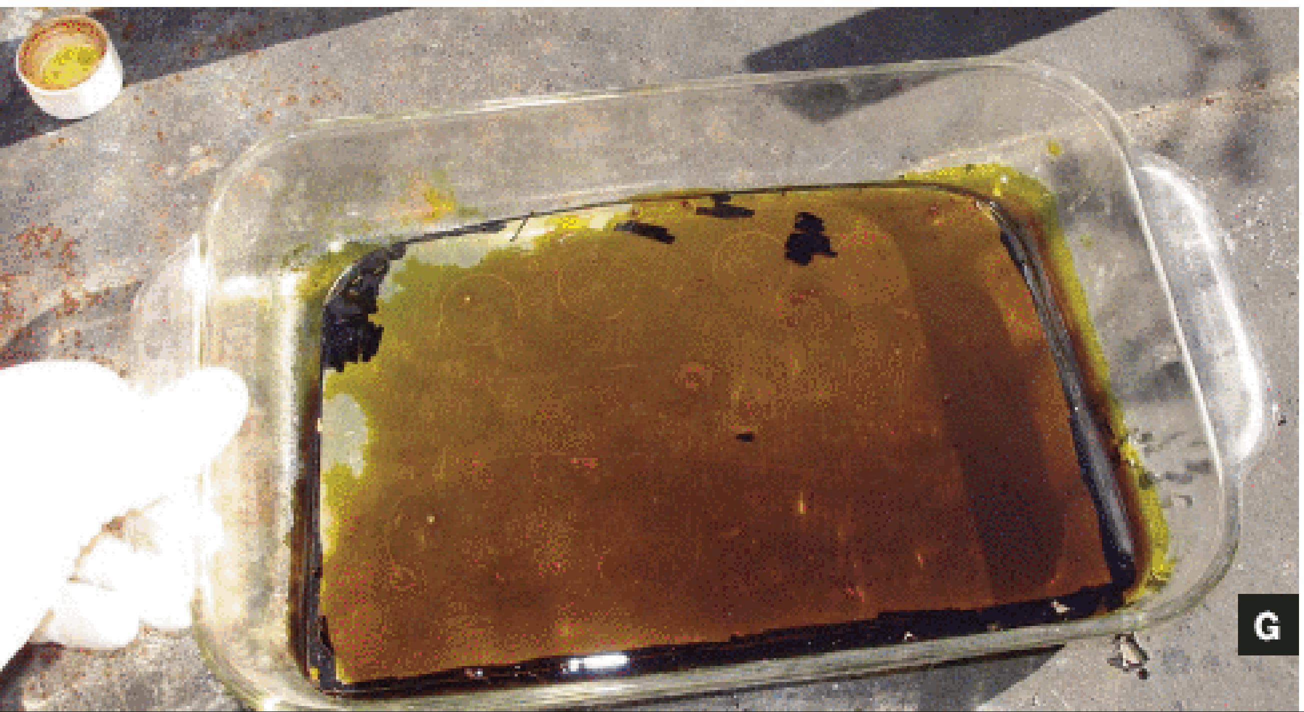
2. Immerse the plate in the dish; the coated areas will remain shiny while the open areas will faintly etch, making the coating pattern visible.

3. Compare the coating pattern to your original artwork and look for areas where the plate should be etched, but are still shiny (coated), and vice versa. For areas that should be etched but weren't, use a knife to carefully scrape the coating away. For areas that should be coated but are exposed, cover them using a paint pen or pieces of tape trimmed to shape. Correcting a few flaws this way is fine, but if large portions of your design didn't make it through, you're better off repolishing the plate and starting over.

4. You can discard this very weak etchant solution by pouring it down the drain and following it with copious amounts of water.

Etch the Metal

This step completes the process. The ferric chloride etchant eats away metal from the object anywhere that coating was not exposed to light.



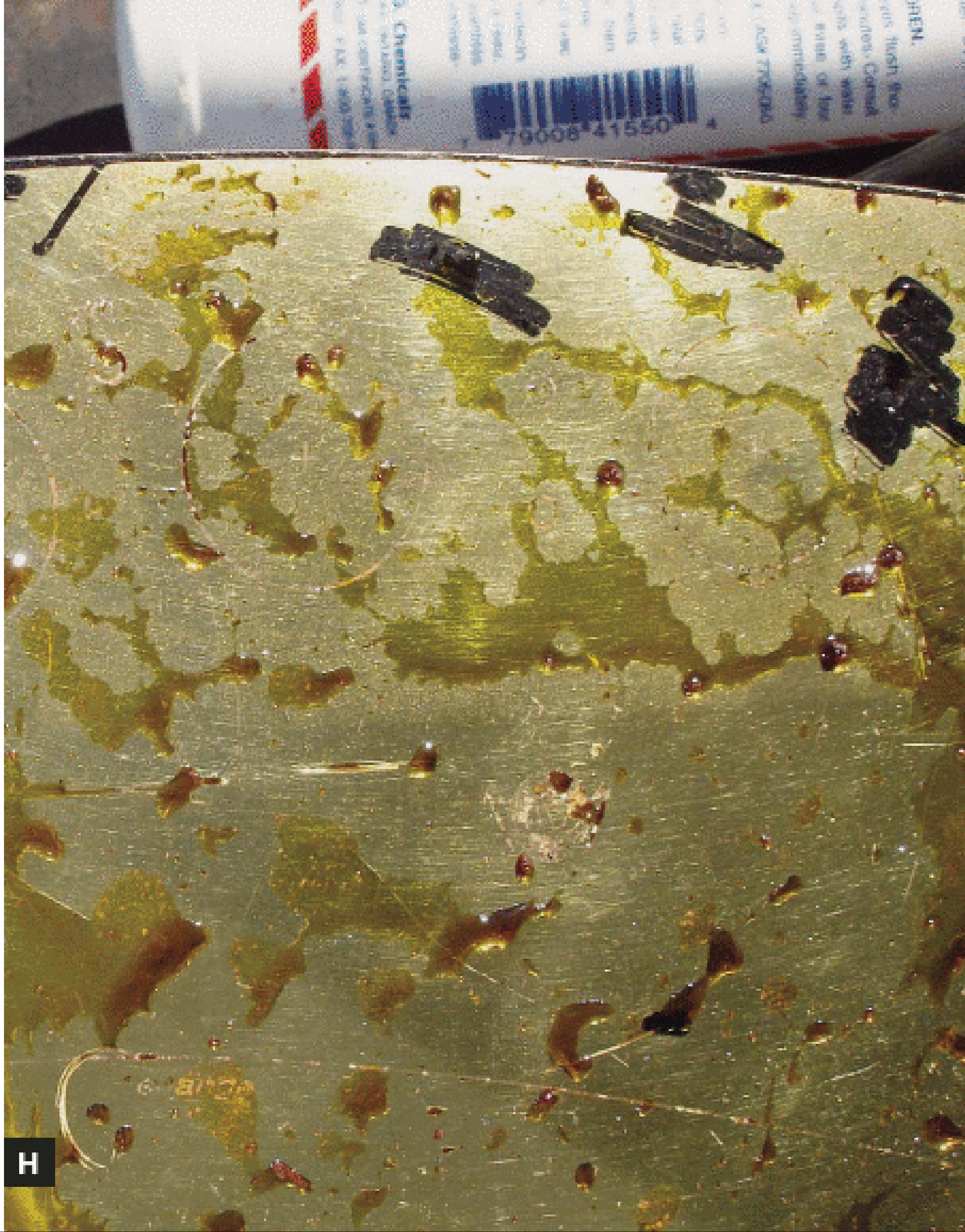


Fig. F: After exposure, develop the plate in 2 baths of ER-8 developer. Used ER-8 liquid is fine for the first bath. Fig. G: Etch the plate in warmed ferric chloride solution, wearing gloves and eye protection at all times.

Fig. H: Monitor progress during etching by lifting the plate out of the etchant and inspecting the surface.

WARNING: FERRIC CHLORIDE ETCHANT IS VERY TOXIC AND CORROSIVE.

It eats people, cloth, and wood, as well as metal. It will kill your pets and your plants. You cannot dump it into any sewer system, since it eats through pipes. Store it in its original bottle, and when it's spent, take it to a chemical disposal site. When ferric chloride contacts aluminum, it makes heat, splatters everywhere, and ruins the metal.

These are not wimpy warnings. Etchant is dangerous stuff. Wear chemical gloves and protective eyewear, and have someone around in case of emergency.

1. Cover the bottom and sides of the plate with packing tape or spray paint, to protect it from being etched.
2. Warm up the etchant to about 120°F by putting the sealed container into a bucket of hot water for 30 minutes. Etching goes faster at elevated temperatures.
3. If the metal plate is heavy, warm it to about the same temperature. (If it's thin, don't bother.)
4. Put the plate into a Pyrex dish and pour undiluted etchant to cover it completely, as much as possible without overflowing.
5. Rock the dish slowly but constantly to etch away metal. I put a pencil under the Pyrex dish to make it easier.
6. The amount of time is highly variable, and depends on how much metal you want removed. With chemical gloves on, you can lift the object out to inspect it. Etching for a full hour might get you 0.02" of depth, which may not sound like much, but it's quite striking and effective. You can feel it, and it's plenty deep to hold paint.
7. When done, remove the object from the bath and let it drain completely into the Pyrex dish. Then rinse it off in a sink with copious flowing water, and wash with hand dishwashing soap.
8. Your item is done! The resist coating can be removed with a bit of lacquer thinner on a cotton ball, or with mild abrasives like the polishing compounds used earlier.

Plating and Painting

So far, the photographs in this article have been showing the brass plate from my Model 11d Nixie clock. Another example, probably the best etched

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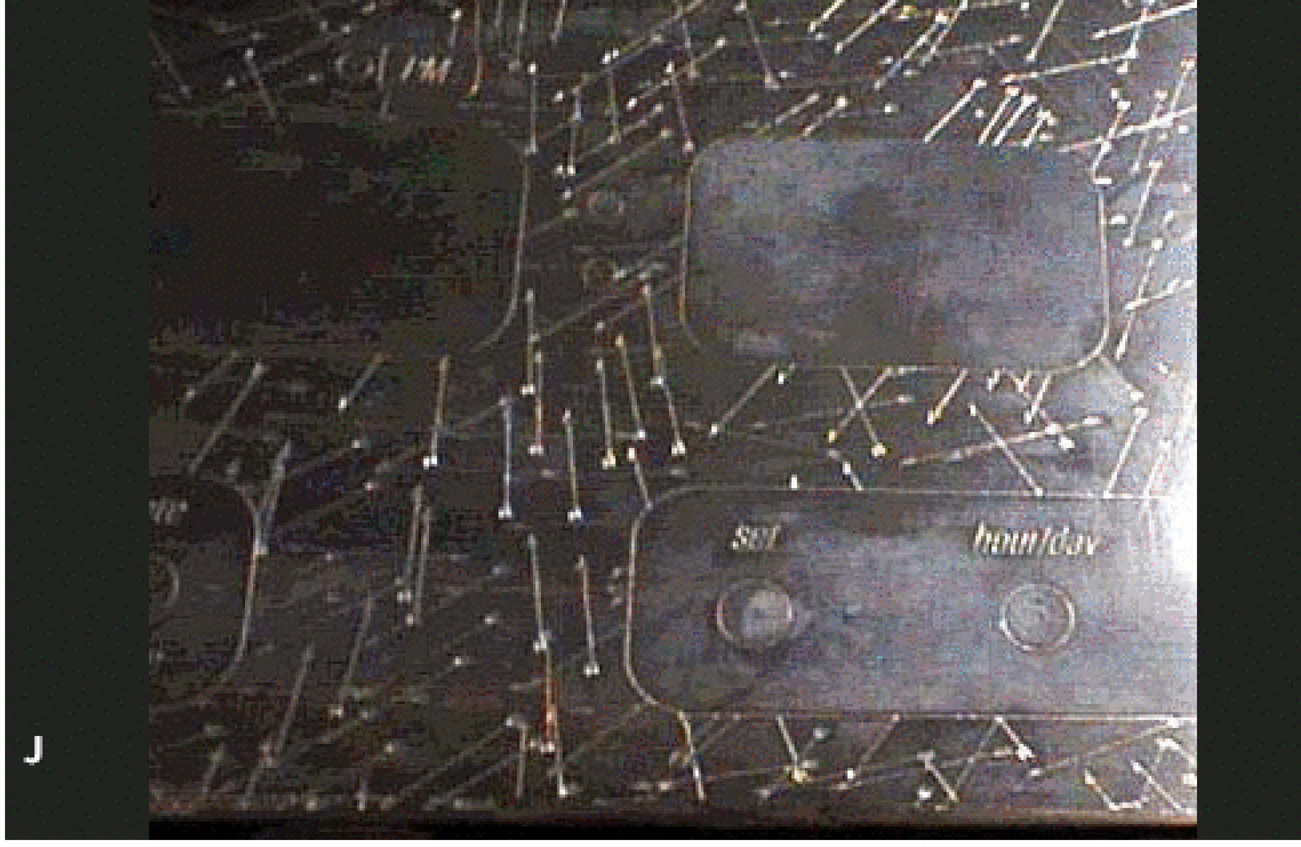

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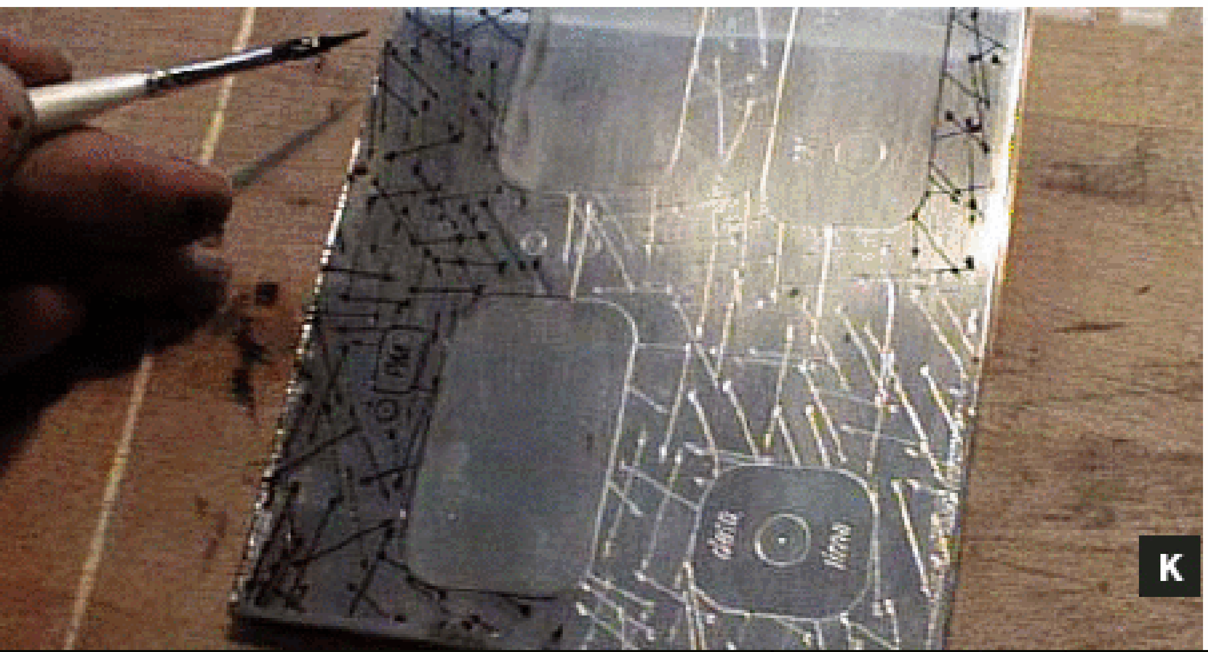

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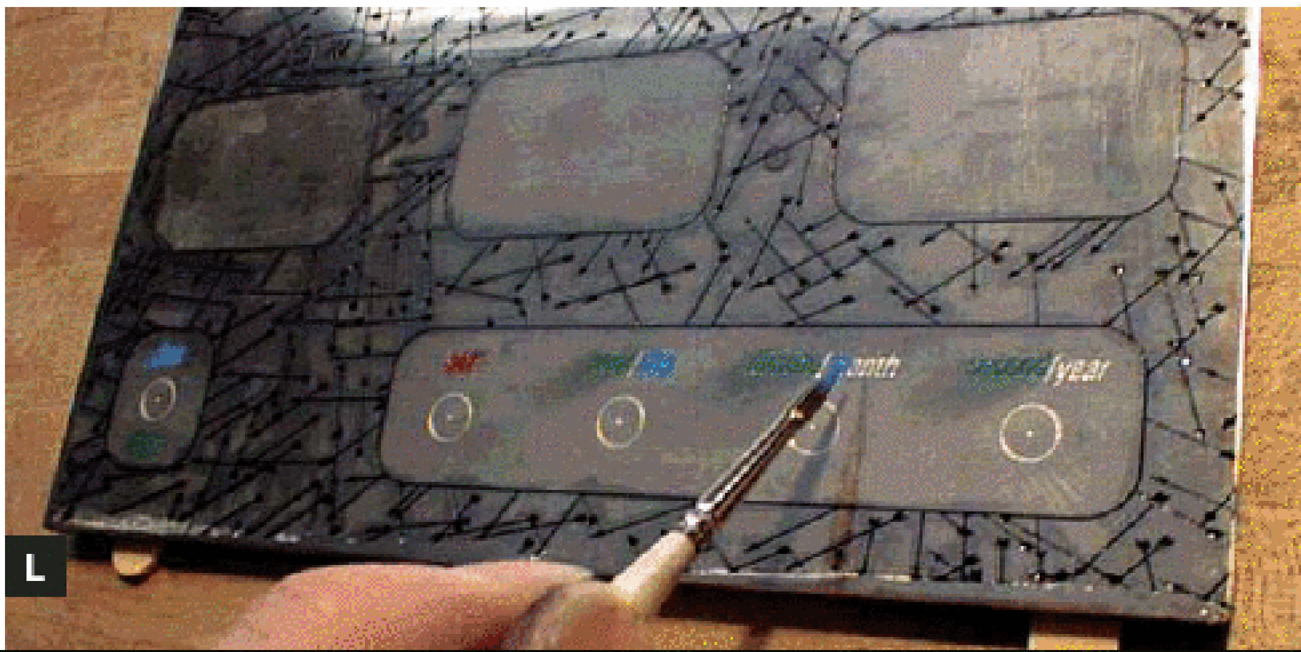

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Fig. I: Another panel, copper this time, fresh out of the etchant bath and washed off. Fig. J: An electroless plating bath tin-plates the etched copper panel, giving it a more neutral color.

Fig. K: Filling in the etched arrow details with a fine paintbrush and black enamel paint. Fig. L: Filling in the color detail with more enamel.

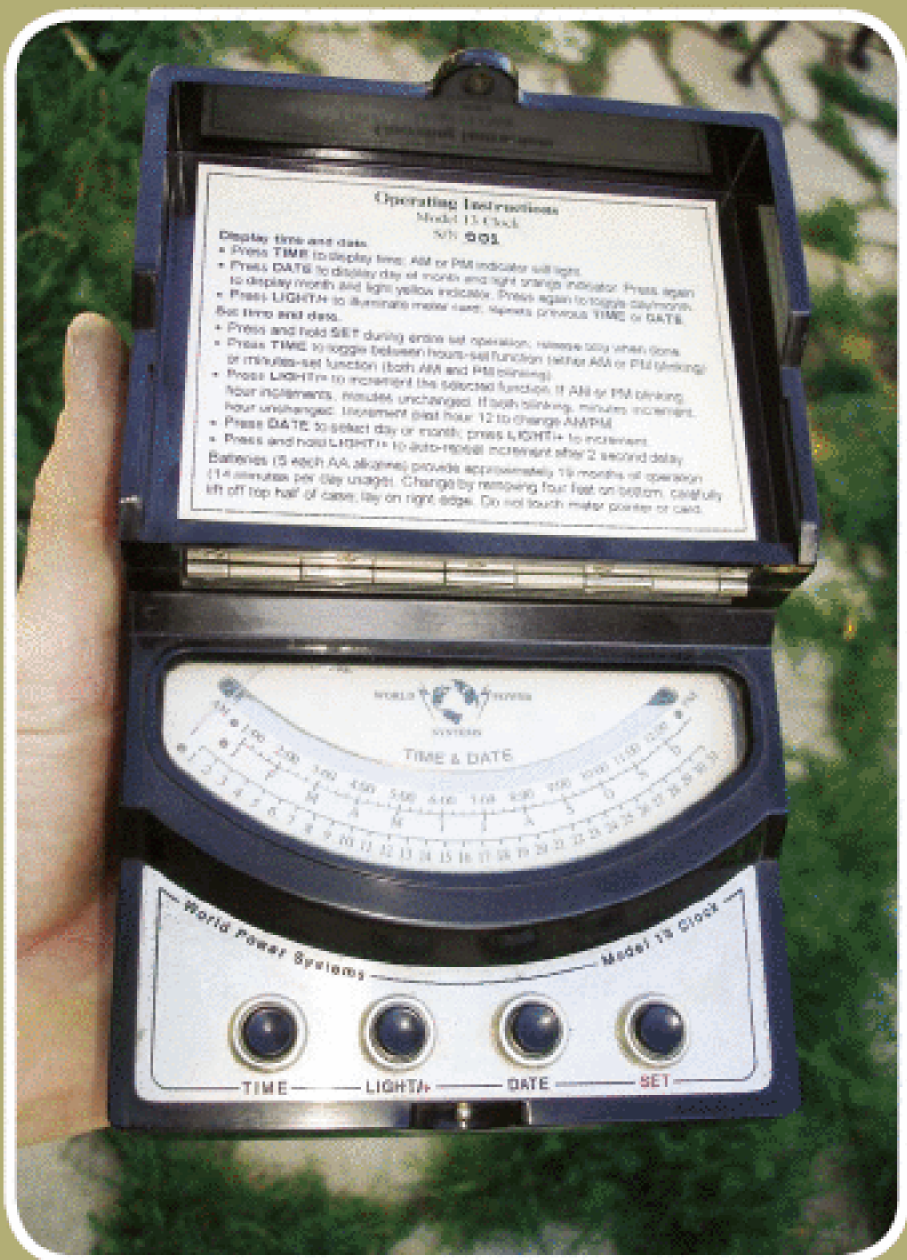
panel I've done, and one of the more detailed, is from my Model 11b Nixie clock.

This was a copper plate, which I tin-plated after etching using electroless plating solution. After removing the plate from the tin bath, the tin plating was dull.

I polished it with dry cotton balls, then used a small paintbrush to fill the etched lines with enamel paint (One Shot brand). I used tiny scraps of paper to carefully wipe the enamel filling flush with the surface, then polished off the excess with small scraps of plain copy paper.

After the paint dried, I shaped the panel by drilling holes for the switch and buttons, and filing out the rectangular areas for the display.

I also used tin-plated copper, painted with black enamel, for my Model 13, shown at right. Instead of using Nixie tubes, this clock shows the time and date with an analog needle gauge.



Tom Jennings (tomj@wps.com) is an artist with a background in technology.

ELEGANT PLYWOOD COFFEE TABLE

Making furniture with no nails, screws, or glue.

By Andy Lee

Photography by Sam Murphy

I've been interested in designing furniture for a long time. When I needed some of my own, I decided to build a set out of ¾" plywood. I chose to work with birch veneer plywood because it reminds me of Scandinavian furniture, which has a clean, elegant style that I love.

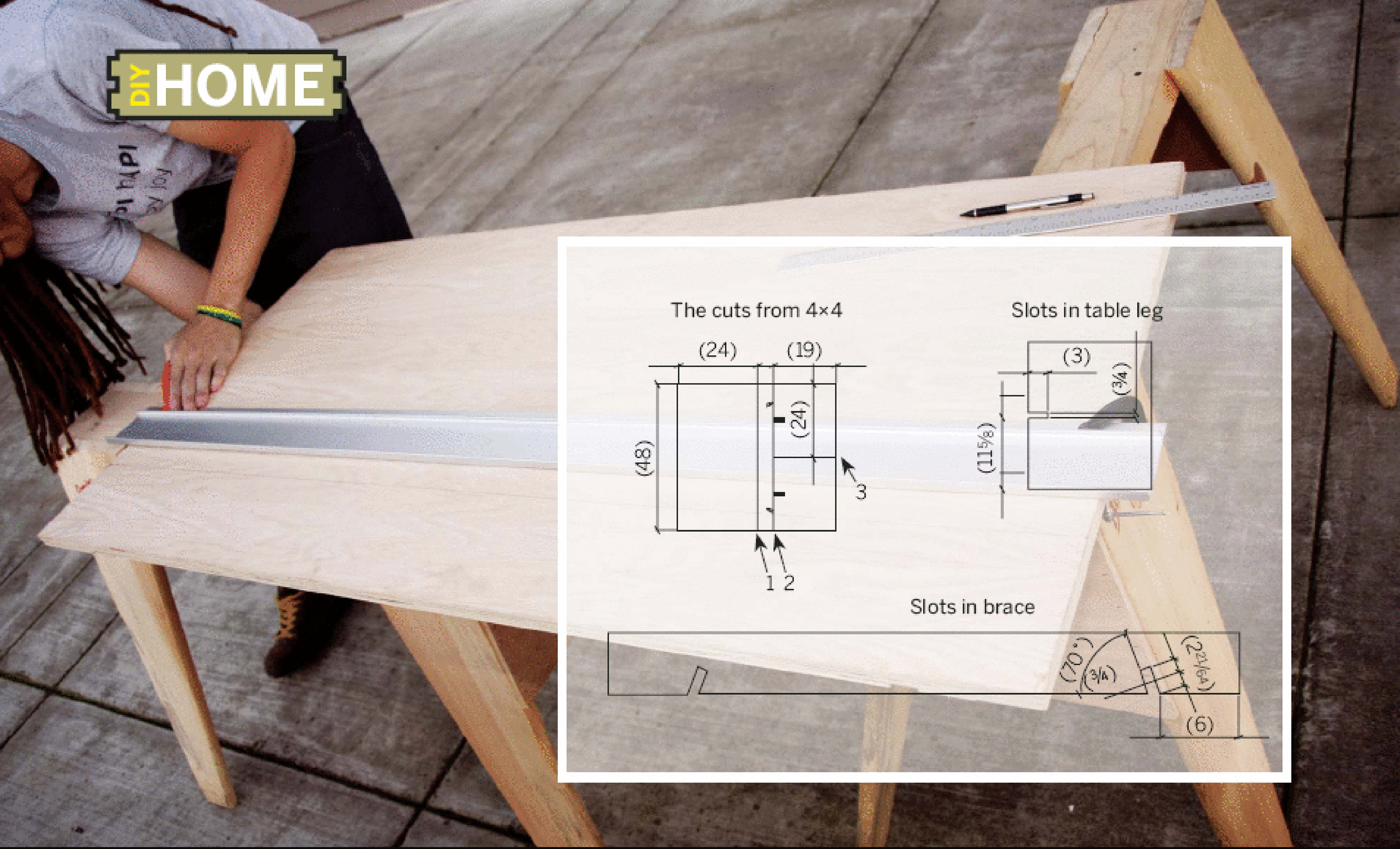
Having done a lot of moving in the last few years, I also wanted to make the furniture easy to assemble without any fasteners. To accomplish this, I designed each component piece with slots that mate with one another and hold the whole piece together. Not having fasteners makes the furniture easy to pack up and transport — each item breaks down into a stack of flat boards.

Finally, I didn't want to create any waste, so each piece is cut exactly from a half sheet of plywood.

Here's how to make an elegant coffee table with a few simple cuts, using a drill, jigsaw or circular saw, clamps, and other familiar tools.

1. Get the wood.

Obtain a 4'×4' piece of ¾" plywood that is in good condition and free from warping and knots. You'll also need four 1"×¼" wooden pegs. Different grades of plywood vary in price, ranging from rough particleboard to finely veneered and pre-sanded. This project will work with any type. I chose Baltic birch veneered 5-ply from a local



Inset: Pattern and dimensions for table's 4 component pieces. Tabletop, brace, and 2 legs are all cut from a single 4'×4' sheet of plywood, with no waste.

hardware store. If your sheet does have a knot or two, plan your production so that they wind up on the underside, rather than facing out. After sanding and painting, the piece will look great.

SAFETY FIRST! Whenever working with or handling wood it's a good idea to use gloves to protect your hands from getting splinters. Wear safety goggles and hearing protection while using any tools, and always secure the material you're working with to a stationary object using clamps or a vice. It's best to work with a partner, and it also makes projects more fun.

2. Measure the wood.

Referring to the pattern above, measure and mark your plywood along lines 1, 2, and 3. These divide the sheet into 4 pieces: a tabletop, a brace, and 2 legs.

To ensure accuracy in measuring, the trick is to measure from 2 or 3 different directions and make sure that they all yield the same result. I often measure cuts I'm about to make from opposite ends of the plywood, and then use a square to ensure their proper angle against the edge of the material.

TIP: To make clean, straight cuts with a handheld jigsaw or circular saw, clamp down a fence at either end of the material and run it along the edge you want to cut. A fence is simply a straight, solid object that provides an edge for your tool to rest against.

3. Cut the wood into pieces.

These first cuts break the unwieldy 4'×4' sheet of plywood into more manageable pieces. I used a handheld jigsaw.

Cut 1 Halve the plywood sheet to produce two 4'×2' pieces. One piece will be the tabletop and the second one will become the legs and the brace that holds the other 3 parts together.

Cut 2 Make a cut parallel to the first that's 5"-10" in from the edge. This creates a narrow 48" piece that will serve as the table's brace. The wider you make this piece, the lower and more stable your table will be. I made a taller table by cutting a 5" brace piece.

Cut 3 Clamp the larger piece left over from Cut 2, and cut it evenly in half, perpendicular to the first 2 cuts. With my table's measurements, this turned a 19"×48" piece into two 19"×24" legs.

When finished, the pieces of the table should look like this. Disassembled as shown in the inset and stacked together, they're a cinch to store and transport.

To assemble the table, slide the slots in the legs into the slots in the underside of the brace, as shown here. Then pop on the tabletop.

4. Cut the slots.

Cut the 4 slots, following the measurements shown on the previous page. Note that although the plywood is labeled as ¾", its actual thickness may vary. So for each slot, you should first measure the thickness of the plywood it will fit around (calipers are handy for this), and make the slot a few hundredths of an inch larger.

There are several ways to cut slots with handheld tools. One method is to use a ¾" hole saw or paddle drill bit and drill a hole at the inside end of the "soon-to-be slot." Then cut 2 parallel lines, tangent to the hole, out to the edge of the board.

Another way is to drill holes at the inside corners of the slot that are just large enough to admit a jigsaw blade, then jigsaw out from those.

The third method is to cut a slot straight out using a router and a ¾" router bit. This is the best method, provided you have the equipment.

5. Test assemble, and set the pegs.

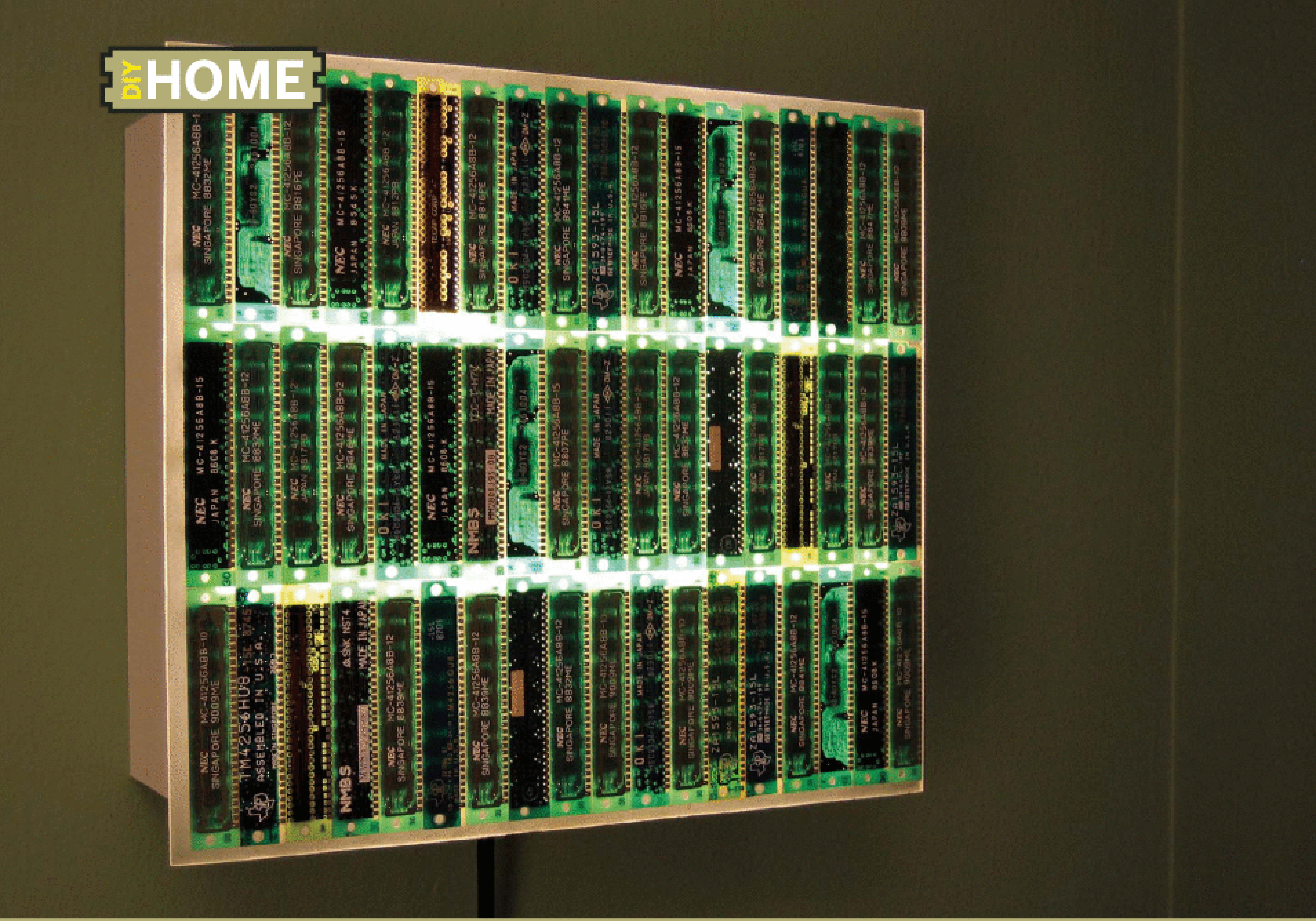
Slide the legs and brace together, to make sure they all fit. Along the top edge of each leg piece, measure 2" in from each end and mark a point centered on the edge of the plywood. Disassemble the pieces, and drill ¼" holes at each of these 4 points, ½" deep. On the underside of the tabletop, mark 4 corresponding points and drill ⅜" receiving holes for the pegs ½" deep. I marked locations by sliding pieces of pencil into the leg holes and centering the tabletop on top.

6. Finish the wood.

You have many creative choices when it comes to finishing your furniture. You can sand the edges, finish them with a router, or level them square. You also need to seal the wood, especially if you intend to use this as a coffee table where you will serve beverages. I used a water-based stain and 3 coats of high-gloss finish for the product, but there are other options. Ask the friendly people at your neighborhood paint store for advice.

Bonus: Now that you know how to make an awesome coffee table, you can use the same general method to make a bench or a desk or a dining room table or a stool. Go to town!

Andy Lee (andyleedesign.com) is a mechanical engineer and product designer. He specializes in consumer and household goods.



THE BYTELIGHT

Make a high-tech mood light from a fluorescent lamp and 54 obsolete SIMMs. By Ross Orr

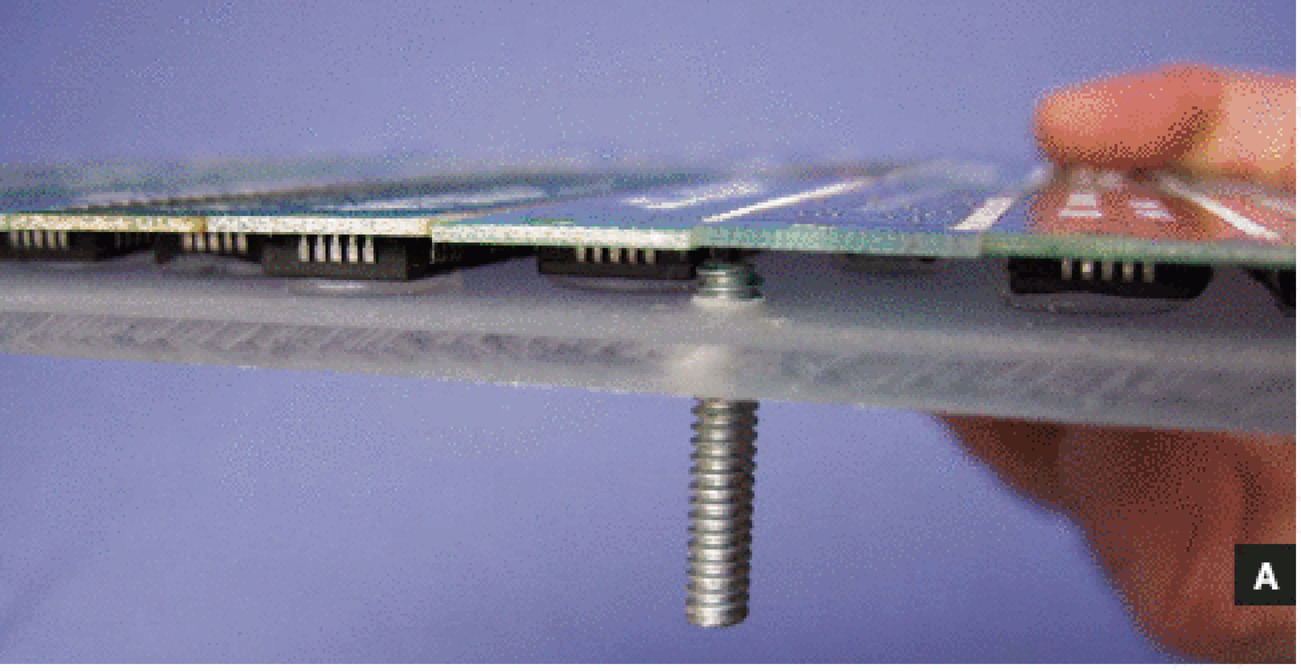
Several years back, I had a volunteer gig with a local charity. My job was to take old Macs that had been donated, and jolt them back to life so they could be resold at our weekly rummage sale.

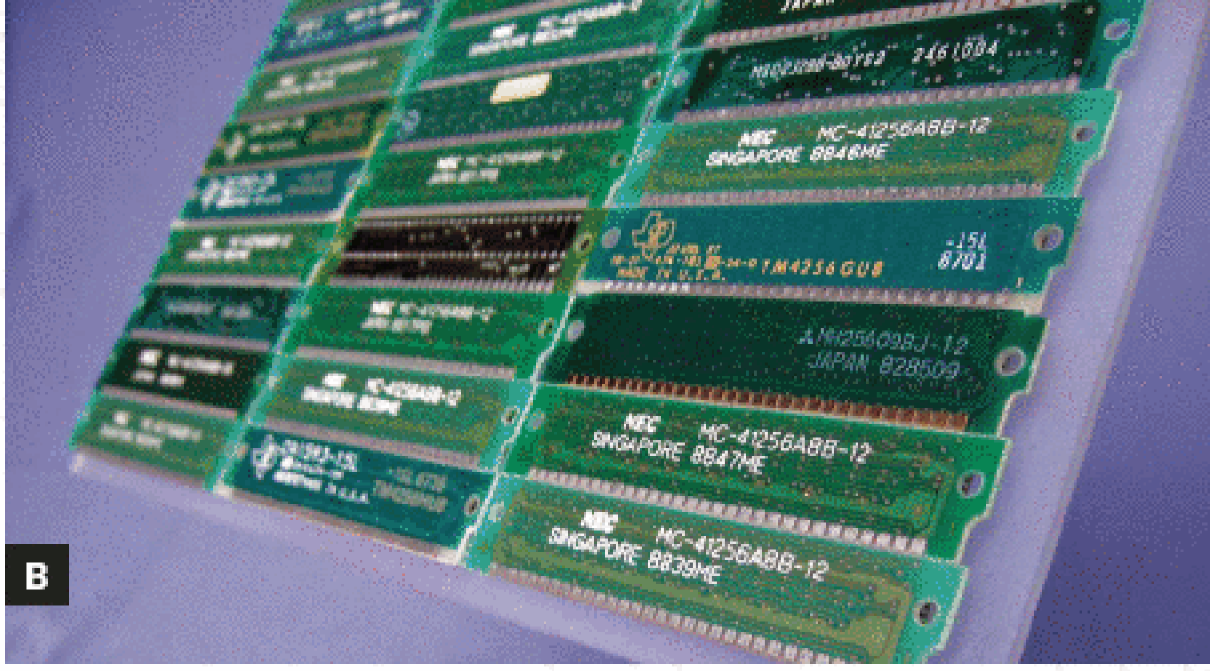
In those days, the low-end machines often came in with 1 or 2MB of memory — that M is no typo, you youngsters! — and I considered it a great victory if I could scrounge enough memory to upgrade them to 4 or 8MB. (I can also remember fitting System 6 on an 800K floppy — but Grandpa will save that story for bedtime another day.) Anyway, we routinely yanked out 256K SIMMs doing these upgrades, and I eventually accumulated a whole sack of them.

I knew these chips were utterly useless, but could never bring myself to throw them out. I kept dwelling on the thousands of dollars that their original purchasers had undoubtedly spent on them. Plus, these little wafers were kind of beautiful: each had its own subtly different color, delicate circuit traces, and cryptic labeling. They were almost like jewelry. I felt I needed to do something to honor their now-defunct preciousness, and thus the ByteLight was born.

The idea is simple, and can be used with any "interesting" piece of circuitry that has outlived its usefulness, as long as a bit of light shines through it. You just need to construct a shallow light box. Fronting it with diffusing plexiglass lets you glue down multiple circuit boards using silicone sealant. You can buy white plexi, but I just used clear scrap I had on hand. Sanding both sides with fine sandpaper on an orbital sander gave it a nicely frosted surface.

Photography by Ross Orr





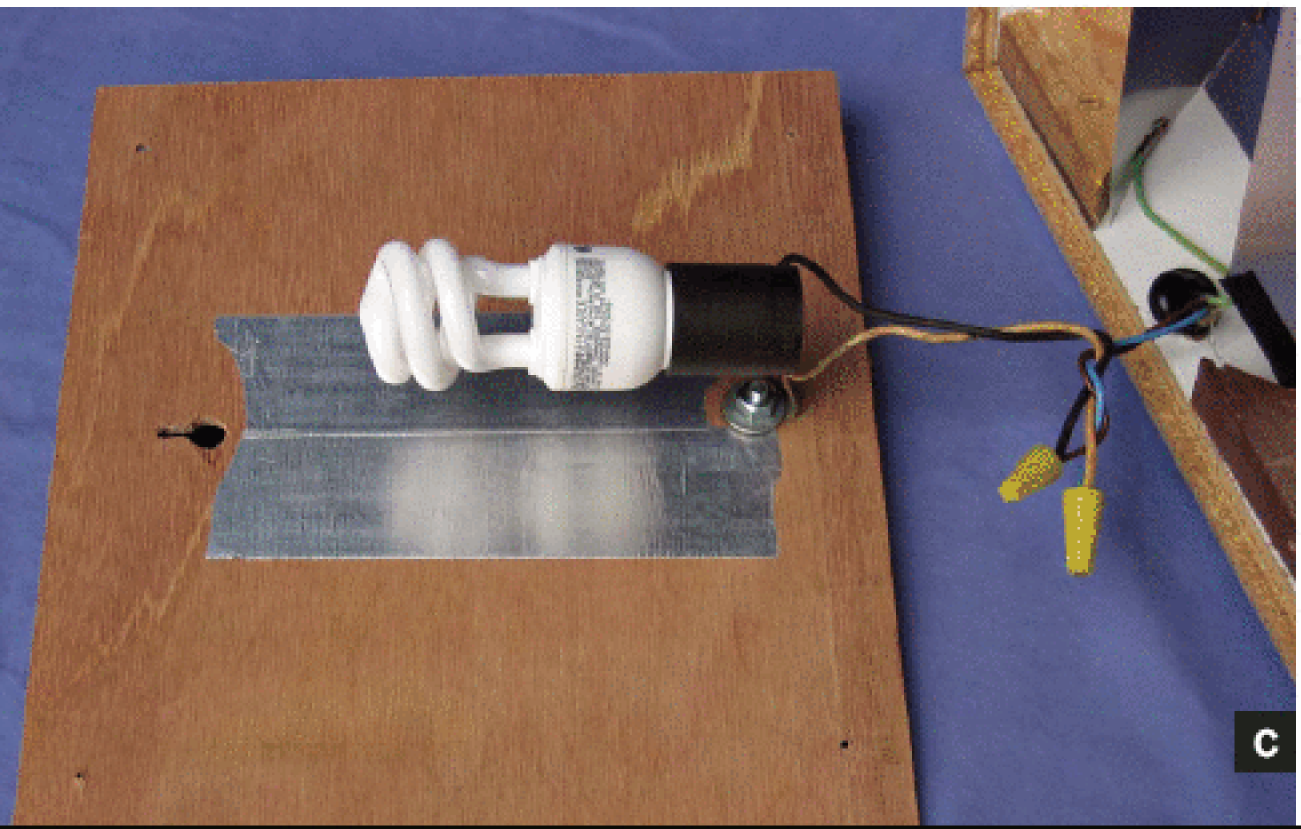


Fig. A: Silicone glue attaches wafers to plexiglass, which is held above the rim of the light box by a threaded rod. Fig. B: Wafers are glued chip side down to show tracery.

Fig. C: Removable light box back with lamp socket and compact fluorescent. Fig. D: The sheet aluminum lining stapled into the box reflects and diffuses light.

I made my box from ½" plastic-faced particleboard from an old sink cabinet. (A tip for neat mitered corners: after cutting the bevels, lay the boards flat, end to end, and run packing tape across each joint. Apply glue, and fold the corners into place. The tape holds the joints in position.)

The front edges of the box are cut away at an angle, so they won't cast shadows on the frosted panel. I added aluminum reflectors to even out the light, but that's optional. For easier access when it's time to change bulbs, I bolted the lamp socket to the removable back panel of the box. I also drilled a keyhole slot centered in the back panel, to make it easy to hang the finished box.

Use fluorescent lamps for your light source, to keep things cool. I used a 10W screw-base fluorescent, which puts out the same number of lumens as a 40W incandescent. Even so, I left a small gap between the plexiglass and the box to let heat escape. The box is sized to be 1" smaller than the height and width of the plexi, which eclipses the gap with a nice floating-plane look.

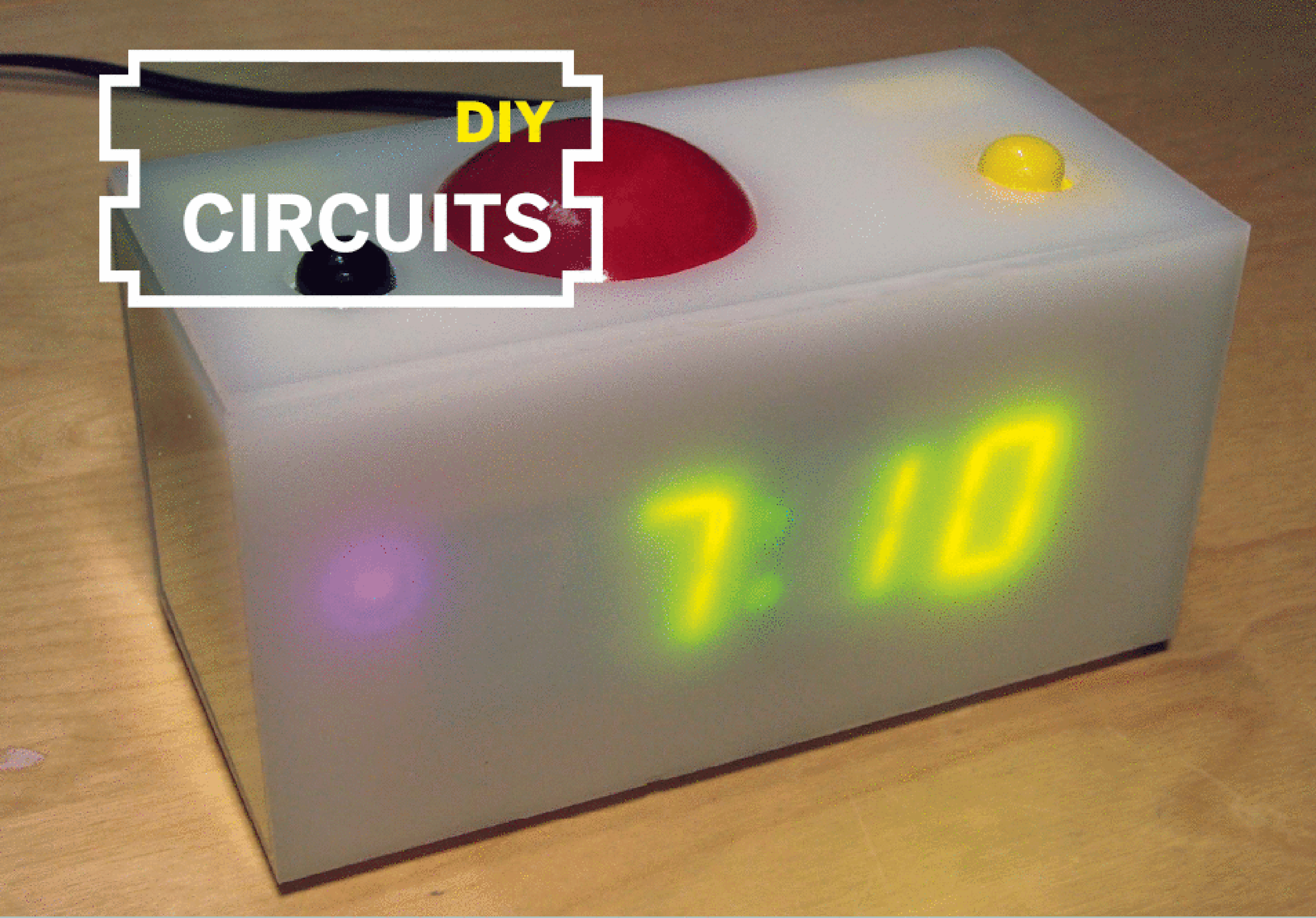
The trick to making the front float is to thread stubs of 10-24 rod into holes tapped in the plexiglass. Then drop these into holes in the box perimeter, drilled oversize and filled with silicone. I used kitchen matches to hold the gap spacing while waiting for the silicone to cure.

The power cable, appropriately enough, is also recycled from a computer. I snipped off its IEC connector, and wired it up to a screw-base lamp socket. The blue (or white) neutral wire in the cable should be connected to the shell of the socket. If your cord has a green or bare ground wire, you can connect that to any metal parts of the light box. Tie the cord into a knot inside the light box, so an accidental yank can't pull it out.

If you're laying out a grid of small boards like these SIMMs, it may turn out they aren't exactly identical in size. So test your layout beforehand, and sand down the edges of the oddballs as needed. I decided I preferred their look with the component side down, to emphasize the patterns of the circuit traces, leaving the RAM chips themselves as ghostly outlines.

The result is a softly diffused green light — a nice ambience for late-night relaxing. And I'm pretty sure I'm the only person on my block with a 13.5-megabyte night light.

Ross Orr hacks low-tech gadgets and invasive plants in Ann Arbor, Mich.



DIGITAL CLOCK

Programming PIC microcontrollers, part 3.

By Sparkle Labs

In parts 1 and 2 of our microcontroller primer (*MAKE, Volume 04, page 158, "Microcontroller Programming," and Volume 07, page 149, "Hello, World"*), we got a PIC chip development system up and running, covered basic inputs and outputs, and left off by showing how to use a PIC chip by itself to control a simple pushbutton counter. In this article, we'll show how to use a PIC along with other chips to make a digital clock.

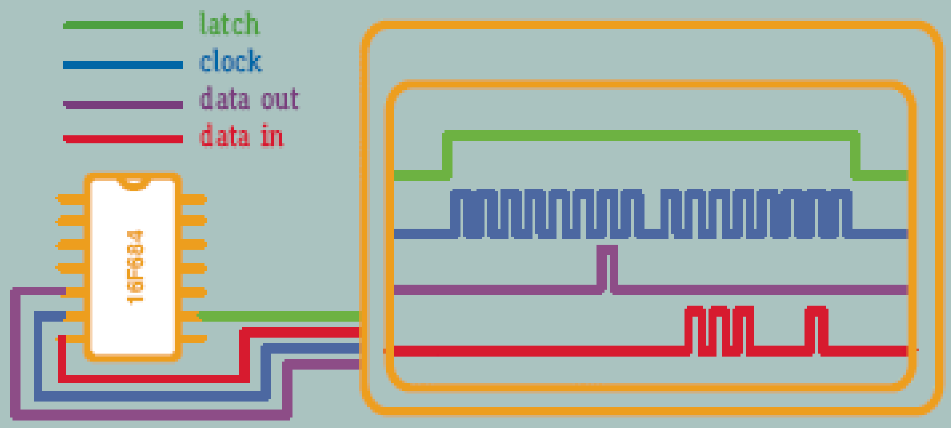
Our two peripheral chips are the DS1305 Real Time Clock (RTC), which keeps track of the time, and the MAX7221, an LED display driver. Both are manufactured by Maxim Integrated Products, with datasheets available at maxim-ic.com. We'll use the PDIP package versions, so they'll fit into a breadboard.

Just like our microcontroller, these special-purpose ICs have settable 8-byte registers that determine how they function. But peripheral chips don't store and run programs on their own, so we can't upload code to them and set their registers directly. Instead, we'll program our microcontroller to tell these chips what to do. The chips' datasheets explain how the microcontroller can communicate with them, as well as how they need to be connected into our circuit.

ICs exchange data over numerous communications protocols. Our clock will use Serial Peripheral Interface (SPI), a simple serial binary protocol that requires just four pins on the microcontroller, plus one more for each additional peripheral device. One pin sends data out to the peripheral(s), one pin receives data, a clock pin pulses high and low to mark each new send/receive cycle, and

Photograph by Sparkle Labs

the latch (or load) pins, one for each peripheral, switch the peripherals on and off. These pins and their connections are collectively known as the data bus.



The LED Display

First, let's look at how to hook up our display driver to run the displays that will show our clock's time. The MAX7221 datasheet explains that this IC is capable of driving up to eight 7-segment digit displays (or up to 64 LEDs in an 8×8 matrix). Referring to the pin description on page 5 of the datasheet, we see that pins 1, 12, and 13 are the data-in, latch, and clock pins, respectively; we'll connect these to I/O pins on the PIC. Pin 18 connects to power through a resistor, the value of which limits the peak current that the chip supplies to the LEDs, to match the LED's power needs and desired brightness. Pin 24 is data out (which we are not using). Pin 19 connects to +5 volts, and pins 4 and 9 go to ground. Physically, pins are numbered on ICs counterclockwise from pin 1, just to the left of the notch on top.

The remaining 16 pins connect to the LED displays themselves. Eight of these pins are the digit drivers, each of which connects to the common cathode of a single-digit display and sinks the current that runs to the segments of the digit that are "on." The other 8 pins are the segment drivers, which supply current to all of the segments that share the same position on the displays.

To turn a digit on, you set the digit driver low for that digit. Then current will flow through from the segment drivers that are set high, and light the segments. Meanwhile, the driver scans through all the displays repeatedly, changing segment pins and refreshing digits fast enough that the LEDs look like they're always on.

Our clock needs 5 digits, 4 numbers and an AM/PM indicator, which we'll sink from the chip's digit driver pins 2, 3, 6, 7, and 11. We'll also use 2 individual LEDs in series for the colon character separating hours and minutes.

For our numeric displays, we'll use 5 Kingbright SA56-21GWA green LED packages. As their datasheet explains, these have 10 pins each. The middle pins on each side (pins 3 and 8) are the common cathode, which you connect to a digit driver on the 7221. The remaining pins connect with the identically positioned pins on other displays, and are collectively fed by the corresponding segment driver. The 2 LEDs for the colon character, meanwhile, are always on, connected between power and ground.

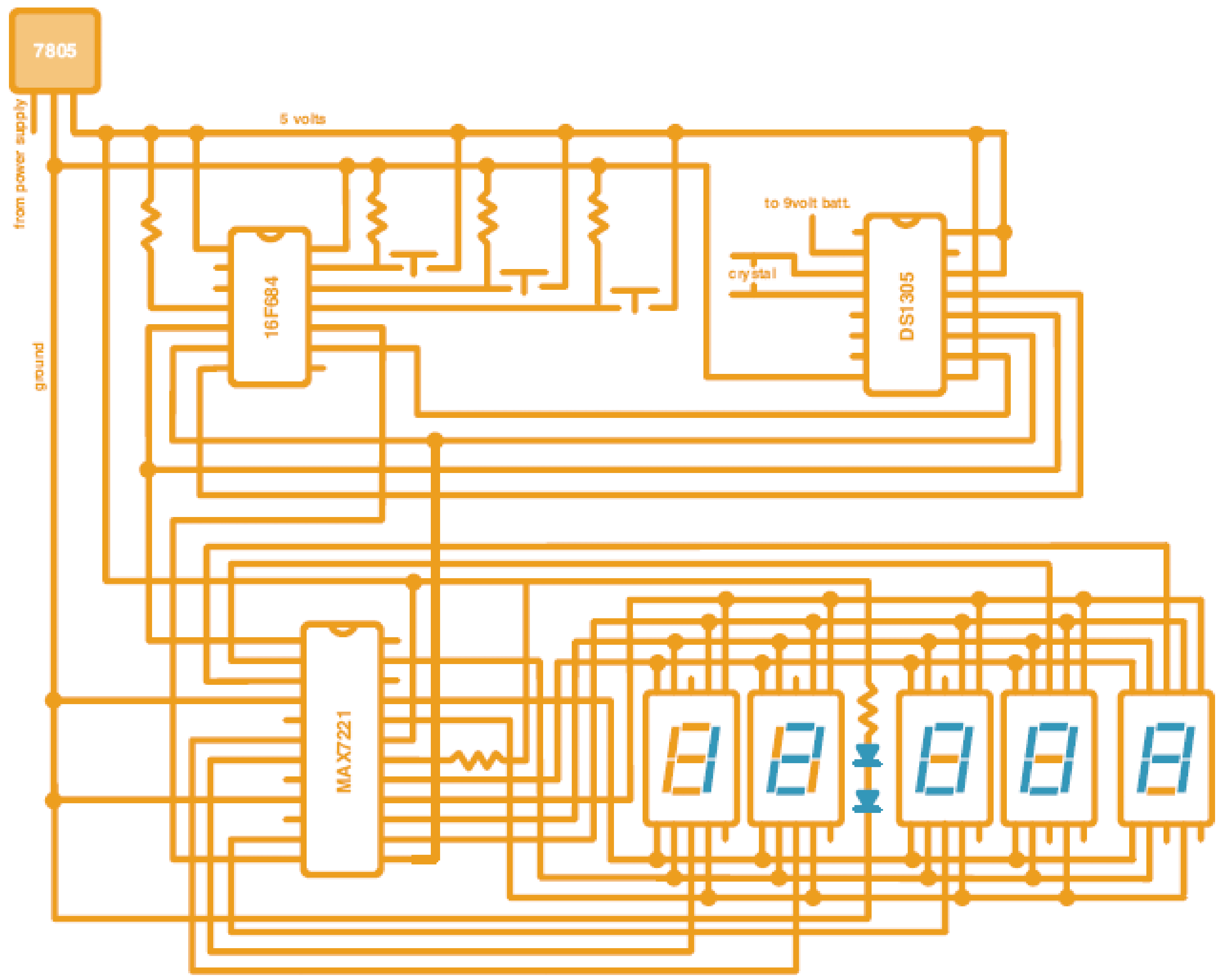
Testing the Display

With our PIC, the 7221, and the display all wired up and powered, we can write some code to talk to the driver and see if it works. Table 1 on page 6 of the 7221 datasheet shows us that the driver takes serial input in 16-bit chunks, and it ignores the first 4 bits of each. The next 4 bits specify which register we want to send the data, with the registers corresponding to the individual digit displays, plus special-purpose registers that control meta-states such as shutdown, display test, brightness/intensity, and decode modes. The last/least significant 8 bits of each 16-bit data chunk carry the data itself, as either individual on-off bits for each segment, or else (in decode mode) 4-bit binary numbers which the driver converts into readable numerals.

At the top of the code, we need to send some startup and initialization data. To send values to individual pins, for example to set the latch pin low or high in order to activate or inactivate the chip, we use the BASIC functions `low` and `high`. To send chunks of serial data to the driver's registers, we use the subroutine `shiftout`, which takes as arguments the data pin, the clock pin, the mode, and the value (the bits themselves). Our mode will always be 1, which specifies Most Significant Bits (MSB) first.

For example, the datasheet explains that after powering up, we need to set the shutdown register (address 1100) to normal operation (1). We do this with the call:

```
low s7221 ' make the latch pin low
shiftout dout, dclock, 1, [%00001100, %00000001 ]
high s7221
```



Digital clock wiring. ICs used are 16F684 microcontroller, MAX7221 display driver, and DS1305 real time clock. Circuit also includes a 32.768kHz watch crystal, 7-segment LED packages (5), and a 7805 voltage regulator. All resistors are 10KΩ, and the two single LEDs separating hour and minute displays are 200Ω. For fun we used tilt sensors along with regular buttons for the Set, Hour, and Minute switches, shown at right of the micro.

After our code makes a few more initializations, we can write information to the display digit-by-digit by calling the function shiftout with the register address of the digit you're writing to, and its new value. If the decode mode register is set to decode that digit, it will look at only the last 4 bits of the data and convert it to a numeral 0-9. Otherwise it interprets each bit as an on-off setting for each of the 8 individual segments.

We set our driver's Decode Mode register to decode just the first 4 digits (DIG 0-3), and our 5 displays are arranged physically in the order 3, 2, 0, 1, 4. At far right, DIG 4 serves as the AM/PM indicator, and because it isn't decoded, we can send it data segment by segment to make an "A" or a "P" character. For testing, we can set our clock to read "1:00" by calling shiftout to send register %0011 (DIG 2) the data %0001 and send registers %0001 and %0010 (DIG 0-1) the data %0000.

Now we have a clock that's correct twice a day. Let's add another chip to make it correct all day.

The Real Time Clock

The DS1305 Real Time Clock (RTC) keeps track of the year, date, day of the week, hour, minute, and second. It has registers that we can read the current time from, or write to, for resetting the time. It also has registers for 2 alarms, and even 96 bytes of RAM for data storage. To run, all it needs is power, ground, and a 32.768kHz watch crystal connected between pins 3 and 4.

To see how to connect the chip to our circuit, we run through the pin description on page 3 of the online datasheet. Pin 1 goes to ground, as we have no rechargeable battery. Pin 2 connects to a +9V battery. Pins 3 and 4 connect to the crystal. Pins 5-7 and 15 we won't use. Pin 8 goes to ground. Pin 9 connects to power, to tell the chip to use SPI protocol. Pins 10-13 are for the SPI bus, and connect to the microprocessor's latch, clock, output, and input pins, respectively. Pins 14 and 16 connect to power.

As with the 7221, you communicate with the DS1305 by sending the address you want to talk to, followed by the data. First, we initialize the chip by sending to the control register ($8F hex, or %10001111) the data %00000111. This sequence of bits starts the oscillator, write-enables the other registers, and enables both alarms, which we may want to use later.

Next, we need to think about how the user interacts with the clock. On power-up, the display shows 12:00 AM. Three buttons, Set, Hour, and Minute, work by switching 3 digital input pins on the microprocessor. Our code defines 2 modes: Display and Set. In Display mode, the PIC reads time data from the RTC, then converts it for display and transmits it to the display driver.

In Set mode, the two other buttons increment the time shown on the display, working like keyboard buttons — advance one with each press, and continuously if held down. As the PIC advances internal hour and minute variables, it updates the display with the new time, and when it leaves Set mode, it writes the new time out to the RTC. On our finished clock we used tilt switches for the Hour and Minute buttons, so you set the time by physically picking it up and steering it around.

The display driver reads digits differently from the way the RTC represents time, so our code needs to convert between the two. The display driver wants each digit in "binary coded decimal," where each digit is represented by a byte (even though it really only requires 4 bits). The RTC uses 4-bit binary coded decimal for separate hours, minutes, and seconds registers, and bits 5 and 6 of the hours register determine if the clock is in 12- or 24-hour mode, and in 12-hour mode, whether it's AM or PM. So, for example, the time 12:35 PM is represented in the RTC hours and minutes registers as:

```
%01110010 %00110101
```

But needs to be sent to the display driver as:

```
%00000001 %00000010 %00000011 %00000101
```

Below is a routine for converting the RTC time into display digits:

```
digit0 = clockmin & $0F
digit1 = clockmin >> 4
digit2 = clockhour & $0F
digit3 = (clockhour & $EF) >> 4
PMlight = clockhour.5
```

`digit0 - 3` are the variables we use for the display. `clockmin` and `clockhour` are the variables in which we store the data from the clock. Rather than using arithmetic operators, we can perform some binary-fu with the bitwise operator AND (`&`) and SHIFT (`>>`), which moves bits to the right and drops the lower ones out. By using these with the hexadecimal numbers `$0F` (15, or `%1111`) and `$EF` (239, or `%11101111`) as masks, we have all the hour and minute conversions we need. The last line of the routine looks at bit 5 of `clockhour`, which is high (1) for PM times in 12-hour mode.

Besides converting real-time clock values for the display driver, the other main thing our code needs to do is handle Set mode, which is easy once you can capture the button presses. You can see how that's done in the project code online.

Alarms and Other Enhancements

Moving forward with our clock, we will want to add an alarm or two. To do this, you need any device that can make noise, and a way for the user to set the alarm. We may want to show the date and make the alarm settable for specific days of the week, which the RTC will support. Perhaps we will also add a light detector, to dim the display at night. And we certainly need a nice case and some pretty buttons.

These are the basics of using a PIC with peripheral devices. There are thousands of such devices available, including accelerometers, temperature sensors, digital potentiometers, and storage devices. In this series of articles we have focused on PICs and PicBasicPro, but you can apply much of the information to other microcontrollers and compilers. Have fun!

Datasheets

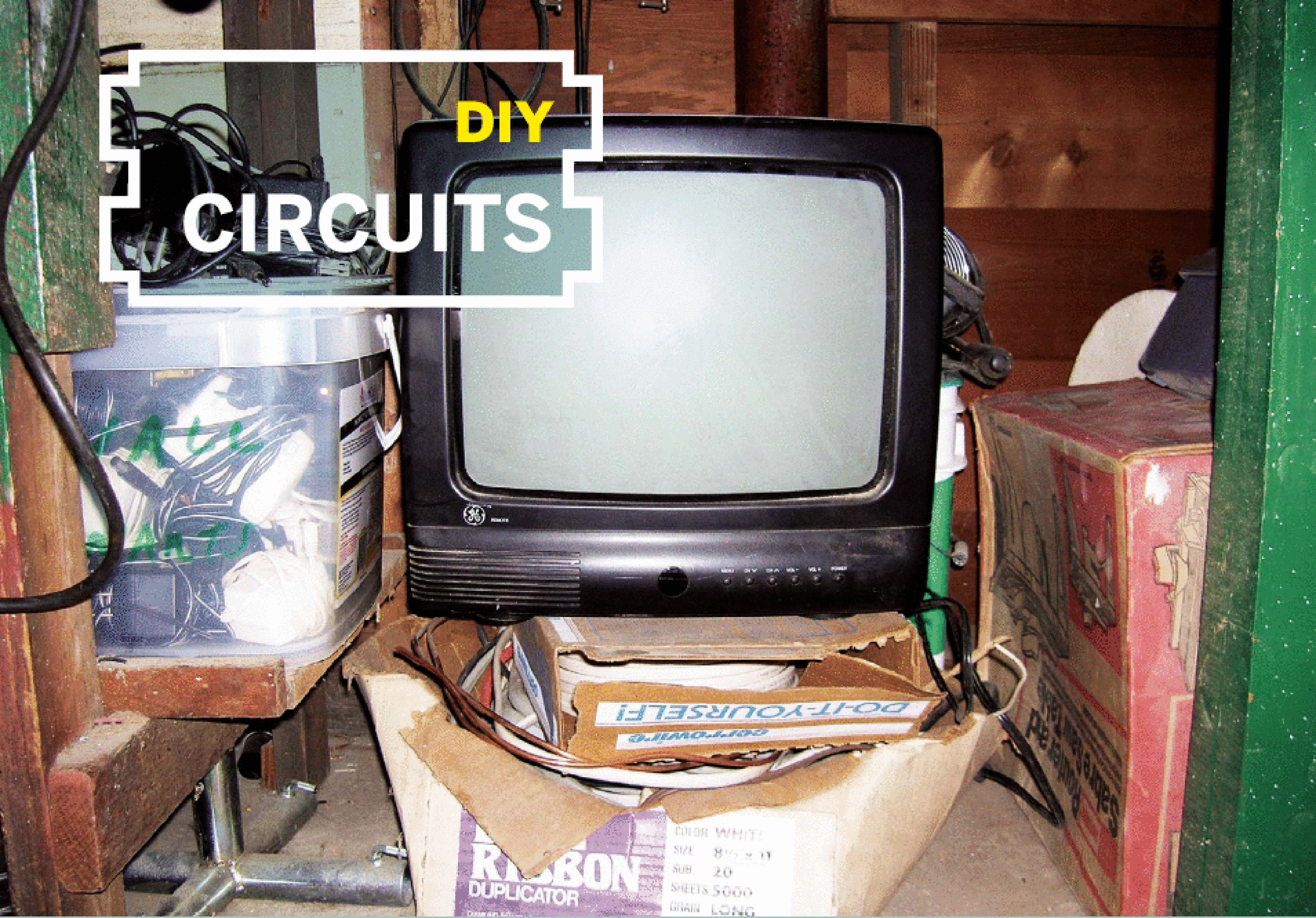
MAX7219-MAX7221 display driver
makezine.com/go/driver

DS1305 Real Time Clock
datasheets.maxim-ic.com/en/ds/DS1305.pdf

SA56-21GWA/A single digit numeric display
makezine.com/go/display

Materials list, development environment, code, additional diagrams, and suggested reading online at makezine.com/09/diycircuits_clock.

Amy Parness and Ariel Churi work at Sparkle Labs. Amy is a digital artist and product designer who pets her cats while working with new technologies and materials. Ariel eats chapati and creates "hi-tech, hi-touch" toys and environments for all ages.



TV SET SALVAGE

Nothing good on TV? Well, there's plenty of good stuff *in* a TV. By Thomas Arey

During the late 1950s and early 1960s, electronics hobbyists found a wealth of parts for projects inside discarded television sets. It was considered a point of pride in amateur radio circles to homebrew a transmitter out of a broken "boob tube." Of course, those were the days of 6146B sweep tubes, big 1-watt resistors, and transformers that would break your foot if they fell off your workbench. Occasionally, if you were really lucky, that scrounged set would turn up a couple of those new transistor thingies.

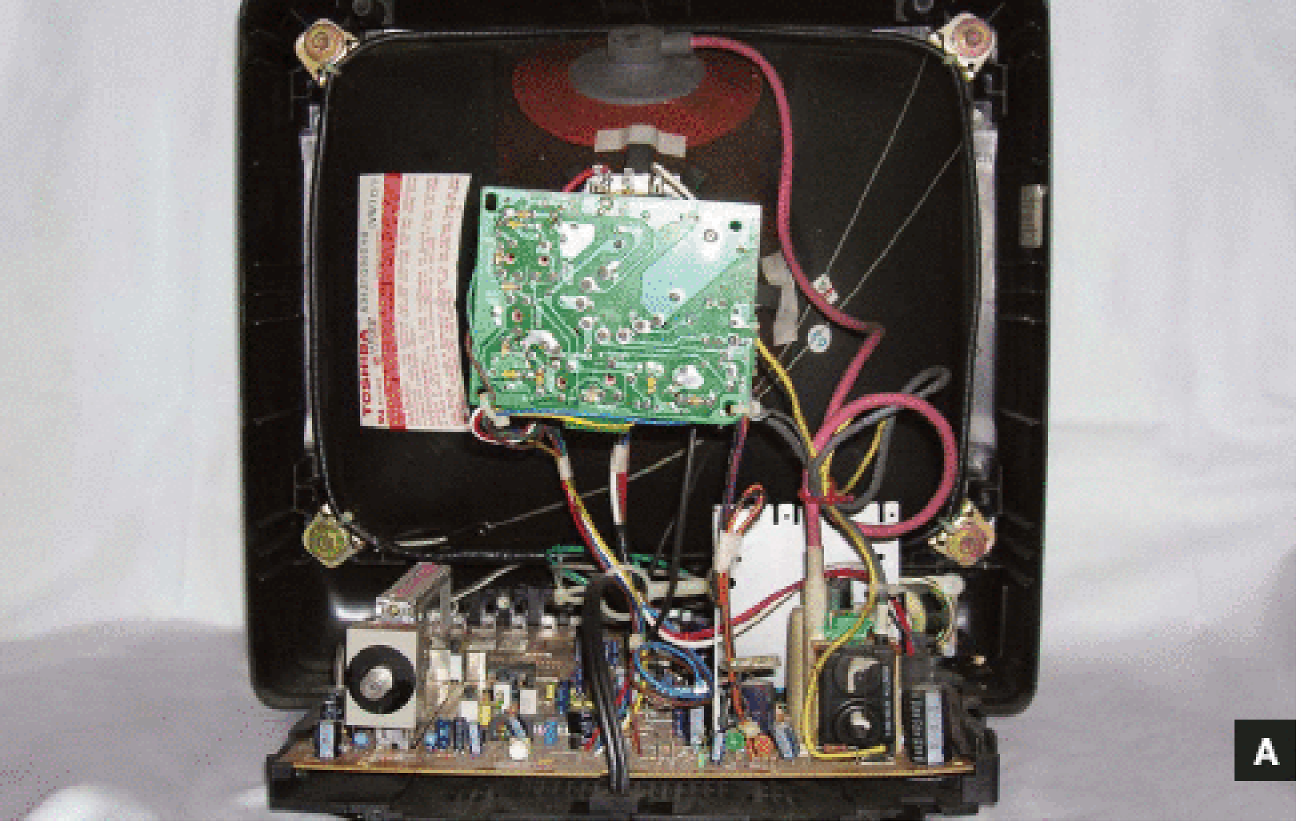
Technology marches on, and the insides of more modern TVs turn up a very different parts complement, lacking in any "hollow state" components except the picture tube. As a radio hobbyist, I wondered: Is it still possible these days to take a discarded TV and salvage the stuff that radios (and many other projects) are made of?

Thanks to a 10-year-old General Electric portable I found on a dumpster dive, I happily found out that the answer is yes.

First, a few words of warning. Do not take a television apart unless you are comfortable handling both high voltages and potentially exploding glass. The power supply in a traditional TV presents 30,000 volts when energized. Even unplugged, the capacitors in the power circuit can hold a charge for months. Also, the picture tube is a large glass vacuum container. If it is dropped or cracked it can shatter into thousands of nasty shards. Wear eye protection and gloves when handling the tube. That said, if you are still ready to own your TV like a true maker, let's go!

Removing the back of my GE set revealed one large circuit board at the base and a smaller one on the back of the picture tube. A thick red high-

Photography by Thomas Arey



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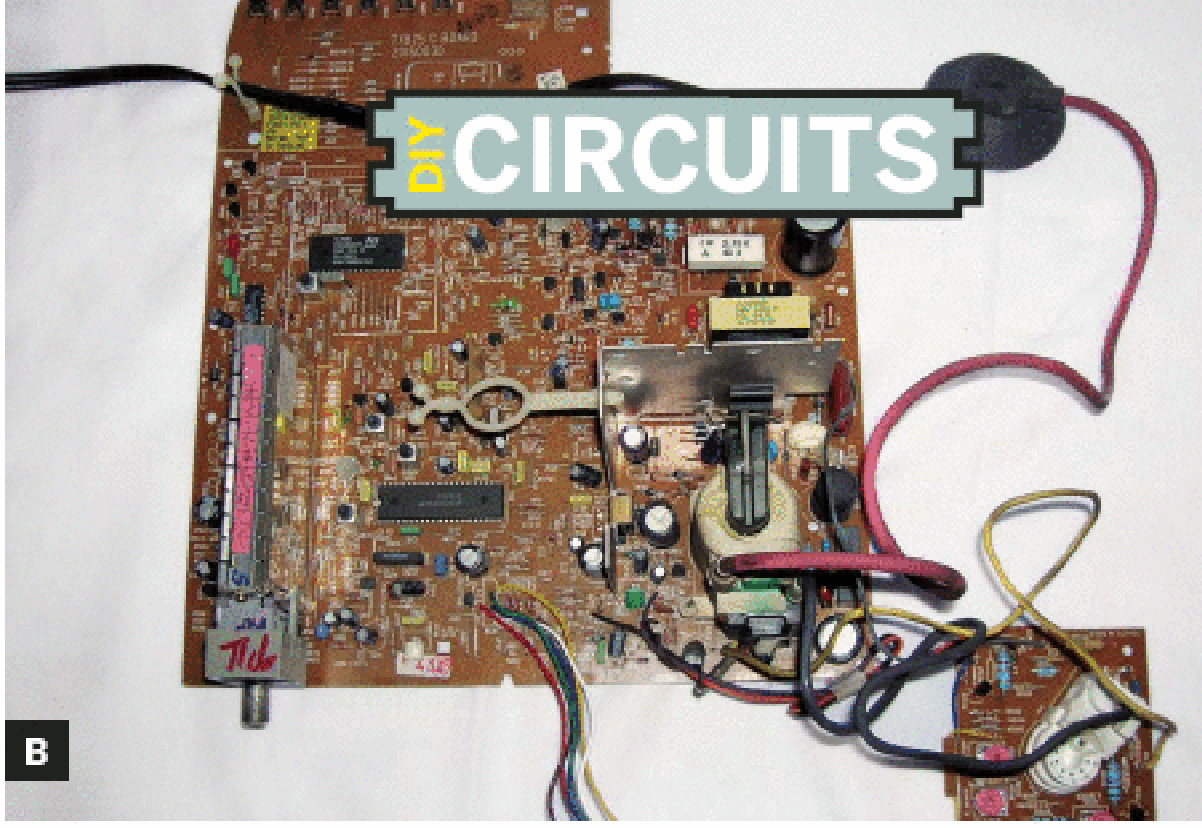

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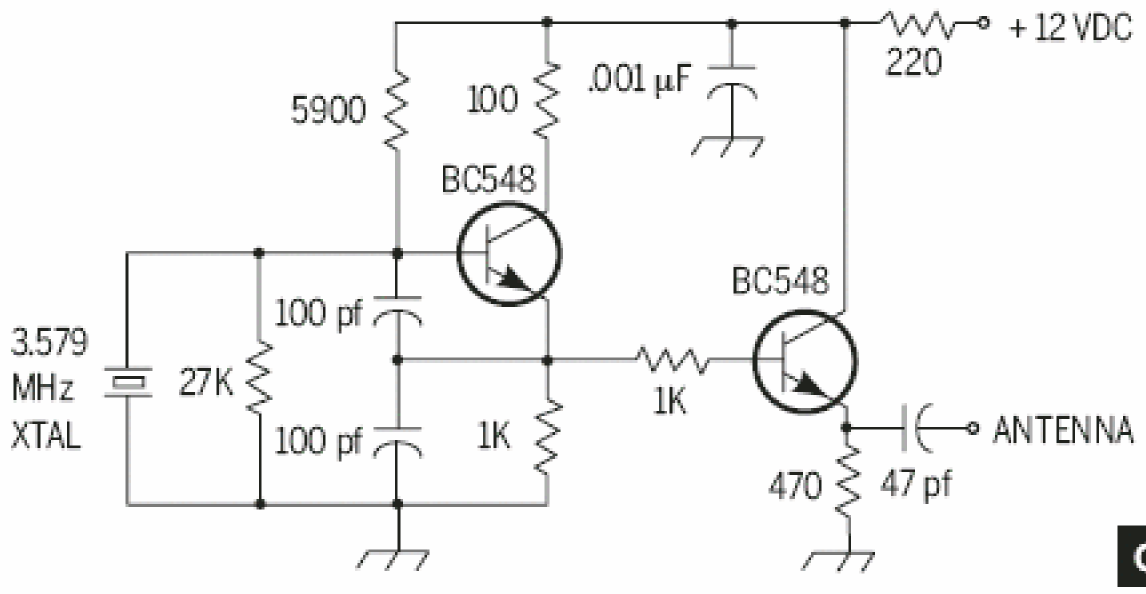

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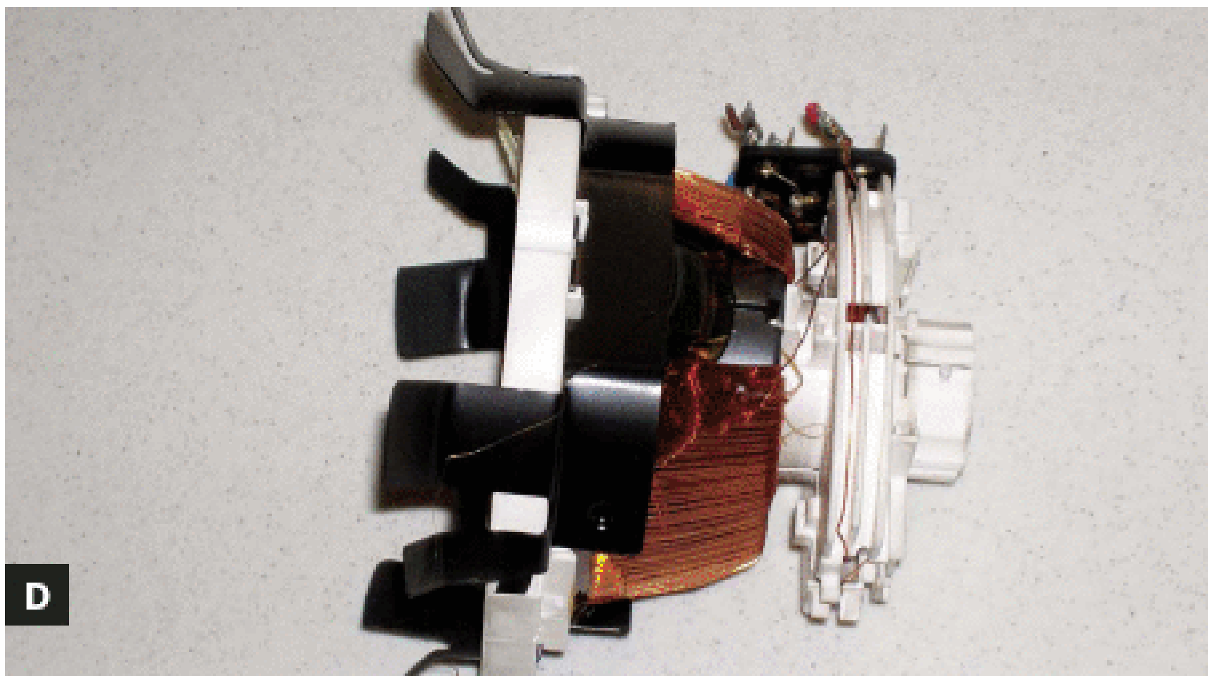


D

Fig. A: Opened TV with 2 circuit boards. Thick, red wire drives the tube from a high-voltage power supply, lower right. Fig. B: Circuit boards snapped out of the opened television without any unscrewing.

Fig. C: Colpitts oscillator circuit uses TV components to generate a sine wave you use as a broadcast carrier. Fig. D: The flyback transformer, which pulls the tube's beam along its scan pattern, has lots of winding wire.

voltage wire connected the power supply to the tube's anode cap. Again, be careful here. Cracking the case and liberating the PC boards required only a Phillips screwdriver. The boards themselves were "snap fit" into place without screws.

The PC boards yielded far more parts than I expected. There were only 3 proprietary integrated circuits; the rest of the circuitry was all discrete, standard components. At the time of this set's design, surface-mount technology had not yet kicked into high gear, so all the parts are easily usable for hobby projects, except fora few large SMT resistors.

I found 18 BC548 (2N2222) and BC558 (2N3906) transistors; both are commonly used in simple oscillators and transmitters. I also found 15 diodes and half a dozen semiconductor components of other types, plus an array of ¼-watt resistors, and ceramic disk and electrolytic capacitors. The RF chokes and slug-tuned inductors showed promise for future experiments, as did the infrared sensor for the remote control.

The power supply circuit included a mains-to-12V transformer and a pair of heavy-duty voltage regulators, and the flyback transformer on the back of the picture tube had lots of wire the perfect size for winding RF coils.

There was one great prize for any radio hobbyist, a "color burst" crystal with a frequency of 3.579MHz, which lies in the CW (continuous wave, used for Morse code) portion of the 80-meter ham band. There were also 4MHz and 8MHz crystals that have potential for other projects.

Using just the parts from this TV, there are many designs for radio transmitters you could build. One example is based on a Colpitts oscillator, which uses two BC548 (2N2222) transistors, a color burst crystal, and some resistors and capacitors. Add a Morse code key or other momentary switch at the oscillator's power point and a ¼-wavelength stretch of wire at the antenna point (65' 3" for a 3.579MHz signal), and you have a low-power radiotelegraphy station that will broadcast your dot-dash signals 25 miles or more, depending on conditions. Just remember to get your amateur radio license before you press the key down.

T.J. "Skip" Arey N2EI has been a freelance writer in the radio/electronics hobby world for over 25 years and is the author of *Radio Monitoring: A How To Guide*.

ACTION MOVIE EFFECTS

Shoot a fight scene with a blood-spurting knife wound and a head smashing through a window. By Zack Stern

The perfect action scene needs combat, gore, and at least one actor going through a window. Here's how I shot a scene with all these ingredients, from making the special effects to shooting and editing the footage.

Movie Glass

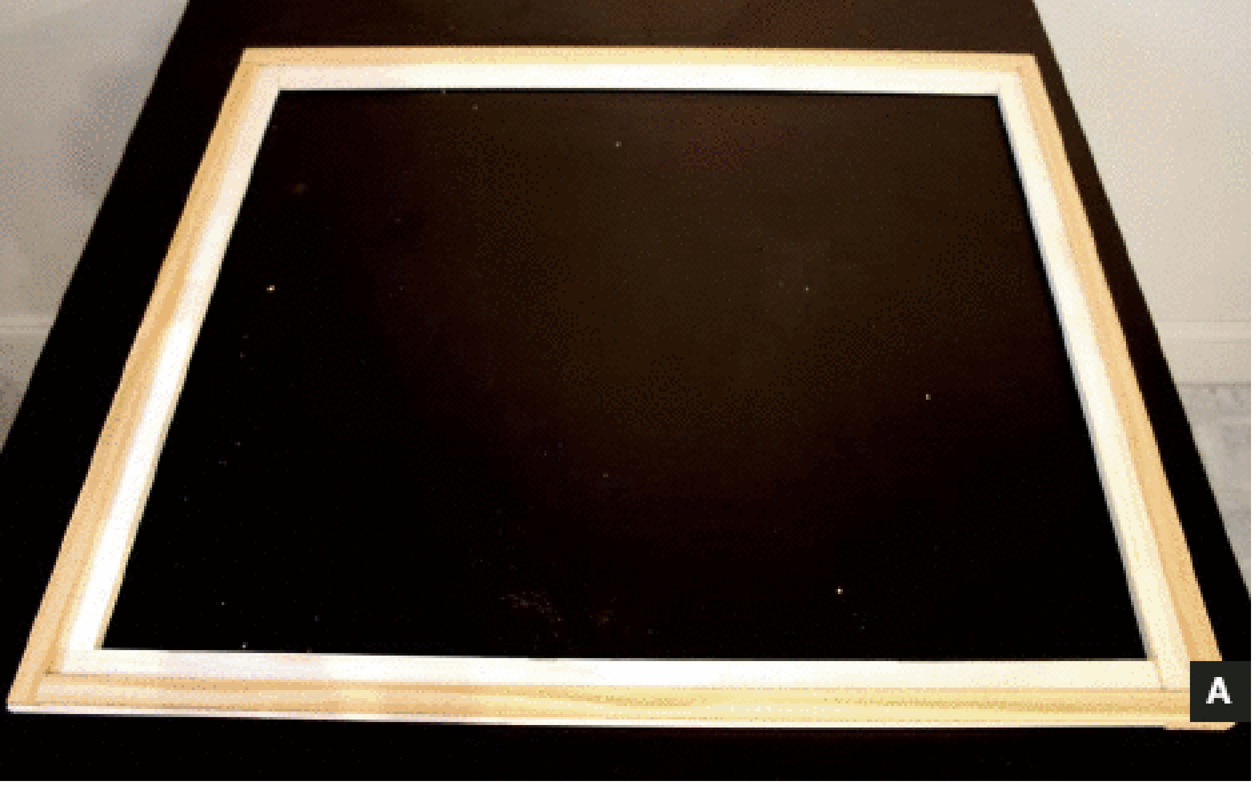
We wanted one actor to shove another's head through a kitchen window. Who wouldn't? We found a good location that had a single-pane window, 30"×26", which we could swap out for our own fake-glass concoction. We made a harmless shattering window pane by casting sugar glass in a wooden frame (recipe next page). If your window is much bigger and has several panes, you can add thin balsa divisions between the panes. These will hold everything together until it's shattering time.

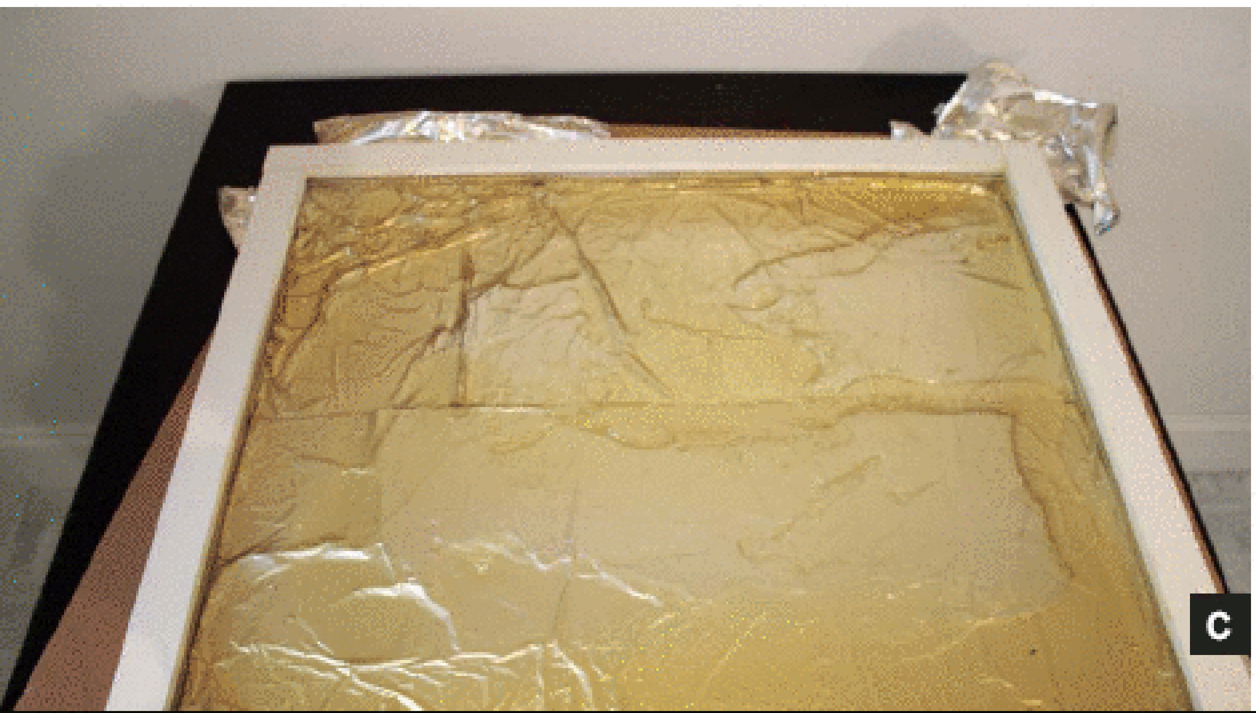
First, glue together a rectangular frame to fit your window, using 3 layers of thin wood. Make all 3 layers flush around the window's outer perimeter, but around the inner edge, sandwich the front and back layers around a narrower middle layer. This leaves a gap for the molten sugar to flow into. Glue the frame together and press the corners under weights until it dries (Figure A).

Put the frame on top of a sheet of cardboard that's larger than the pane, and cut more cardboard to fit snugly in the frame and match the thickness of the bottom layer of wood. Cover the cardboard in the frame with aluminum foil (Figure B). Be careful to keep the foil flat; even small wrinkles in the foil will be cast into the sugar glass.

Cook the water, corn syrup, sugar, and coloring

Photography by Zack Stern





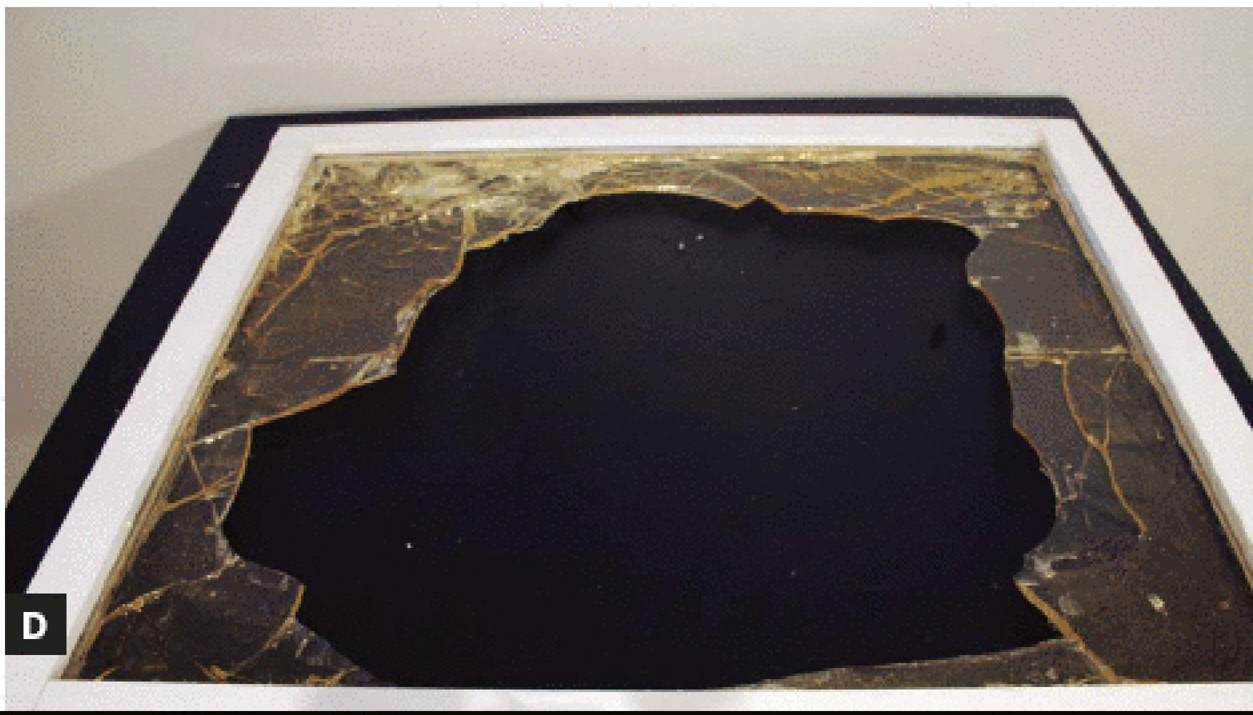


Fig. A: Making the frame.
Fig. B: Foil over cardboard supports the pane.

Fig. C: Sugar pane poured into the frame.
Fig. D: Finished pane, broken (by villain's head).

MATERIALS

- Thin strips of wood
- Wood glue
- Aluminum foil
- Sheet of cardboard
- Balsa wood strips (optional)
- 4 cups water
- 2 cups light corn syrup
- 7 cups sugar
- Food coloring (optional)
- Pot, stove, candy thermometer

in a pot on a stove. Use a candy thermometer to monitor the temperature, and when it approaches boiling (212°F), lower the flame and let it simmer for half an hour.

Turn the flame back up and heat the liquid to 302°F (about another half hour). Pour it into the frame (Figure C). Use a spatula to gently spread the mixture, but don't disturb the foil.

With each batch, pour an extra spoonful onto a piece of scrap foil; use this to gauge the composition, and convince your actors that they'll have fun smashing through it (Figure D). Aim for a thickness of about .75cm (or 7.5mm), otherwise the window will be either too easy or too hard to break. We needed 2 batches to fill our big window. If you use multiple batches, pour half at a time to avoid bumpy layers.

The sugar glass will take about 2 hours to fully cool and harden. After that, it'll slowly melt and otherwise decay, so you should plan to have the window cooled and ready somewhere between several hours and one day before the shoot. Be gentle moving the window, keep the foil on until shooting time, and peel it off carefully to avoid cracking.

Blood-spurting Knife Wound

Use a Dremel or other tool to cut an arc into the knife that's sized to fit around the victim actor's neck, arm, fingers, or other body part. Work on the back side of the knife (whichever side you don't want to show on-camera) to hide mistakes and gouges. Then use a Dremel and a metal file to dull all of the knife's sharp edges. Also dull the tip of the knife. Be sure to remove any metal filings. You don't want any actors getting hurt.

Cut a small length of tubing to run from the far edge of the arc to the knife's handle. If you have big hands and can palm a turkey baster, attach that to the tube, and glue the tube to the knife

MATERIALS

Cheap knives (2) Identical, with blades at least 1mm–2mm thick; ours cost $1.50 from a dollar store.
Turkey baster Or large medicine dropper or squeeze bulb
A few feet of thin plastic tubing From hardware store
Strong glue Or hot glue and glue gun
Red food coloring
Cornstarch
Water
Dremel Or cutting tool
Metal file

handle. Otherwise, use a medicine dropper. Or you can also run a longer tube through the knife-wielding actor's sleeve to his other hand, where he won't have to conceal the bulb.

Mix red food coloring, water, and a little cornstarch to make fake blood. Or use cheap red wine, or other on-hand substitutes. Pour it into a bowl and squeeze the bulb to load the knife up.

Roll Camera!

To get the most out of your special effects, make a shooting script that describes exactly what you need to include, shot by shot, and cross them off as you go. A storyboard can also help visualize each shot ahead of time, so that you don't miss anything important. For example:

SHOT 1. Wide, establishing shot of kitchen with HERO chopping a carrot.
SFX: CHOPPING

An establishing shot orients the audience to your location. Show the whole room, including the window.

SHOT 2. Close-up of chopping, a shadow falls over the hands.
SFX: CHOPPING
HERO: *I've been expecting you. I'm making us soup.*
ASSASSIN: *I've already eaten.*

Edit this to be just a few seconds. This shot will increase the pace of the sequence and establish the knife. Don't record the dialogue until the next shot.

SHOT 3. Wide shot from original, establishing perspective. Over-the-shoulder, ASSASSIN moves away from camera, toward HERO. HERO spins wildly, swinging the cleaver.

Record the action from both shots 2 and 3 from this angle, as one continuous shot. Mime the chopping, making no sound. When editing, begin the video of shot 3 a few frames after the Assassin begins moving. Let the dialogue lead the video, so you hear it begin over shot 2 and continue into shot 3.

Mark points on the floor where your actors can stand well apart during the knife swing. Be careful; you're using a real knife! Keep at least 1' of extra room between the blade and your actor. Because you're shooting the characters in-line, the audience won't be able to see the gap. When editing, cut this shot to end just when the knife would make contact.

SHOT 4. Cutaway, extreme close-up of HERO's eyes.
SFX: THUNK (knife drives into ASSASSIN)
ASSASSIN: *Aaagh!*

Cut to this 1-second (or less) shot when the knife would hit the Assassin. Later, slam a knife into a chicken to record this sound; it'll squish into the flesh and thud when it hits bone. When editing, layer that sound effect into the sequence. Don't record the Assassin's yell until the next shot.

SHOT 5. Medium, reverse shot of original perspective (over-the-shoulder from HERO to ASSASSIN). Knife is embedded in his arm, spurting blood. ASSASSIN grabs the knife.

HERO punches him in the face, knocking him down. He falls out of frame, pulling out the knife.
HERO: *That was for Lt. James Mitchell. He was*

one day from retirement.
ASSASSIN: (Groveling) *I just do what they —*
SFX: THUD
SFX: CLANK *(knife hits the floor)*

Use a waist-up medium shot to show the actors and the cleaver effect together. Use the prop knife, and for more blood spurting from under Assassin's shirt, hide extra blood-filled bulbs and tubes running out to production assistants (read: siblings, friends, or children) to squeeze. Assassin should yell from the knife impact to begin the shot; edit the beginning of that sound to overlap shot 4.

Punching is another trick of perspective. The instigator should be able to swing fully and not reach the other actor, while the recipient then jolts his head in response. The camera angle obscures the point where the contact would occur, so the audience believes what it hears. For the sound effect, punch a whole chicken or slab of beef.

SHOT 6. Cutaway, close-up of bloody knife.
HERO: *And this is ...*

This short cutaway should last 1 second or less. Bloody up the real knife and floor, and drop the knife into the frame. As with previous shots, let the sound of the knife begin in the preceding shot, and edit this shot to show the last 20 frames of the knife clattering on the ground. Also, don't record dialogue here; overlap it back from the following shot.

SHOT 7. Reverse shot, low perspective behind ASSASSIN toward HERO. HERO grabs the back of ASSASSIN's neck and hair, twisting out of frame toward the window.
HERO: *... for me.*

Shoot this with the full line, "And this is for me" so you can edit the audio to lead the video again. Add more blood running down the Assassin's arm and hand.

The audience thinks the Hero is pulling the Assassin, but for safety the Assassin is pushing the Hero's hand, controlling the action. The Hero should lightly hold the head and neck of the Assassin, but the Assassin should lead with his head and neck to trick the viewers.

SHOT 8. Wide shot of HERO driving ASSASSIN's arms and head through window.
SFX: CRASH

Use this break to make sure everything is set up properly for this, the one-take-only shot. Practice the choreography first with an open window.

As in the preceding shot, the weaker character leads all of the action, pushing through the fake window with their arms. While the sugar glass will crumble and shatter on impact, long sleeves can prevent scratches from the edge of the break. Have the actor tuck in his chin to protect his face.

For the sound effect, don some goggles and record a large, round bottle, like an apple juice jar, shattering on cement. Or search for a clip online.

SHOT 9. Wide, reverse shot of HERO pulling bloody ASSASSIN back in, then pushing him stumbling toward the door.
HERO: *You tell El Gato that I'm sick of running away. You tell El Gato I'm coming for him.*

Add blood to the Assassin's face before this shot, and he can stumble out of frame during the dialogue.

SHOT 10. Overhead crane shot starts tight, then pulls back. HERO drops to knees. The floor is filled with blood, glass, and the knife.
Cut to black.
HERO: (Yelling) *El Gatoooooooooooooooo!*

To be your own crane, firmly attach the camera to a strong tripod and swing the tripod from a ladder.

For tips on how to record convincing effects and clear dialogue, visit makezine.com/09/diyimaging_effects.

Zack Stern (zackstern.com) is a San Francisco video producer and writer who has current or upcoming articles in CRAFT, *ReadyMade*, and other publications.

TILT-SHIFT PHOTOGRAPHY

Flexible lens makes scenes look miniature.

By Dennison Bertram

One of the fancier lenses in the world of SLR and DSLR photography is the tilt-shift lens. You might not know what these lenses look like, but you probably have seen their effects. Architectural photographers use tilt-shift lenses to eliminate the perspective distortions that sometimes give buildings the appearance of falling over. Aerial photographers use them to make large cities look like toy models. Art and portrait photographers use them to control exactly where the focus falls.

Tilt-shift lenses cost $1,000-plus, which is far beyond what most photographers will pay to experiment. Fortunately, building your own tilt-shift lens is easy, and doing so will open up a remarkable array of creative optical effects.

To build your own tilt-shift lens, you start with a spare lens that's built for a film format larger than that of the camera you'll use the lens on. For example, I used a 6×6 lens (designed for 6cm film) to make a tilt-shift lens for a 35mm camera body. With 35mm or APS format digital SLR cameras, you'll need a lens built for 6×6 film or larger. The oversized lens gives you extra room to move and distort the image that lands on the film or CCD, while still filling the frame. (You could use this hack to mount a 35mm lens on a 35mm camera, but it would only work with a macro lens, for very close objects.)

Assembly

Using a rotary tool or hobby knife, hollow out the middle of the camera body cap (Figure A), then grind or file it down smooth, so there are no rough spots or burrs (Figure B).

The plunger will act as a flexible camera bellows, allowing us to tilt and shift the lens to our heart's

Photography by Dennison Bertram

Fig. A: Hacked lens begins with a standard plastic body cap. Fig B: Body cap is hollowed out.

Fig. C: Humble plunger becomes camera bellows. Fig. D: Plunger bellows should fit tightly to lens.

MATERIALS

- **SLR (single-lens reflex) or DSLR (digital SLR) camera body** with interchangeable lens mount
- **Oversized lens** I used an old Carl Zeiss made for the now-obsolete Pentacon 6 camera format. Millions of these were manufactured, and eBay is full of good deals on them.
- **Rubber plunger with bellows design** Any will do, so long as it's flexible and not too large.
- **Stiff cardboard (non-corrugated)** Or stiff, black plastic
- **Plastic body cap to fit camera body** I use a lot of these in my work. They're the perfect way to attach your camera to your own hacked-lens creations, and they're also cheap.
- **Hot glue and glue gun or other adhesive** You need to bond the body cap to the cardboard/plastic and the cardboard/plastic to the plunger rubber. If you want a more robust setup, skip the glue and attach the pieces with small hobby nuts and bolts.

desire. Cut a hole in the top of the plunger, where the stick is (Figure C), making it just large enough to stretch around the base of your lens (or make it a bit smaller and enlarge it later).

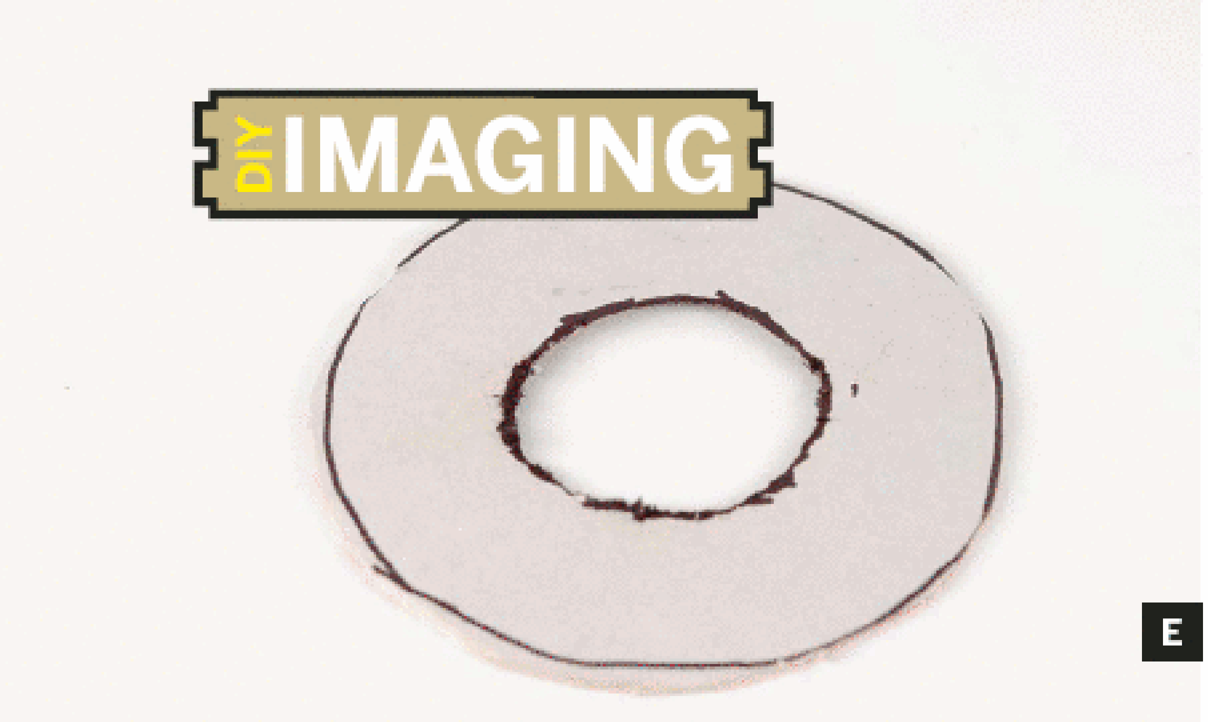
Go ahead and stick your lens onto the plunger to see if it fits, and trim the rubber as necessary. Don't worry about gluing the lens down yet, but the hole should be tight enough so the lens fits snugly (Figure D). I even cut grooves in the rubber to let me screw the precious lens into place. Keep holding onto the lens, though; don't expect the rubber to hold so tight that you can let go.

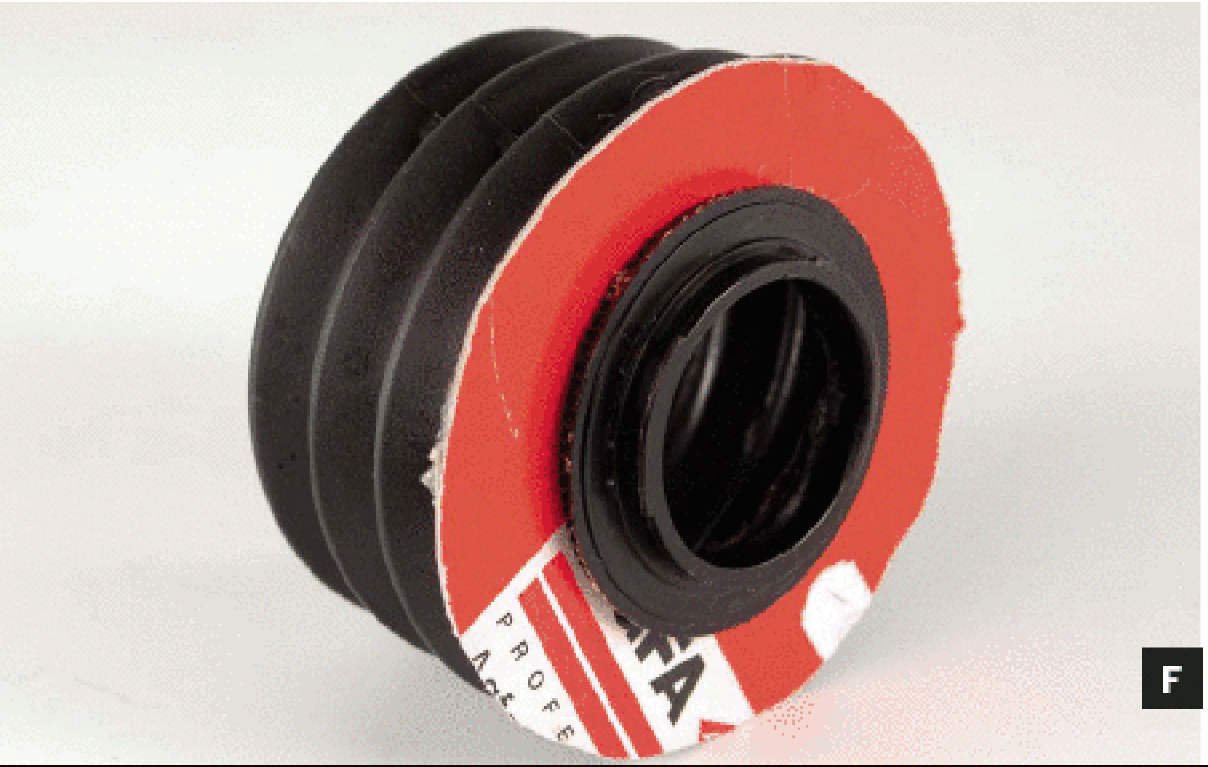
If you're really enterprising; you could buy a bayonet adapter for the lens you're using, attach it to the plunger bellows, and then screw your lens onto that when needed.

Next you need to build the backing. To do this, I cut a ring out of cardboard with the inner circle the same circumference as the body cap and the outside matching the bottom of the plunger (Figure E). Although not shown here, it helps to paint one side of the cardboard black, to cut down light refraction inside the bellows.

Then I hot-glued the parts together, body cap into ring, and ring, black side in, onto bellows (Figure F). The hot glue is for expediency; if, after some experimenting, you think you'll use this lens setup often, I recommend finding something sturdier than hot glue and cardboard to hold it together.

You're all done! Attach your lens, and you're ready to shoot.





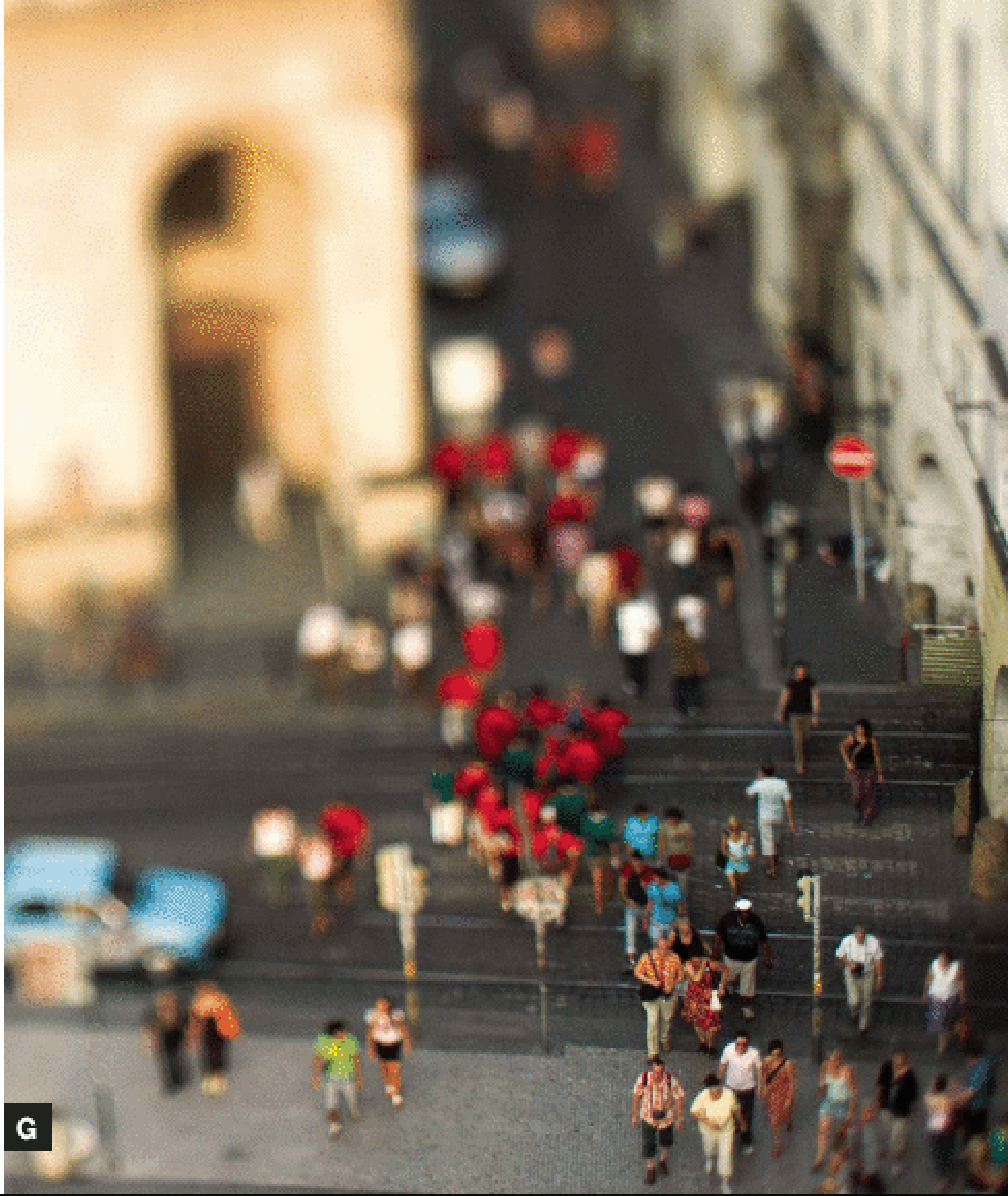


Fig. E: Cardboard backing ring.
Fig. F: Finished assembly.

Fig. G: Bendable lens makes Prague look miniature.

Shooting

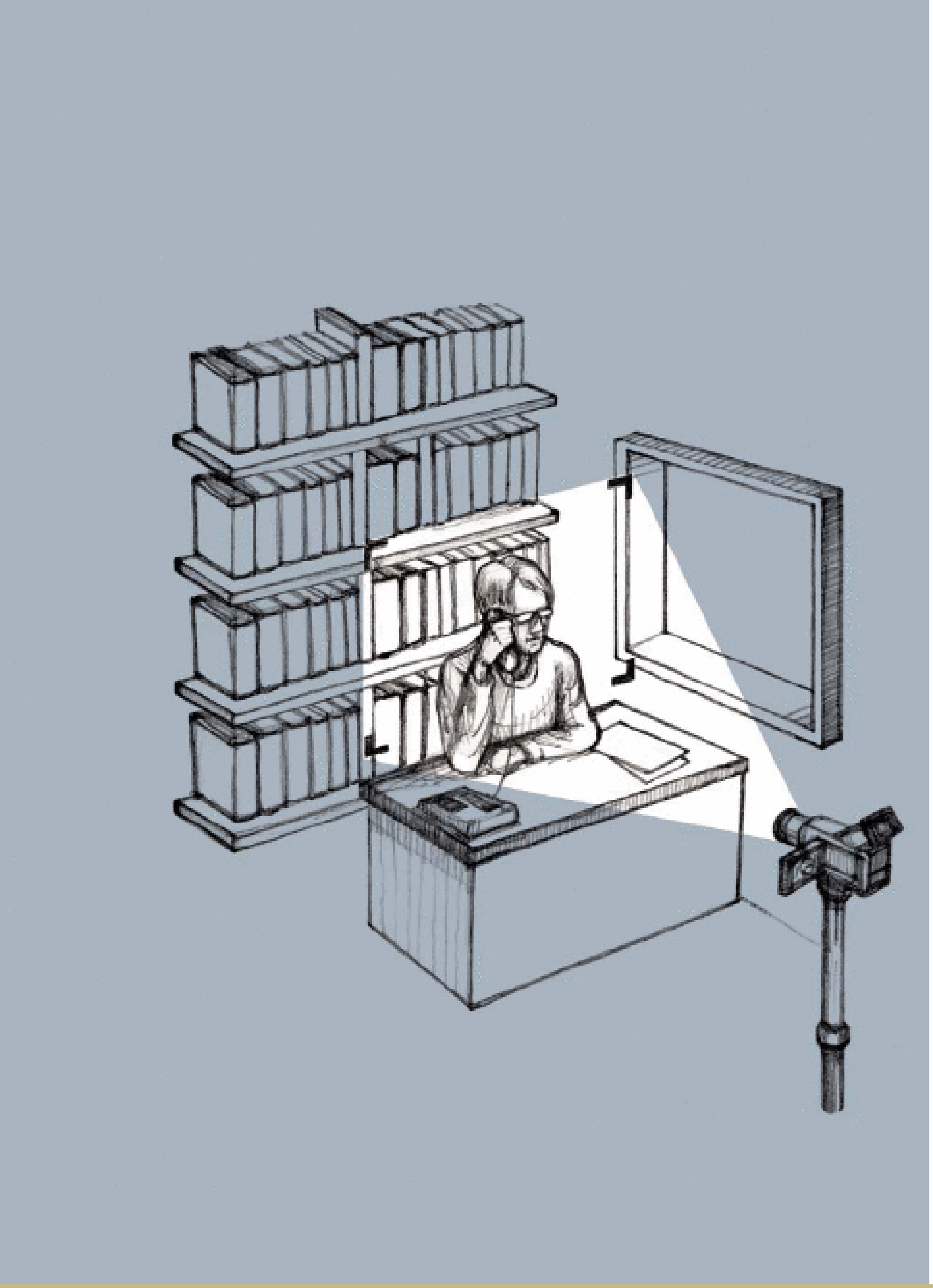
This hack works surprisingly well. The image quality of the Zeiss is awesome, and I didn't get any optical interference between it and my Nikon DSLR's CCD chip. But there are a number of things to keep in mind while shooting. First, automatic exposure modes will not work with this lens, so you have to shoot manually. The apertures will still work, but in general you want to shoot with the lens wide open, or it will be far too dark to focus.

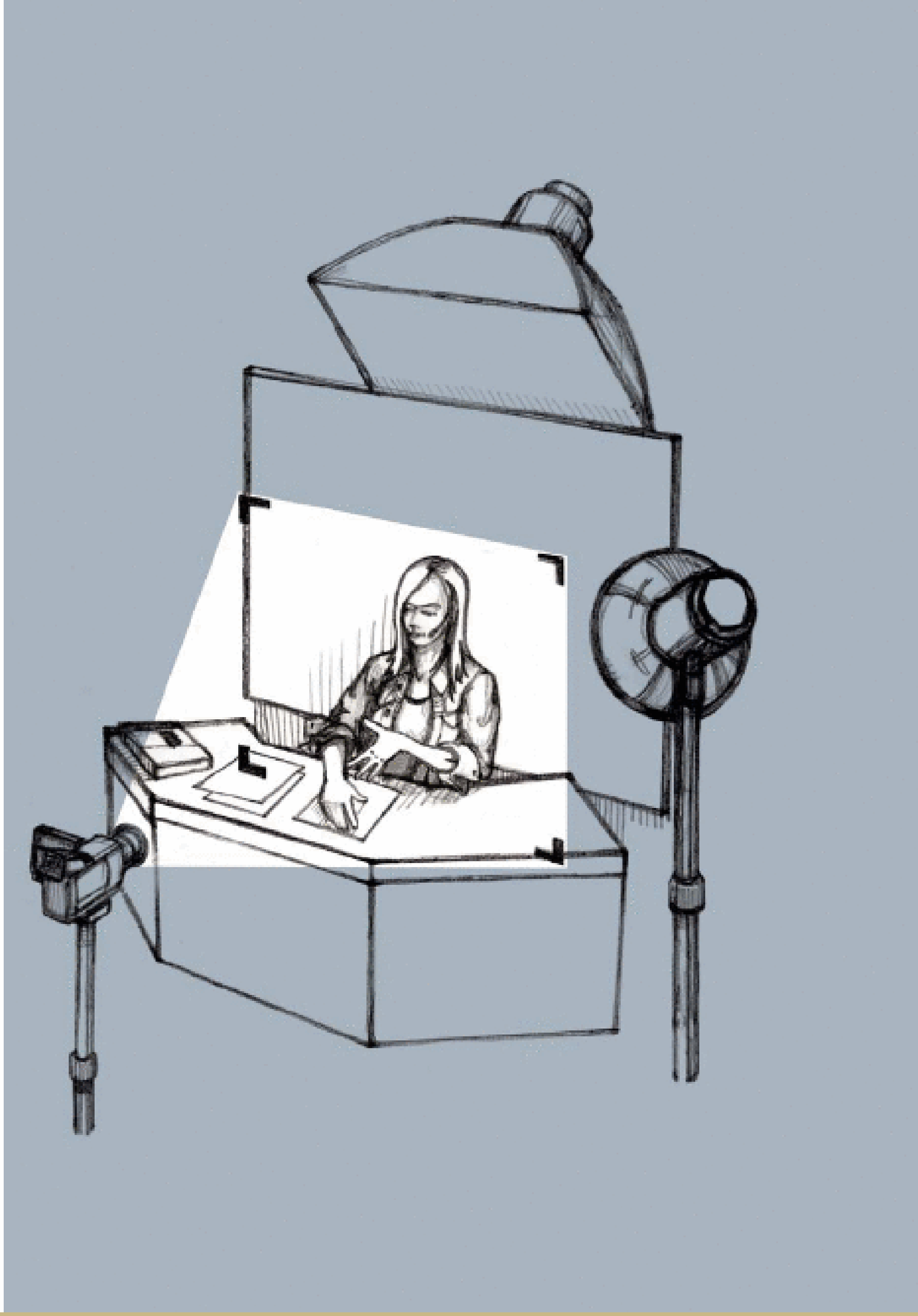
Needless to say, auto-focus also won't work. With this lens, you focus (or selectively un-focus) by squeezing the lens and plunger down, bending it, and twirling it around to get the cool effects you want. To give a "miniature" effect to a cityscape, tilt the lens forward or backward so that the only things in focus are in the middle ground, in mid-frame horizontally. The blurred foreground and background simulate the look produced by a macro lens taking a close-up of something small (Figure G).

If you want to use a lens like this in low light conditions, where you'll need to hold the lens in one position for a long time, you might augment this design with an adjustable mechanical frame that controls the lens' range of motion. If you build a tilt-shift lens with a frame, a photographic bellows will be more flexible than a plunger.

A note to digital camera users: dust is a common problem with most digital cameras. Projects such as this one can exacerbate the situation. Before using this lens, be sure to clean it out with some strong puffs of air, to get rid of any loose dust particles that might be inside.

Dennison Bertram is a fashion and beauty photographer who lives in the Czech Republic.





ONLINE VIDEO PRODUCTION

Tips and techniques for daily content.

By Andrew Michael Baron

As creator of *Rocketboom*, I've been producing a 3-minute daily video news report since 2004. Here's how I prevent the every day thing from becoming everyday.

Camera

Use a MiniDV camera that takes MiniDV tapes. We have a $350 Panasonic, an older $2,000 3-chip model, and a nice new Sony HDR-HC1 MiniDV/HDV camcorder, which at $1,400 is the best deal on the market right now. Tapeless cameras will also work, but their storage is too expensive. It's nice to keep all your source material archived at full resolution. A 60-minute full-res video will take up a whole hard drive, or you can capture it onto a tape that only costs a couple of bucks.

There's really only one feature I recommend for people investing in a new camera: make sure it has a microphone input or a line-in jack. If not, you'll be dependent on the camera's built-in microphone, which in many environments will prevent you from doing good interviews and getting clean audio.

Also consider whether the camera is a single-CCD or 3-CCD model. A 3-chip camera processes each color separately, producing a brighter and sharper picture. Most cameras under $500 are 1-chip; these are also fine, but may look a bit more grainy, especially in low light. Most people use 1-chip cameras, since 3-CCD models have only recently become affordable.

Illustrations by Damien Scogin

So, you want to produce an online news show year-round on a daily schedule, and keep it interesting? Use a good MiniDV camera with a tripod and a separate microphone. Pay attention to lighting and image compressibility. Always keep an eye out for good source material. Cook up techniques that work with what you have and are capable of.

In a pinch, however, anything will be fine. I often use footage from my little still camera that records video. If I happen to be somewhere without my camera, and someone else has one, I'll get their contact info and try to hook up with their footage later. Even if I do have my camera, it's nice to get more footage and a different perspective to work with. Pictures, video, audio: these are all assets that can be used.

We get source material from pretty much everything under the sun, so it's helpful to always look around and see what's available. Sometimes you don't need video at all; just an audio clip is fine, and you can build a story with images, website data, and other stuff surrounding the source.

Holding the Camera

Use a tripod whenever you can. Do it! Otherwise, hold the camera as still as possible. Too much jerkiness can ruin a scene. The "raw" quality of videoblogging can be charming, but not when the camera is jerky and moving around a lot.

Compression-wise Shooting

When a video is compressed, the file size can be twice as large if the frame contains a lot of fine detail and movement. If you are shooting trees and moving the camera around, your video won't compress easily. I never sacrifice any detail and movement that is important to a shot, but otherwise I try to keep these to a minimum.

Lighting

Most cameras auto-adjust for lighting, but the darker it gets, the more grainy the video will look. Too much darkness is not charming either. Use the same lighting sense you have from taking still pictures; for example, have the light coming from behind you, but don't stand in front of it. The brighter the light, the more brilliant the picture (until you go overboard and everything becomes overexposed and saturated).

Sound

Nicer handheld microphones use a microphone cable, and you will need an adapter like a Beachtek to convert their XLR plug to the ⅛" mini that you can plug into a camcorder. This is worth it and will make a big difference. Cheap microphones add a lot of noise to the signal.

If you're interviewing people on location in loud surroundings, it's best to have separate handheld

Every picture tells a story: Rocketboom production tricks have added visual appeal to phone interviews, made single-camera shoots look like multi-camera, and covered up creatively for missing footage and sound.

microphones for everyone. But if you don't, treat your camera like a microphone. When someone is talking, bring the camera way up close to the person, get a good audio signal, and don't worry about the video. Then, later, when they are finished, take B-roll footage of the environment, and try to capture the stuff that they were talking about. Then in post-production, take the audio track and lay B-roll over it where appropriate. The audio comes first, and you cut the video to match.

Situations

We've come up with a lot of tricks for navigating various constraints. Here are some examples, and you can watch the reports themselves at rocketboom.com/vlog/archives, where they are organized by broadcast date.

For our Nov. 30, 2005 webcast, we did a phone interview. To set up, we pointed a camera at Amanda Condit here in New York City, and our interviewee Joshua Davis pointed a camera at himself in California. Amanda called Joshua, and they did the interview with both people being taped. Then Joshua mailed us his tape, and we put the segment together with assets he gave us, website images, etc.

When you shoot a great musical performance, you can build an entire broadcast over one song. Shoot the entire song from one angle, keeping the mic the same distance from the performers throughout. Then shoot in and around the scene to get B-roll to add in. This is a favorite technique, and I used it for our June 17 and July 20, 2005 shows. Both of these look like 2-camera coverage, but if you are really savvy, you can see where I cheated.

Our April 6, 2006 show was a phone interview recorded as audio only, with no video. Our interviewee Erin Peterson didn't have to do anything but talk to us. We added visuals afterward using images from Flickr, and Amanda filmed an intro and outro of herself starting and ending the phone interview, to frame it.

For our episode on Aug. 10, 2005, Amanda went to cover a garden and did a lot of talking, but we screwed up and the audio was off the entire time. We didn't realize this until much later, and we decided to turn it into an "art piece" by adding music and effects to the silent footage.

Andrew Baron is the creator and producer of Rocketboom, a 3-minute online daily news show with a daily audience of more than 300,000.

Photography by Alek Komarnitsky

OUTDOOR WEBCAM ENCLOSURE

Capture winter scenes from hanging sewer pipes. By Alek Komarnitsky

I anteed up the big bucks for a wireless security webcam with motorized pan, tilt, and 10x optical zoom — specifically, the D-Link DCS-6620G. Nice webcam, but I wanted to put it outside so people everywhere could view my Halloween decorations and infamous Christmas lights.

The problem is that the webcam is rated only down to 32°F, and here in Colorado, temperatures can drop below zero. Suitable prefab outdoor enclosures cost about $500 and include a blower and heater, so I decided to build my own simpler webcam enclosure. It cost me a whopping $27, and it has successfully stood up to two full seasons of Rocky Mountain rain, cold, and snow.

I installed the webcam at my neighbors' house, hanging it from a 6" can light fixture under an eave that had good line-of-sight to our house. The basic idea was to attach 2 brackets hanging down from the inside of the can, and build an easily removable enclosure that would hang from a rod running horizontally through the brackets.

For the brackets, I straightened two 5" L-brackets in a vice, and extended their internal cut with a hacksaw. Then I used sheet metal screws to anchor the brackets to the inside walls of the recessed light fixture. I screwed in an adapter to convert the fixture's socket into a power plug for the webcam, which is the only physical connection the webcam needs.

I made the enclosure itself out of 6" inner diameter, foot-long ABS sewer pipe. (Yes, sewer pipe — no expense spared!) I cut a 1' length of

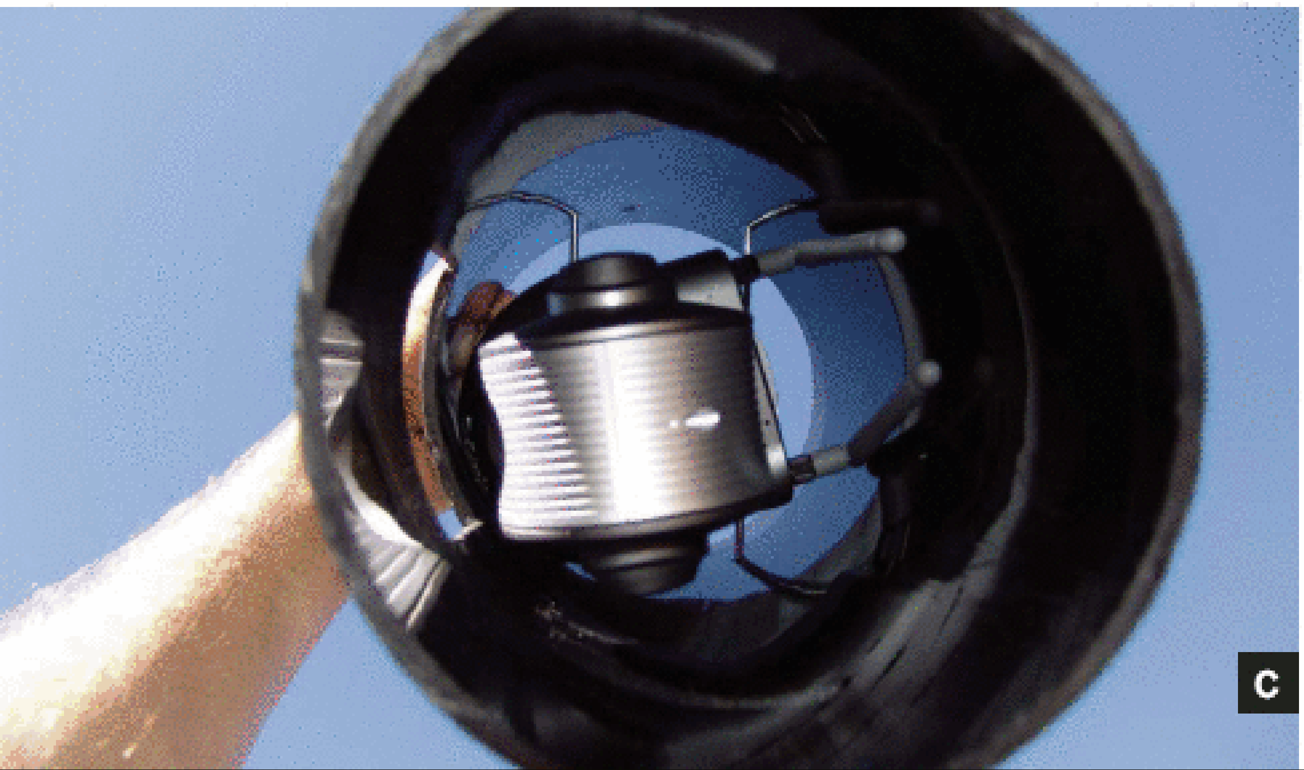


Fig. A: Metal rod "hanger" attaches to can light with metal brackets. Fig. B: D-Link DCS-6620G webcam with cover plate.

Fig. C: Internal view of webcam enclosure. Fig. D: Webcam assembly hangs from friendly neighbor's second floor balcony.

MATERIALS

D-link DCS-6620G with threaded base and transformer
6" ABS plastic sewer pipe, 1' long cut down from 2' section sold at Home Depot
6" ABS end cap
5" round cover plate
5" metal L-brackets (2)
Sheet metal screws (4)
1' threaded metal rods (3) with matching wing nuts (6)
¼-20 bolt with washers and nuts
Light socket to 2-prong plug adapter
Electrical tape
Clear plastic CD case cover from free AOL install disc
Outdoor recessed can light fixture already installed in good location for observation

pipe and drilled 2 holes at one end to hang it from. A threaded rod runs through the pipe and the hanging brackets inside, and 2 wing nuts hold the rod in place.

Before installing the webcam enclosure at my neighbors' house, I tested the basic concept on a recessed ceiling light in our upstairs hallway. The pipe hung securely, but this indoor can light was 6½" in diameter, which meant that the two brackets stayed visible on either side of the pipe. The light fixture at the neighbors' is just 6" wide, so the pipe fits around the brackets and conceals them, which looks nicer.

Inside the enclosure, the webcam itself hangs from 2 more rods that run through holes drilled side by side farther down the pipe. To suspend the webcam upside down, I ran a ¼-20 bolt through the center of a 5" cover plate and screwed it into the webcam's tripod mount. I added extra nuts onto the bolt to reduce the chance of stripping the webcam threads. Inside the pipe, the cover plate rests on the 2 lower rods, and the webcam hangs underneath.

For the enclosure's view port, I cut a hole in the pipe and made a window by taping on the clear plastic from a free AOL install CD case.

E

F

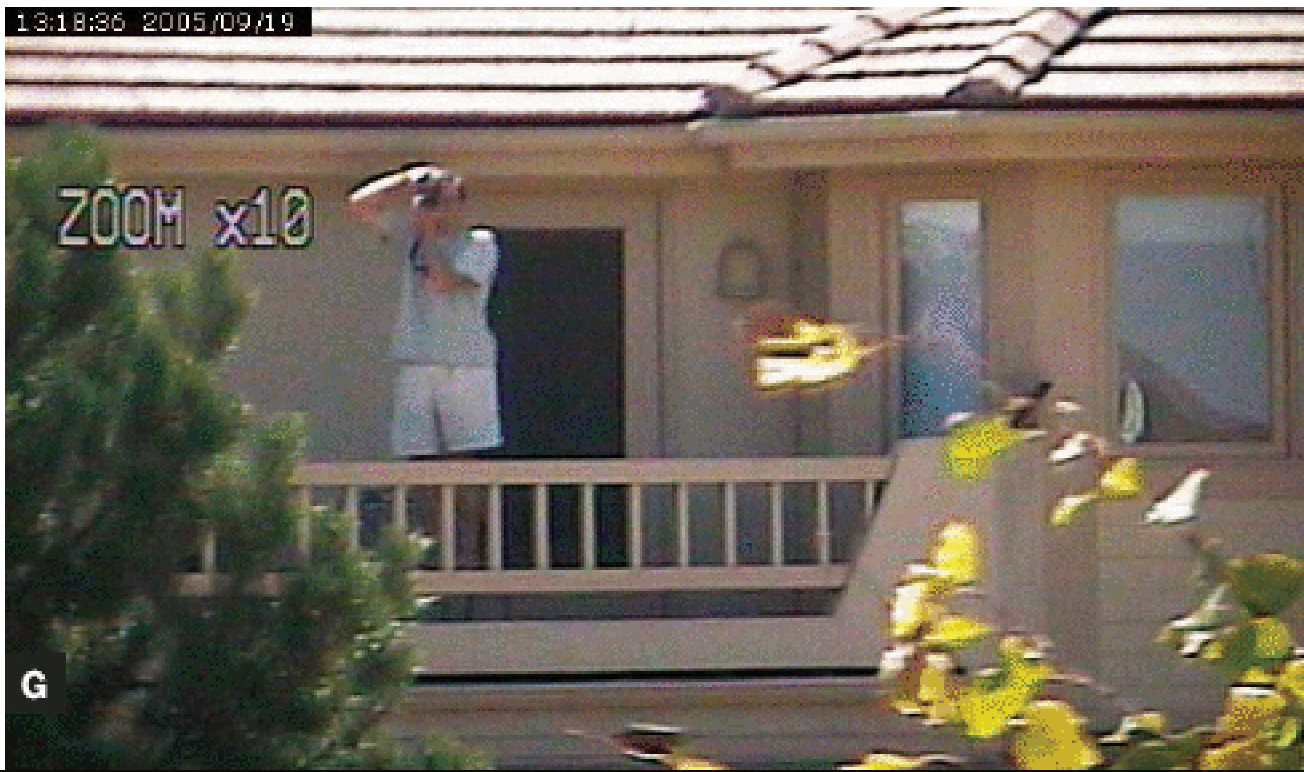


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Fig. E: Portable webcam assembly can be hung under eaves or placed freestanding, weather permitting.

Fig. F: Webcam view at 2x optical zoom last fall. During the winter, the aspen leaves drop and open up the visibility. Fig. G. 10x webcam picture of Alek taking picture of it.

I put a flat ABS end cap at the bottom of the enclosure, which is where the webcam's 120VAC-12VDC transformer sits. This provides some warmth for low-temperature operation. I left the end cap vented (there's about a ¼" opening on the top) to prevent fogging in the viewport. The flat end cap also lets me unhook the webcam and set it down to operate anywhere, connected via extension cord, weather permitting.

You can optionally add a cheap wireless temperature sensor inside the PVC, and also one taped to the outside, in order to provide a "delta temperature" reading.

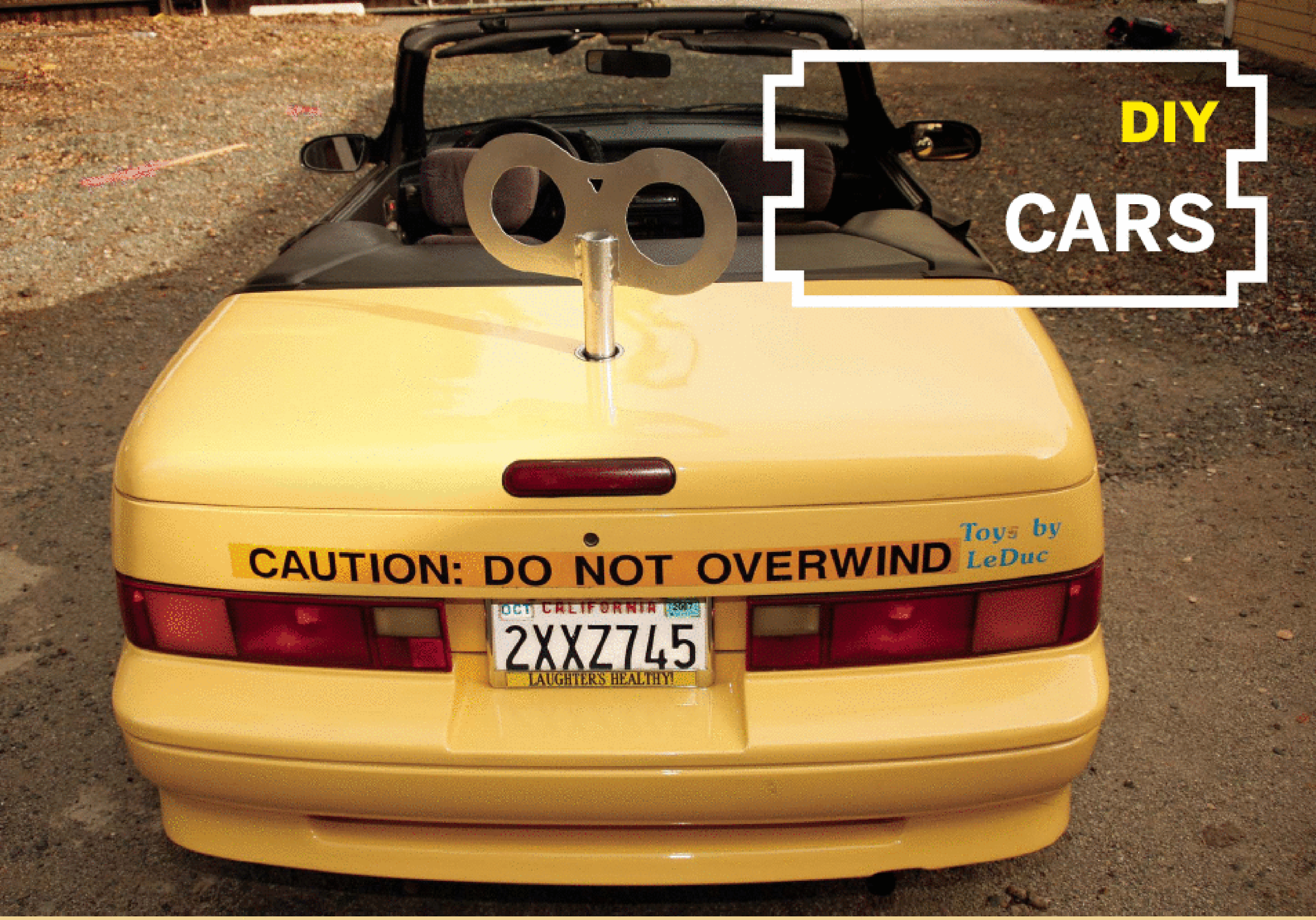
Actual installation was super-duper easy since the entire unit is self-contained, with only a power cord coming out of the top. Plug that in, run the threaded metal rod through the PVC-bracket-bracket-PVC, screw down the wing nut, and you are ready for action!

The installation has worked great, although I did crack some plaster around the light fixture — oops! The webcam works even with the temperature dipping below 0°F a few times. The only issue was that the wireless signal would sometimes drop out, so I installed a Pringles-can antenna at my house pointed toward the webcam, and have had no problems after that.

The webcam enclosure is an integral part of my Controllable Christmas Lights for Celiac Disease website, which lets people remotely view live images of thousands of Christmas lights, and also control them with a click of a mouse. Besides being fun for people around the world, the site has raised over $16,000 for charity.

(Before making my Christmas lights controllable through my website in 2005, I simulated this effect with canned photos and a CGI script. The ruse spread far and wide before I invited the *Wall Street Journal* to reveal it as a hoax. But that's another story.)

Alek Komarnitsky lives in the Republic of Boulder. When not spending time with his wonderful wife Wendy and two sons Dirk and Kyle, he enjoys tinkering with stuff. Read more at komar.org.



WINDUP CAR

Mod a cute convertible with a big rotating key.

By Sunny Armas (with Paul LeDuc)

Photograph by Sam Murphy

When my pickup truck broke down, a friend lent me her Geo Metro convertible for 2 weeks. Well, I'm a good-sized guy, and at first I felt a bit silly driving this tiny car, but I quickly fell in love with it. It's easy to park, great on gas, and a blast to drive. I decided to buy my own, and I thought that if I'm willing to be seen driving this toy-sized car, why not go all the way and put a big windup key on the back?

I called my metal sculptor friend Paul LeDuc for his help and ideas, and we talked about the project. I knew I wanted a big key that would turn slowly, to make the car look as toy-like as possible. I also wanted the key to be easily removable and fit in the trunk to prevent people from trying to rip it off, and to keep the option of driving a little more low-profile. Also, I had just had the car painted, so I wanted to be careful that any mods would not damage the nice new finish.

We decided that the key should be about 16" across. For the flat part, we drew a template and used a plasma cutter to cut the shape out of ¼"-thick steel plate. The harder part was the center tube, which needed to mount neatly through the trunk of the car. For this, Paul strolled through the hardware store and found a nice chrome mounting ring for finishing bathroom sink drains. The threaded, 1½" inside-diameter ring had some height that would help guide the key, and included a rubber gasket, washer, and nut to secure it around both sides of an aperture.

Paul used a grinder to remove the strainer from the bottom of the sink mounting ring, then cut a hole in the center of the trunk deck (lid) with

Fig. A: To turn the key, a windshield wiper motor is mounted under the trunk deck. Power comes from the dashboard cigarette lighter, via wires that run under the carpet and out the same hole as the brake light wires.

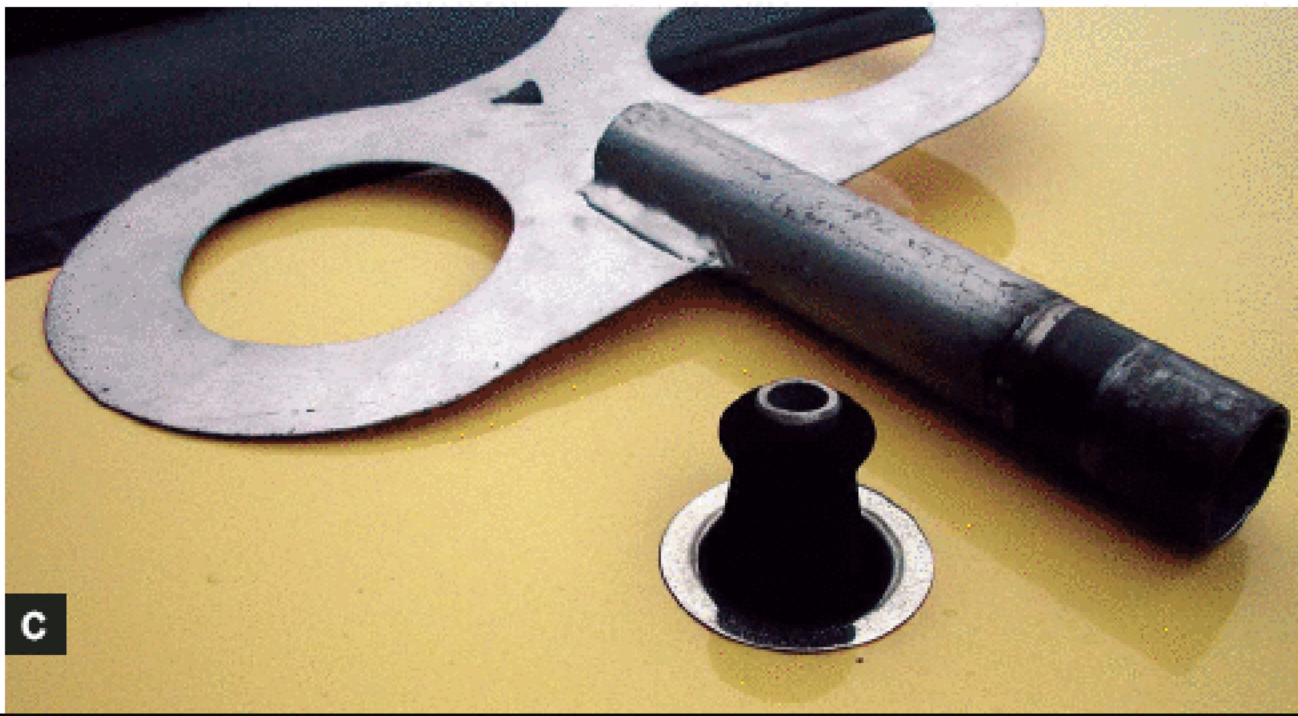


Fig. B: The key to making a cute little car even cuter.
Fig. C: Friction mount made from a foam bicycle handle grip makes the key easily removable, and lets you twist it and stop it without harming the motor.

a drill and a hole saw. He slid in the drain ring, and fitted the washer and nut on the back. Then he found some steel tubing in his shop that fit perfectly into the sink ring, cut a length of that to be the key's center tube, and welded it to the flat key shape.

To turn the key, we used a spare windshield wiper motor that I had. These run off a 12VDC car battery, of course, and they turn slowly with a lot of torque. To connect the key to the motor and make it removable, we made a friction mount out of a foam bicycle handle grip. We welded a 2½"×⅛" disk to the shaft of the motor, and welded that to a 5" steel rod that's the same diameter as bike handlebars (⅞"). The shaft protrudes from the middle of the hole in the trunk, and with the foam grip over it, the key slides over it snugly.

The great thing about the foam connection is that it lets the motor run freely if the key's movement is impaired, like if someone grabs it, and it also lets you turn the key when the motor is off. This means that little kids can turn the key before the car starts, and imagine that they're helping the car go!

To attach the motor, Paul removed the trunk deck, laid it upside down, and welded together a framework that would hold it securely and keep it aligned straight up. He made the framework out of 1"- and 2"-square tubing, welded to the deck's ribbing with minimal damage to the paint, and tapped screw holes in to serve as motor mounts.

The motor is powered from the car's cigarette lighter. To do this, I ran wires under the carpet, starting in front near the dash, between the seats, and threading them back into the trunk through the same hole that the brake light wires run out of.

To connect the wires to power, I cut the fan off an old cigarette-lighter-powered fan, and ran the circuit through an old VW bus light switch, which I mounted next to the car's gearshift. I positioned the switch so that when I shift between neutral and first, my thumb can easily turn the key motor off and on. That way, when I stop the car, the key stops, and when the car starts moving, the key starts up again — bringing smiles to all, or at least to most.

Sunny Armas lives in San Jose and enjoys bringing smiles to others. He has helped Paul LeDuc with many other art projects, including parade floats and metal waterfalls.

Photography by Paul Spinrad

YOU ARE A THINK TANK

FROM MAKER TO MAKER

Who doesn't appreciate a really good tip now and then? Especially the kind, as one reader put it, "that changes your life." Whether it's something as practical as looking good in party photos or something more creative like figuring out how to judge the amount of propane in a tank, we all rely on our friends and neighbors to tip us off to the new and the good. *—Arwen O'Reilly*

If the Shoe Fits

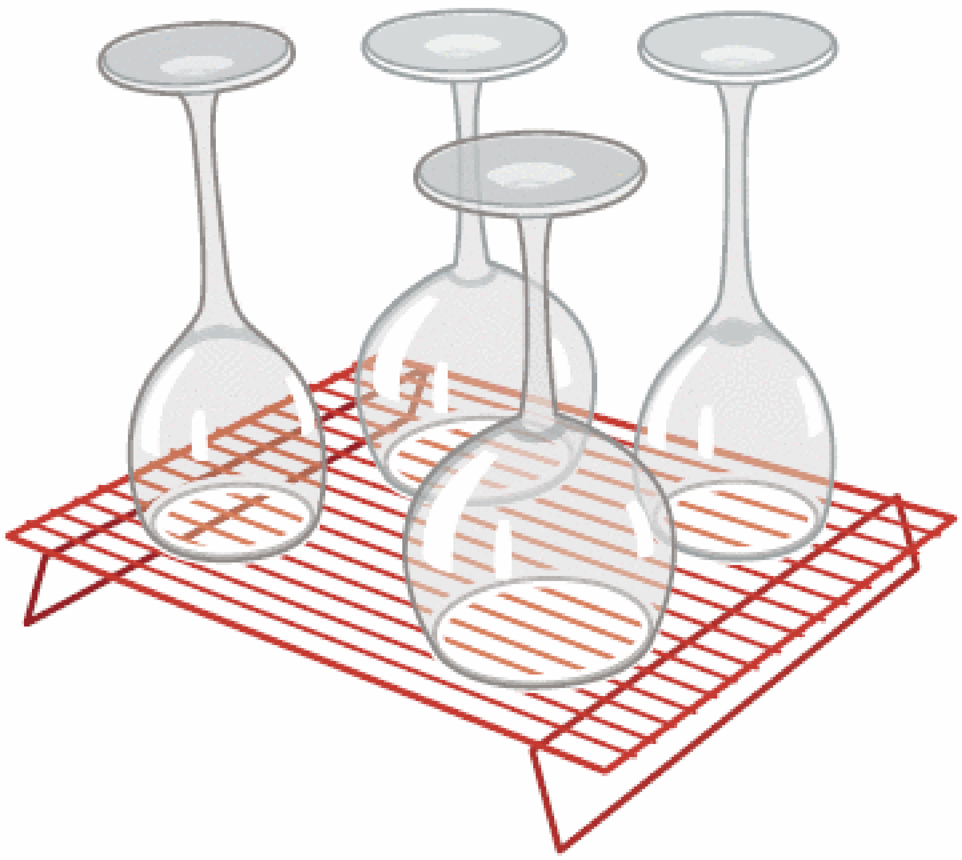
Gina Trapani from the Lifehacker blog has a great tip from a reader: buy a clear plastic shoe organizer and use it to store your gadgets. You'll be able to see everything at a glance, and each cable can have its own compartment. makezine.com/go/shoefits

BB Q&A

Boing Boing reader Ross points out a great way to judge how well your barbeque will go: "There is an easy way to see the level of propane in a current tank. Just warm up some water and pour it on the side of the tank. Since the gas is liquid and cool, the water's heat will cause the tank to form condensation at the current level of the propane. I do this before any cookout so I can get propane before the guests arrive rather than the last minute dash." makezine.com/go/propane

Party Favor

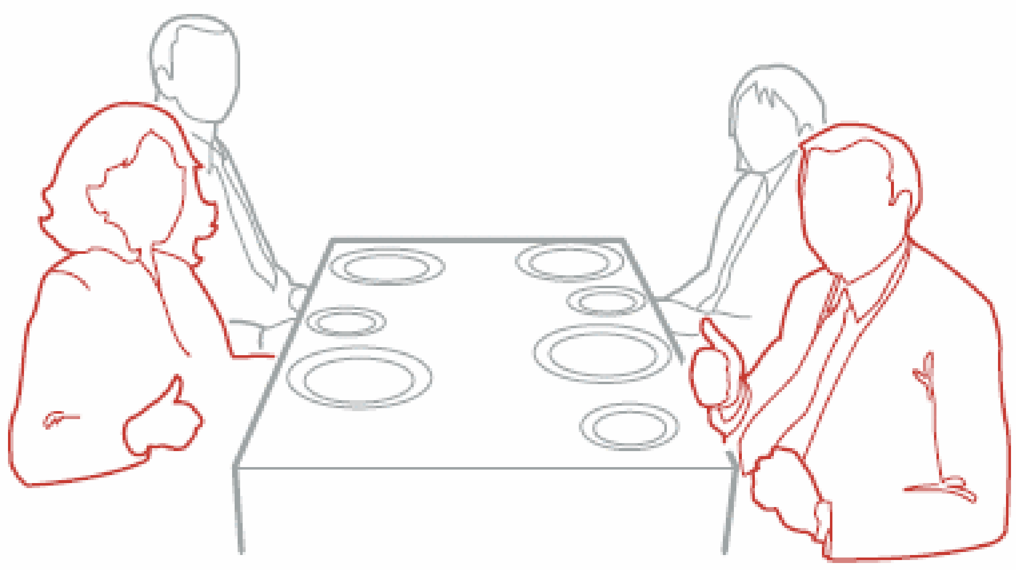
I found this great lifestyle hack on Flickr, of all places: Meg Hourihan suggests using a cooling rack on top of a cookie sheet to dry wineglasses when there are too many to fit on a normal dish rack. makezine.com/go/glasshack



Don't Say Cheese!

Terrie Miller, MAKE's webmaster, has a couple of photography tips: "My brother-in-law relayed this great tip: when the photographer comes around taking candids at the next company party, or the waiter snaps a photo of your table at a restaurant, give him your most enthusiastic 'thumbs up' sign. You'll have a better chance of looking happy and engaged in what's happening, instead of looking awkward and embarrassed (if not actually sullen)."

She adds, "If you're the photographer, here's another good tip: tell your group to wave. I learned this from Derrick Story (see his blog, thedigitalstory.com/blog, for more good tips) when he took our favorite group photo at our wedding reception ... everyone was laughing and smiling, with no frozen poses in the bunch."



Illustrations by Damien Scogin

Have a tip for MAKE readers? Send it to tips@makezine.com.

BUILD A CLOUD CHAMBER

CATCH THE GHOSTLY TRACKS OF COSMIC RAYS USING DRY ICE, ALCOHOL, AND A BASKETBALL DISPLAY CASE.

By Dr. Shawn

HOLD OUT YOUR PALM FACE UP. IN THE time it takes you to read this sentence, two high-energy subatomic particles will likely have pierced clean through your hand.

We live in a radioactive environment and there's no escape. At sea level, the flux is roughly one particle per palm size per second, which means San Franciscans sustain an astonishing 20 million hits through their bodies each day. Denver is higher in elevation, so its protective blanket of air overhead is thinner. As a result, Mile Highers get hit at roughly twice that rate.

These particles make their presence felt by ionization — that is, ripping electrons away from their atoms. Since atomic electrons are electrically charged, they interact with all other charged particles (e.g. other electrons, protons, helium nuclei, and so on), and so any of these, when sent screaming through space, becomes a type of ionizing radiation. In addition to charged particles, some photons, such as X-rays and gamma rays, also have enough oomph to whack electrons out of their atomic orbitals and so they, too, make the list.

Much of the radiation around us comes from nuclei in the soil and the air that have too much energy to be stable; they shed their excess by expelling elementary particles. But most of the damaging corpuscles have their origins deep in outer space where pulsars, supernovae, and even stranger cosmic players accelerate elementary particles to fantastic energies and hurl them out into the cosmos. After perhaps 100,000 years of silently streaking between the stars, some of these tiny wanderers end their existence when they strike the nucleus of an atom in the air high over our heads, and explode.

Since energy and mass are two sides of the same coin, some of the enormous kinetic energy these particles often carry instantly converts into wholly new particles, sometimes thousands of them, that shower down toward Earth. Most of these new particles interact with still more atomic nuclei and quickly range out — never reaching the ground. But one exotic species, the muon, does not feel the nuclear force. As a result, muons do not get absorbed in the air. Most survive to reach Earth's surface where they fall from the sky in all directions as a steady spray of subatomic machine gun bullets that we call "cosmic rays."

METHOD #1: THE 30-SECOND CLOUD CHAMBER

It turns out that these exotic particles, as well as the more mundane radiation produced by the decay of unstable nuclei near us, can be made visible inside a chamber that takes about 30 seconds to assemble if you've got some dry ice on hand. (Dry ice is easy to get from many ice warehouses or welder's supply stores. Visit dryicedirectory.com to search for dry ice dealers by area code.)

YOU WILL NEED:

- Large jar with metal lid
- Rubbing alcohol
- Dry ice (1 cake)
- Towel
- Flashlight

Simply take a large jar with a metal lid and warm the jar under a flow of hot water. Then thoroughly rinse the inside with rubbing alcohol and dump out the excess. Replace the lid. Center a cake of dry ice on top of a towel. Then place the jar, lid side down, in contact with the dry ice and wrap the

Inside the trophy case cloud chamber when chilled and illuminated by an LCD projector. Although they do not show up well in this photograph, the alcohol droplets and particle tracks are clearly visible to the naked eye.

Photograph by Shawn Carlson

remaining dry ice up in the towel to prevent it from "smoking." The alcohol will evaporate from the warm sides of the jar and condense near the frigid lid.

Do this in a darkened room. Shine a bright flashlight into the jar from the side, and you'll see pinprick-sized droplets of alcohol coalescing near the bottom. After a minute or two, when the dust

Muons fall from the sky in all directions as a steady spray of subatomic machine gun bullets that we call "cosmic rays."

inside the jar has settled out, you'll also see something extraordinary. About once a minute, just above where the droplets are forming, a ghostly line will suddenly appear and then disintegrate as falling rain of alcohol. These spectral emanations are caused by ionizing particles of radiation passing through your jar.

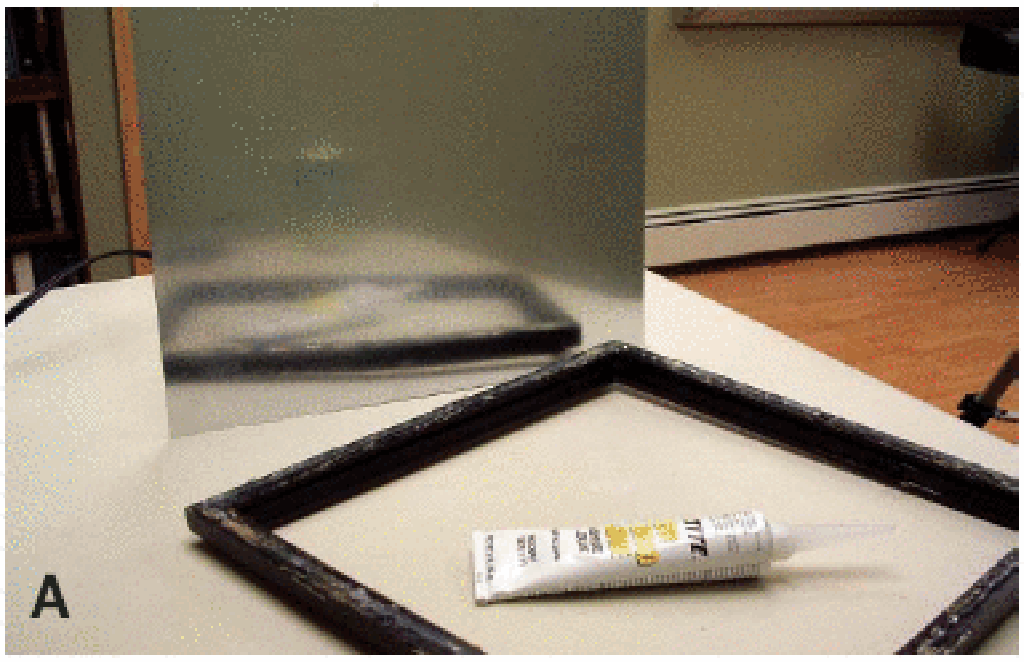
These thin trails of vapor form because the ions that the passing particles leave in their wake attract the electrically neutral alcohol molecules, just like a balloon that has been electrically charged by rubbing on someone's hair readily attracts small bits of electrically neutral dander. The alcohol molecules just above where the cloud appears are almost, but not quite, cold enough to form droplets. But when a passing particle lays down a trail of ions, those ions can pull together enough alcohol molecules to entice droplets to form. These droplets coalesce along the track and essentially amplify its width over a trillionfold to make the particle's passage plainly visible. For obvious reasons, a radiation detector that uses tiny droplets to reveal its quarry like this is called a "cloud chamber."

While the cloud chamber in a jar couldn't be simpler to construct, it has three drawbacks. First, it's small, so you often have to wait a long time before another cosmic ray will happen to pass through at just the right spot. Second, the curved glass makes the tracks hard to see. And finally, the show only starts after any dust particles inside have settled, and it stops as soon as the alcohol has all condensed. That limits you to just a few minutes of good viewing.

A far better chamber would operate with a large enough volume for tracks to appear every few seconds, have flat sides for clear viewing, and would contain a reservoir of alcohol large enough to keep the show going for hours.

YOU WILL NEED:

Basketball display case
Thick black felt to cover the top and bottom of the chamber
Sheet metal a thin square measuring 26cm a side
Hardware cloth mesh same size as metal
Silicone aquarium cement one tube
Stapler
Rubbing alcohol
Dry ice
Small wood screws 4 to 6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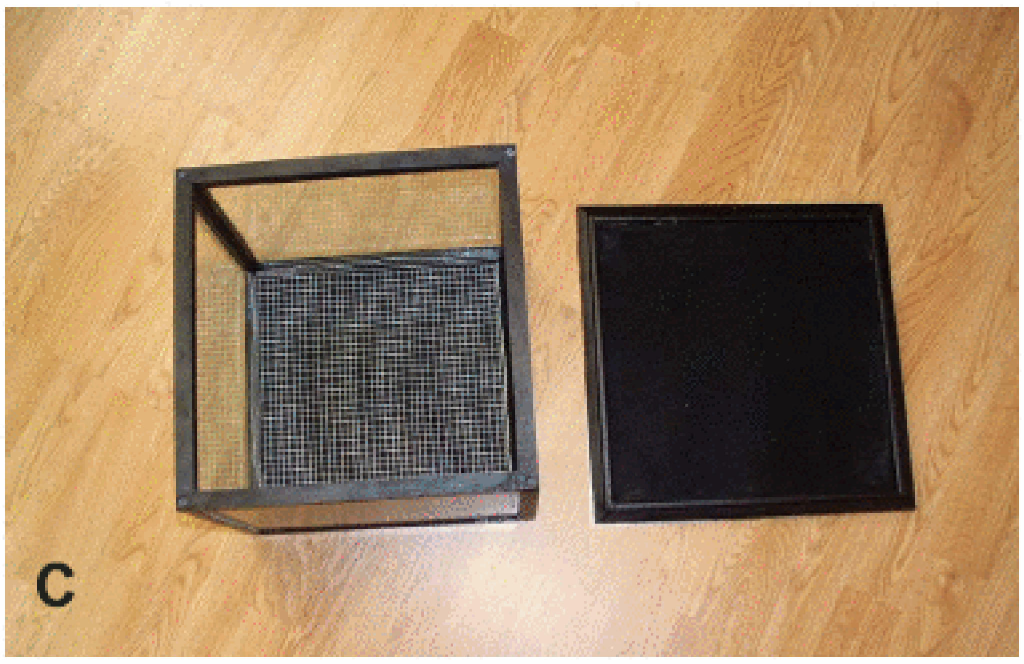
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D

Photography by Shawn Carlson

METHOD #2: THE BASKETBALL CASE CLOUD CHAMBER

Here's how to make a superior cloud chamber.

The trick to creating cloud chambers is to find the right vessel. And nothing I've found so far trumps a basketball display case. I purchased a new one for $30 from a local craft store, but you may need to check online or peruse your local trophy stores. These cases are clear glass on the top and three sides. The back is lined with a mirror and the bottom is covered with thin particleboard. Each side is about 26cm long. When the chamber is operating, tracks form within at a height of about 4cm, which makes the active volume a whopping 2,700 cubic centimeters. That is far larger than any other homemade cloud chamber I've seen, and results in a particle track every few seconds.

First, to let the chill of the dry ice in, replace the thermally insulating particleboard on the bottom of the display case with a thin piece of conducting sheet metal. (Find a local supplier of sheet metal and have them cut it to size.) Gently push out the bottom and use the silicone cement and screws to seal your sheet metal in its place (Fig. A). Turn the assembly upside down and rest about 10 lbs. of books on top to insure a firm connection. Run a bead of silicone all around the inside joint to make sure the seal is airtight; air currents will destroy the tracks as fast as they form.

When the cement sets, cut a square of black felt to exactly fit inside the bottom of the case. This will soak up the excess alcohol used in the chamber and provide a good black contrasting background to view the tracks.

Adding the felt to the lid is trickier. First, cut a square just large enough to completely cover the exposed glass on the inside of the top. Turn the top of the case upside down and drop the felt inside. Now comes the tricky part — fastening the fabric in place. You can't simply use glue, cement, or epoxy because alcohol eventually dissolves virtually every adhesive.

A better solution is to pin the felt against the top using a wire screen. Cut the screen so that it is 2-3 cm (about 1") wider than the felt, and use a pair of pliers to bend down the four sides. Press the felt down, and then delicately staple the wire frame in place using ordinary office staples. (Figs. B and C)

Finally, to block out all of those track-destroying air currents, you need to seal all of the wood/glass joints with silicone. Run a bead of caulking along all of the joints inside and out, and then spread the silicone smooth with your finger. Let the silicone set up overnight before testing your chamber.

That's it. You're done.

ENTER THE SUBATOMIC UNIVERSE

Place the bottom of the chamber directly on top of a block of freshly cut dry ice (Fig. D). You want the entire bottom surface to come to the same temperature. (Any variation will cause air currents to flow inside the chamber and obliterate your tracks.) So if the chamber is larger than the block of dry ice, you'll need to create a tile of four blocks, and then center the chamber on that. As before, wrap exposed dry ice with a towel to prevent smoking.

NOTE: If your supplier gives you irregular hunks of dry ice, you'll need to create a dry ice and alcohol bath. First, wrap the dry ice chunks in a towel and pulverize with a hammer. Next, dump the pulverized pieces into a plastic kitchen trash bag. Lay the bag on top of a doubled towel to provide insulation, and pour in several cups of isopropyl (rubbing) alcohol. (You'll waste less dry ice if you chill the alcohol in your freezer first.) Then wet the top of the bag with alcohol to provide a conductive seal, and press the bottom of the chamber onto the bag. This will chill the chamber nicely and avoids the mess and alcohol fumes of a traditional alcohol and dry ice bath.

Next, fully charge the top pad of felt with alcohol and evenly moisten — do not saturate — the bottom pad. The alcohol on the bottom helps conduct heat out of the chamber and hastens the formation of the cloud. For this, you'll want the highest concentration of alcohol you can find. Go to your local auto supply store and purchase a bottle of Iso-Heat. This product is used to remove water from fuel lines and, as it turns out, is pure anhydrous isopropyl alcohol.

Now close up the chamber and wait. It will take a while for all the dust in the air inside to settle out and for the temperatures of the different parts of the chamber to equalize. The show will start in about 20 minutes and it will go on for hours.

To see it, turn out the room lights. Then shine a very bright column of light in from one side. A bright flashlight will work, but the batteries soon give out. I use the light from an LCD projector. The placement of the light is absolutely critical. The light must shine across the bottom of the chamber where the droplets are forming, and you must position your head low and at a steep angle relative to the light. Experiment a bit to find the positions that best illuminate the chamber and provide the most spectacular viewing.

After the chamber has reached equilibrium, droplets will form very fast near the bottom and less so as you move up. The top of the cloud will be about 4cm above the bottom. That's where you want to focus your attention, where the wispy telltale tracks you are looking for will suddenly spring into being. Their appearance, like tiny ghosts dashing through a fog, is something out of Harry Potter.

If you measure their rate and directions, you can learn a great deal. Consider adding a digital camera, shooting either through one side of the case, or through a hole cut in the felt and wire screen on the top. Take a steady march of images and keep only those that happen to capture a track. Long, straight, and slender tracks are most likely made by muons. Thick, stubby tracks that start and stop inside the chamber are created by alpha particles. Their rate will let you set an upper limit on large radioactive nuclei in your environment, like radon.

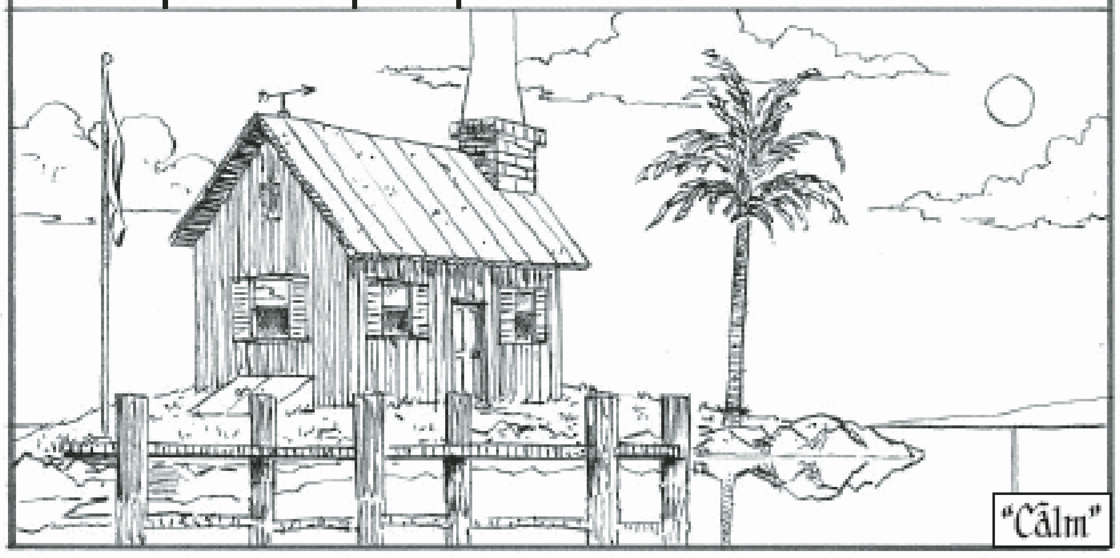
Once you've astonished yourself, make plans to show your chamber to every person you possibly can. No demonstration I know is better able to get people excited about science than this one.

Dr. Shawn (Shawn Carlson, Ph.D.) is a former columnist for *Scientific American*, and the only person ever to win a MacArthur Fellowship for science education. He is the creator of the Society for Amateur Scientists (sas.org), Super Science Fair Support Center (scifair.org), and Labrats (labrats.org).

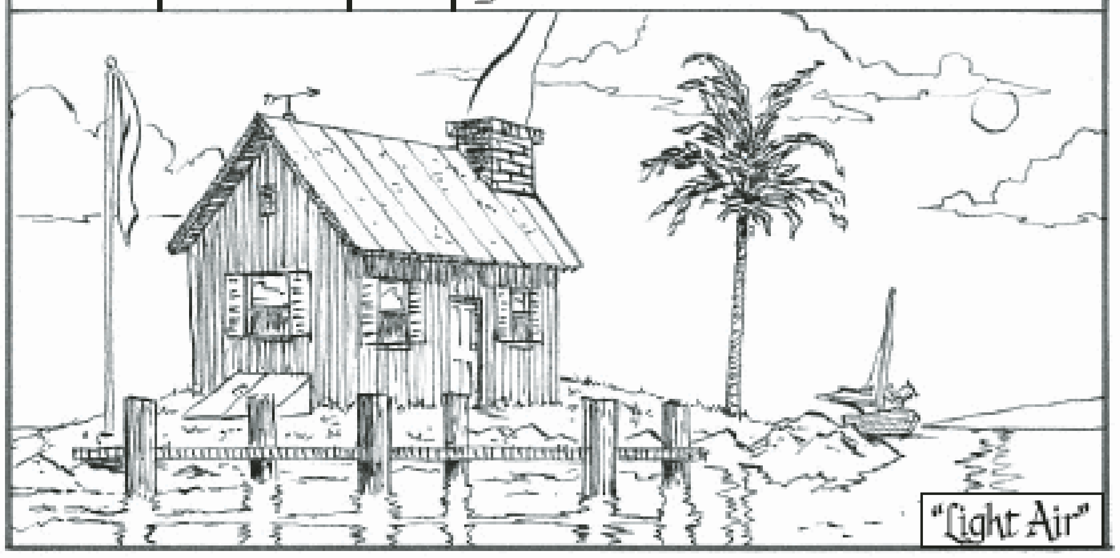
HowToons.com

BY SAUL GRIFFITH & NICK DRAGOTTA '07

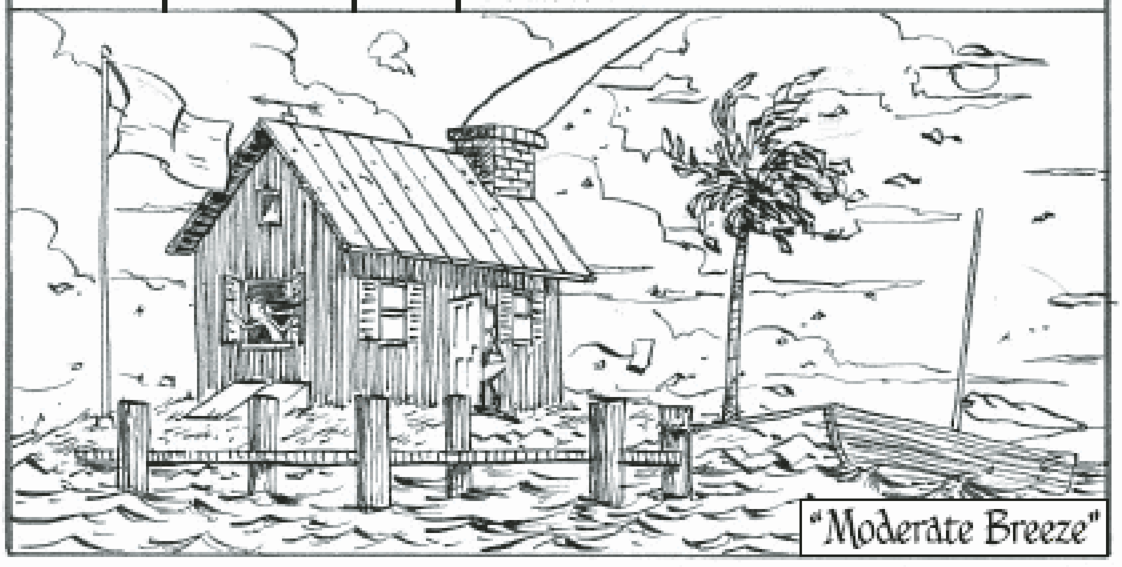
FORCE	SPEED		
0	0 knots 0 mph 0 km/h	SEA	Sea like a mirror.
		LAND	Smoke rises vertically.



FORCE	SPEED		
1	1-3 knots 1-3 mph 1-6 km/h	SEA	Ripples with the appearance of scales are formed, but without foam crests.
		LAND	Direction of wind shown by smoke but not by wind vanes.



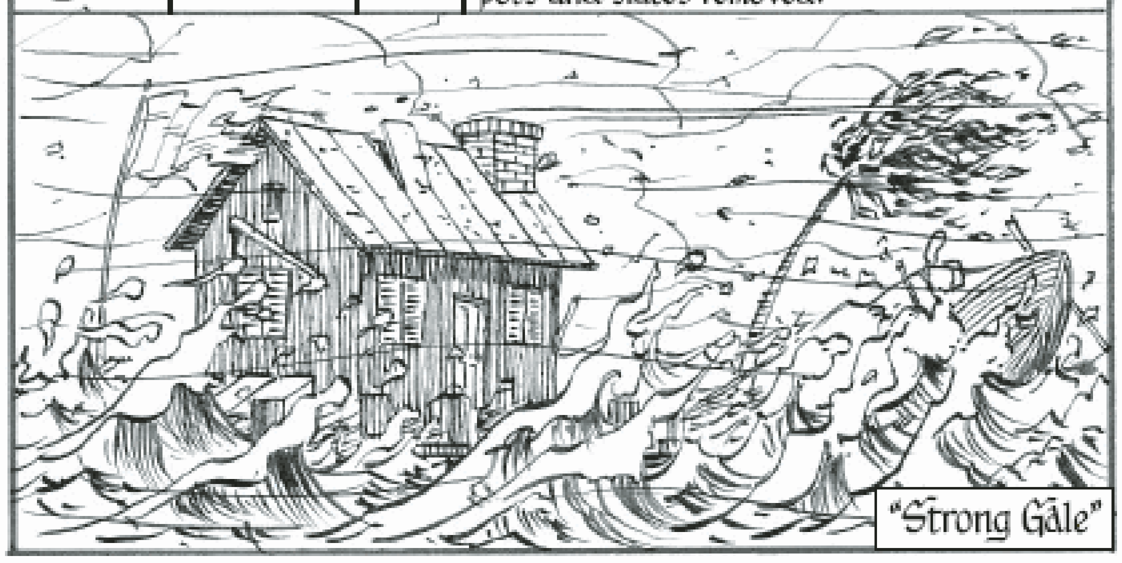
FORCE	SPEED		
4	11-16 knots 13-18 mph 20-29 km/h	SEA	Small waves, becoming longer, fairly frequent white horses.
		LAND	Raises dust and loose paper; small branches are moved.



FORCE	SPEED		
5	17-21 knots 19-24 mph 30-39 km/h	SEA	Moderate waves, taking a more pronounced long form; many white horses are formed.
		LAND	Small trees in leaf begin to sway; wavelets form on inland waters.

FORCE	SPEED		
8	34-40 knots 39-46 mph 63-75 km/h	SEA	Moderate high waves of greater length; edges of crests begin to break into spindrift.
		LAND	Breaks twigs off trees; generally impedes progress.

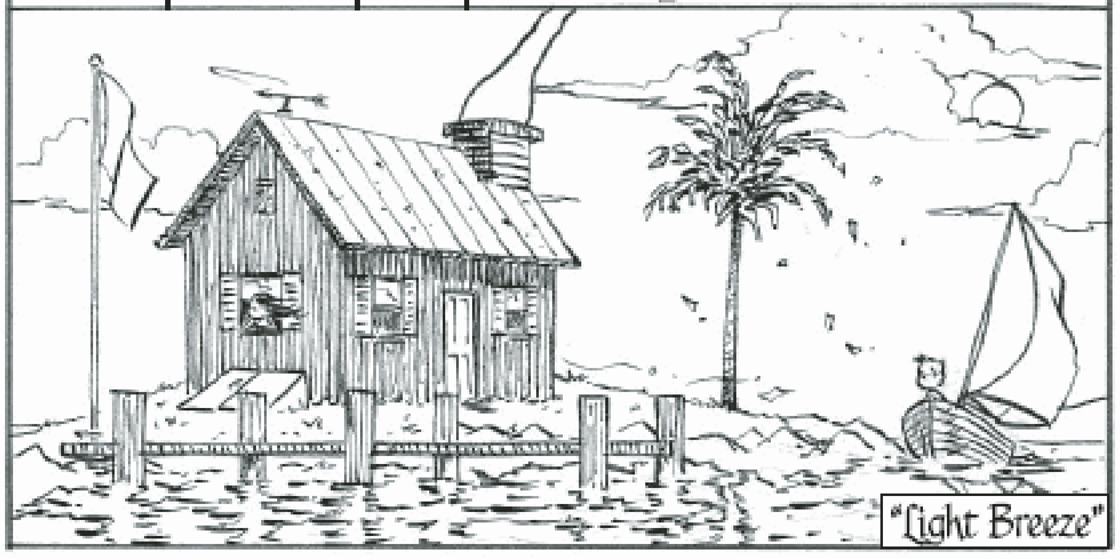
FORCE	SPEED		
9	41-47 knots 47-54 mph 76-87 km/h	SEA	High waves. Crests of waves begin to tumble and roll over. Spray may affect visibility.
		LAND	Slight structural damage occurs, chimney pots and slates removed.



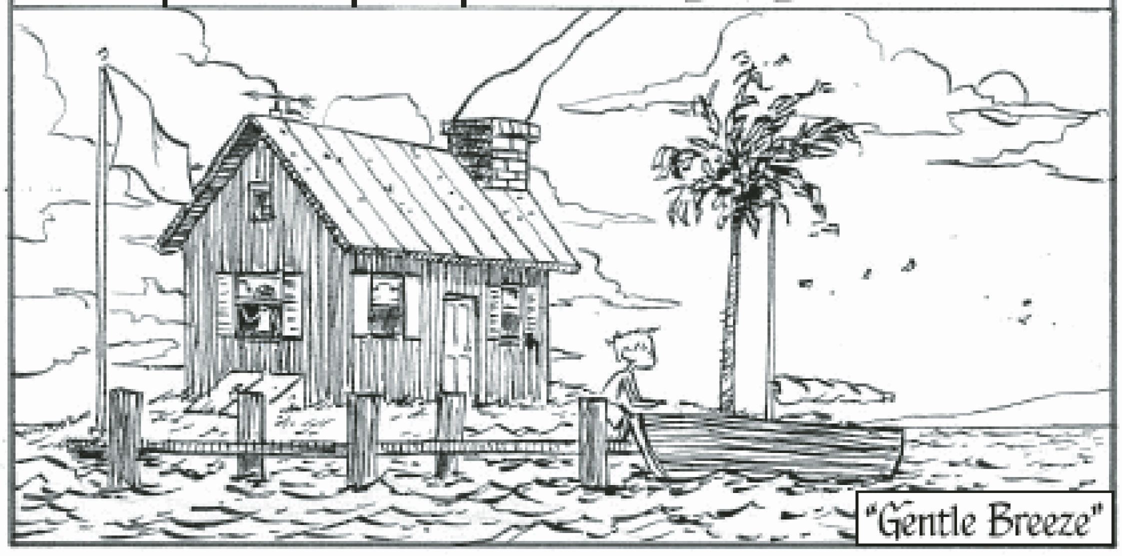
FORCE	SPEED		
12	over 63 knots over 72 mph over 117 km/h	SEA	Huge waves; air is filled with foam and spray. Sea white with driving spray; visibility very seriously affected.
		LAND	Countryside is devastated.

Over thousands of years sailors have learnt to estimate the speed of the wind just by looking about. This technique matured into what we now call the Beaufort scale. The universe tells you everything you need to know about it as long as you are prepared to watch, to listen, to smell, in short to observe.

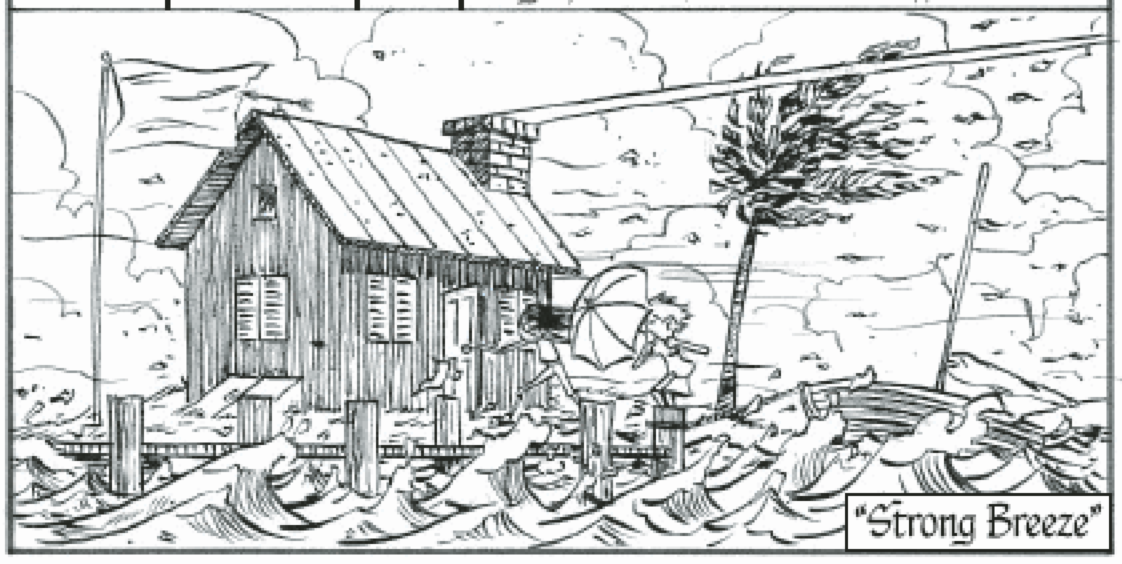
FORCE	SPEED		
2	4-6 knots 4-7 mph 7-11 km/h	SEA	Small wavelets. Crests have a glassy appearance and do not break.
		LAND	Wind felt on face; leaves rustle; ordinary vane moved by wind.


"Light Breeze"

FORCE	SPEED		
3	7-10 knots 8-12 mph 12-19 km/h	SEA	Large wavelets. Crests begin to break. Foam of glassy appearance.
		LAND	Leaves and small twigs in constant motion; wind extends light flag.


"Gentle Breeze"

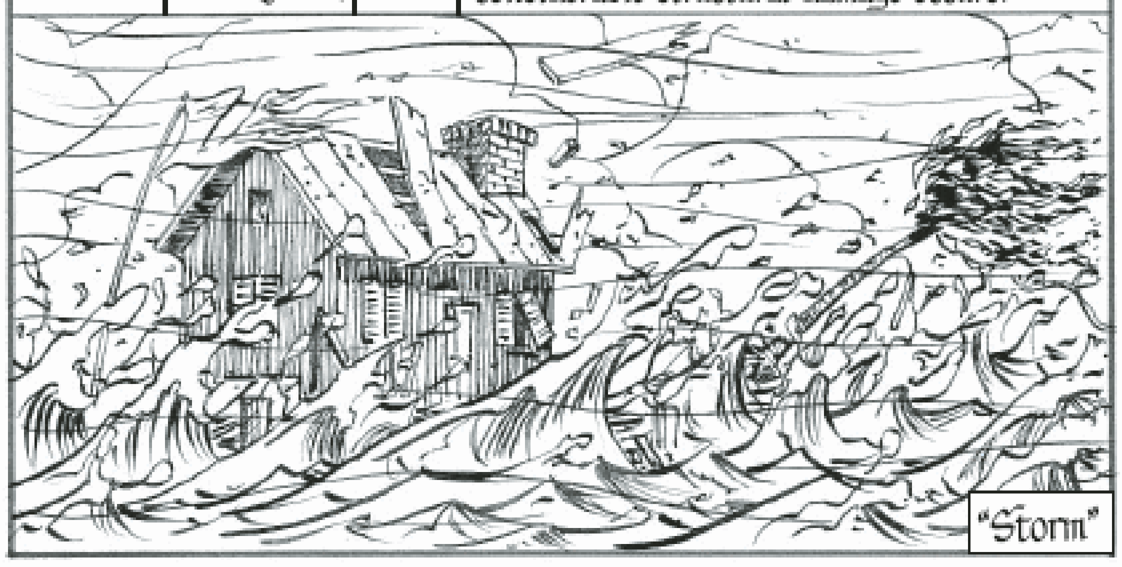
FORCE	SPEED		
6	22-27 knots 25-31 mph 40-50 km/h	SEA	Large waves begin to form; the white foam crests are more extensive everywhere.
		LAND	Large branches in motion; whistling heard in telegraph wires; umbrella use difficult.


"Strong Breeze"

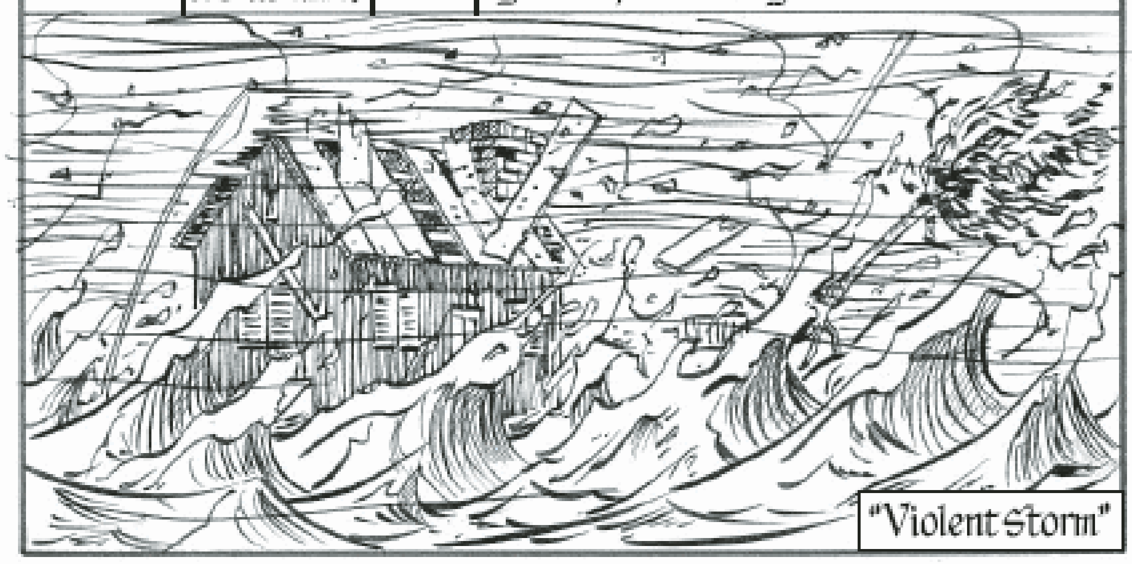
FORCE	SPEED		
7	28-33 knots 32-38 mph 51-62 km/h	SEA	Sea heaps up and white foam from breaking waves starts to blow in streaks with wind.
		LAND	Whole trees in motion; umbrellas discarded; inconvenience felt when walking.

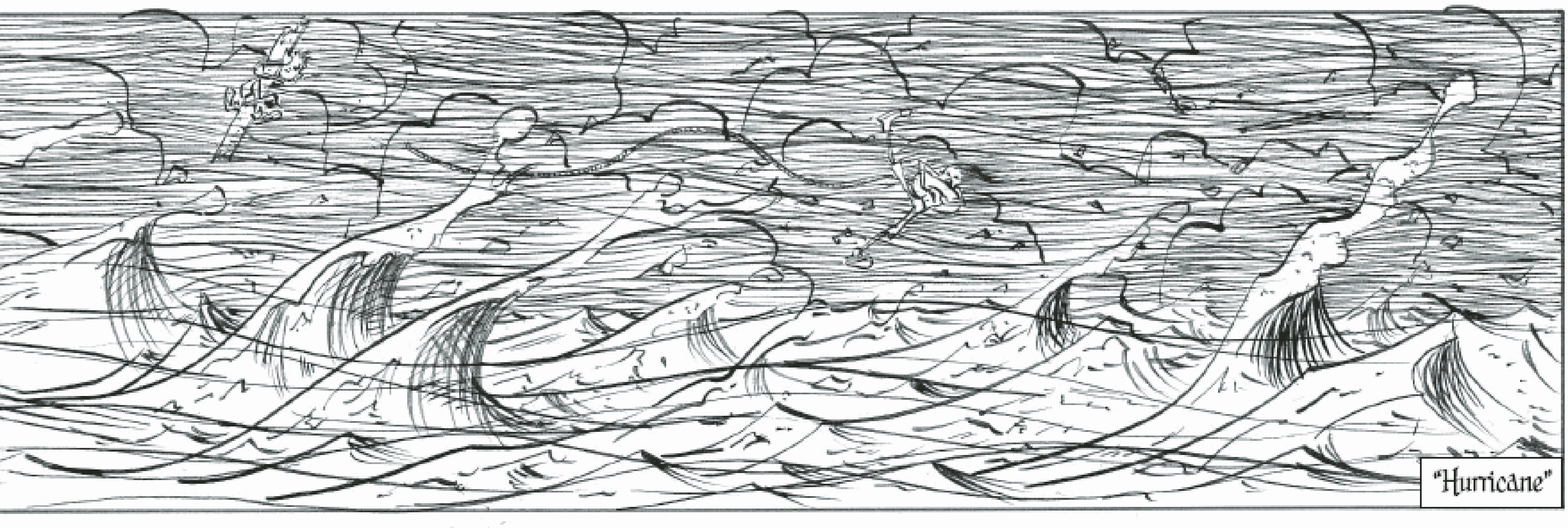

"Near Gale"

FORCE	SPEED		
10	48-55 knots 55-63 mph 88-102 km/h	SEA	Very high waves. Surface of the sea takes on a white appearance. Visibility affected.
		LAND	Seldom experienced inland; trees uprooted; considerable structural damage occurs.


"Storm"

FORCE	SPEED		
11	56-63 knots 64-72 mph 103-117 km/h	SEA	Exceptionally high waves. The sea is covered with long white patches of foam.
		LAND	Very rarely experienced on land; accompanied by widespread damage.


"Violent Storm"


"Hurricane"

MakeShift

By Lee D. Zlotoff

Photograph by Doug Adesko

The Scenario: There was a time when high school, however trying and tedious it often seemed, was still a refuge from the realities of the big, bad world. Alas, those days have gone the way of the slide rule and mimeograph machine. The threats that once stalked only distant cities and bad horror movies are now just as likely to find their way onto a high school campus as anywhere else.

The Challenge: You're in metal shop one sunny morning when an announcement comes over the PA system that the school has been ordered into a lockdown. The teacher must lock the door to the room and let no one out for any reason. The announcement doesn't explain why (A riot in the cafeteria? A crazed gunman on the loose in the area?) or how long you may be stuck here. The lights and power are still on, but you quickly discover that the cellphone system has been shut down or is not working, and neither is the school's internal phone system. And if the school has a wi-fi network, it's also dead.

In order to find out what's going on, or let all your parents — who will no doubt be freaking out any time now — know that you're OK for the moment, or to alert someone to the fact that your buddy Chester here will need his insulin shot within the hour, the class concludes it needs to try and establish some kind of communication with folks outside the school. Thinking this will at least keep everyone in the class focused on something besides the crisis, the teacher gives her OK.

The metal shop itself is on the top floor of the school, with a row of windows that open and face out toward the surrounding community, the nearest houses of which are about a quarter-mile away.

Your Items: The shop itself has an assortment of sheet metal, wire, angle iron, and other assorted metal parts available. You also have the following: a half-dozen cellphones of different makes and models, a laptop computer with a wireless card, a walkie-talkie that one of the janitors left, and a cordless telephone — though, as we've said, the line it's connected to in the school is down.

Using some or all of this stuff, you need to devise as many ways as you can to try and create a communications link with the outside world. And yes, if you pull it off, it will be counted as extra credit toward your final grade. Good luck!

Send a detailed description of your MakeShift solution with sketches and/or photos to makeshift@makezine.com by May 11, 2007. 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 sweatshirt. 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.

Lee D. Zlotoff is a writer/producer/director whose numerous credits include creator of *MacGyver*. He is also president of Custom Image Concepts (customimageconcepts.com).


PRIMER

Working with Carbon Fiber

Form, lay up, and cure your own high-performance composites.

By John Wanberg

It seems as though nearly everything "high performance" these days boasts some amount of carbon fiber in its construction. Originally used in aerospace, carbon fiber has moved into the mainstream and can be found in luxury automobiles, mountain bikes, and sports equipment.

Some laptops and cellphones even use printed decals to simulate this lightweight material's cutting-edge look. The good news is that you don't need a state-of-the-art manufacturing facility to work with carbon fiber composites. In fact, you can do it at home.

This article discusses some of the basics of carbon fiber construction and explains how to create a carbon fiber iPod case. All you need are some basic woodworking tools and skills, and the right materials. And because the same process also applies to fiberglass and Kevlar composites, these skills give you multiple ways of boosting your future projects to a new level!

Photograph by Meiko Arquillos

UNDERSTANDING CARBON FIBER

Composites are created from two or more dissimilar materials that act together as one. While concrete and plywood are technically composites, the term *composite* in industry has come to refer to reinforcement fibers held together in a resin matrix and formed in a mold. Carbon fiber is one of several textiles used in this class of materials. When joined together through a procedure called a *layup*, the fiber and the resin form a material with properties that exceed those of either constituent material.

As a rule of thumb, composites offer their greatest strength in the direction the fibers run — similar to how wood is strongest along the grain. Because of this, you can "tune" a composite's strength characteristics by controlling and combining the directions of the fibers. If you want strength over the length of a part, simply align the fibers lengthwise. Likewise, if you're making a tube that needs torsional (twisting) strength, it's best to arrange the fibers helically, like springs, weaving them together with opposite rotations.

The table below describes the three most common forms of manufactured fibers: woven, unidirectional, and filament. Each general type can be produced from carbon, fiberglass, aramid (Kevlar), boron, basalt, and several other materials, which are chosen according to their particular physical properties.

FIBER TYPE	CHARACTERISTICS
Woven (aka "cloth")	Comes in rolls and resembles the thick nylon fabric used in trampolines. Weave styles vary according to the fibers' directional alignment, drape (how well the cloth conforms to mold surfaces), and wet-out (how easily the fibers can be infiltrated by resin).
Unidirectional	Comes in rolls and resembles a very fine, wide paintbrush. Composed of parallel fibers that are intermittently joined over their width by thin resin-coated fibers that keep the strands aligned into an easily usable form.
Filament (aka "roving" or "tow")	Comes on reels as continuous strands of fibers, loosely gathered into a thread. It can be easily unwound and placed wherever necessary in a layup.

Resin is available in hundreds of different types, each with its own chemical and physical characteristics. In general, polyester, epoxy, and vinylester liquid resins are the most widely used in composite constructions.

You can also buy *pre-preg* fiber, which already has the resin mixed in. Pre-preg is easier and less messy to use, and it doesn't waste resin, but it's also more expensive, is more difficult to obtain, has a limited shelf life, and comes in limited resin types. Most pre-preg comes shipped cold and must be used immediately, or can be frozen (to retard curing) but must be used soon. Another type, *elevated-temperature cure pre-preg*, ships normally and is cured in an oven or autoclave. Molding a composite using pre-preg is known as a form of *dry layup*, while starting with separate fiber and resin is called *wet layup*.

When constructing high-performance composites, designers attempt to do several things at once: orient the fibers for highest strength, inhibit delamination (the peeling apart of fibers), and ensure dimensional accuracy. In addition, they try to minimize voids and bubbles in the composite, which weaken the structure, and keep the resin-to-fiber ratio down to somewhere between 50/50 and 40/60, which is the optimal range for strength and lightness. Many automotive enthusiasts who purchase carbon fiber hoods for their cars complain that they often weigh more than the original steel. This arises from too much resin, either in a thick, glossy top coating called a *flood coat*, or in a generally poor layup.

MAKING THE CASE

We're going to create our own composite iPod cover using wet layup, and *compression-mold* it by using C-clamps. This relatively low-tech method proves successful for making flat shapes out of sheets of material. For shallow rounded forms, you can compress the shapes under plastic bags filled with sand, clamped between wooden boards. Since the iPod has a simple rectangular shape, we can create a nicely consolidated, smooth-surfaced shell by using an internal mold (or *mandrel*) with blocks clamped on its large sides. Although this demonstration explains how to make a case for an iPod mini, you can use this same method to make a hard, lightweight case for practically any device that has a uniform cross-section over its length.

A

B

Fig. A: iPod minis and their carbon-fitted cases.
Fig. B: Measure the iPod.

These instructions include a metal belt clip for the case. If you don't want the clip, just skip the steps that involve the screws, the T-nuts, and the metal strip. For diagrams with complete measurements of all the parts, see makezine.com/09/primer.

PREPARE THE MANDREL

1. Use calipers to take close measurements of the iPod and determine the mandrel size (see Figure B). To guarantee a snug (but not too tight) fit for the iPod, the mandrel's width and thickness should measure .02" to .04" more than the iPod's actual dimensions. The iPod mini is only slightly over ½" thick, so you can form a mandrel easily using a ½" thick piece of medium-density fiberboard (MDF) that has been bulked up with tape to the correct dimensions. If you anticipate taking your iPod in and out of the case frequently, you should line the interior walls of the case with felt or velvet to keep the iPod from getting scratched. In this case, it's advisable to oversize the mandrel even more to account for the thickness of the lining.

For the mandrel's height, add 1" to the height of the iPod. This translates to a total height of 4.75", which will allow enough extra carbon fiber material for clean trimming of the final part.

Here's What You'll Need

MATERIALS

1.5" diameter carbon fiber "sleeve" material, at least 2' length but it's good to have more on hand, just in case sollercomposites.com

Two-part epoxy, slow cure, high-strength from a hobby or hardware store

Scrap piece of ½" thick medium-density fiberboard (MDF) about 6" square

Masking tape

Clear packing tape

Polyethylene sheeting 3-5 mil (75-125 micrometers) thick

Clear lacquer spray paint

Rubber band

Button-sized amount of modeling clay

Petroleum jelly

Latex or nitrile gloves and face mask

For the belt clip:
Matching #6-32 threaded T-nuts (2), ¼" hex button-head socket cap screws (2), and ½" slotted set screws (2) from hardware store, or try mcmaster.com or smallparts.com

12"×1"×.028" strip of stainless steel from hobby or hardware store, or mcmaster.com part #8457K49. You only need 3", but 12" is a typical length.

TOOLS

Table saw or bandsaw

Drill press or drill and drill bits

Router with ¼" round-over bit

Dremel with rotary file or cut-off bit

Calipers

Ruler

C-clamps (2) and vise

Flat-blade screwdriver

Hex/Allen wrench to fit button-head socket cap screws for belt clip

Hammer

Pliers

Metal file

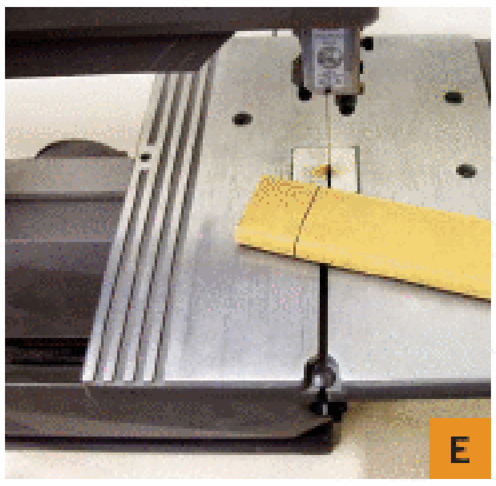
Sandpaper

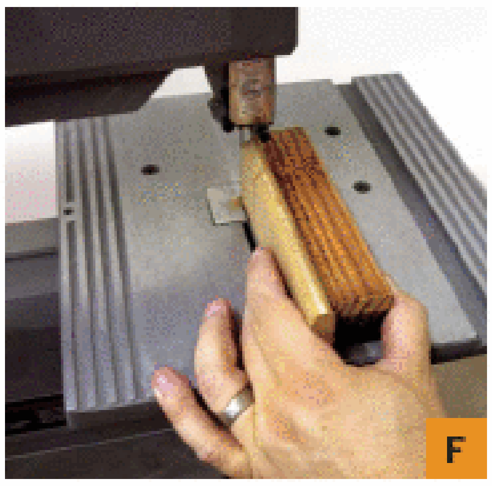
Scissors

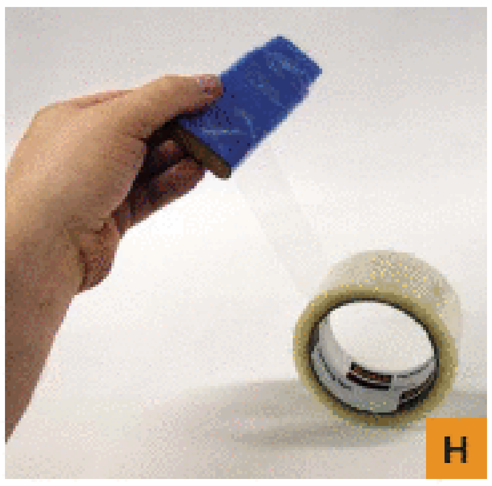
Sheet metal snips

Marker

Photography by John Wanberg







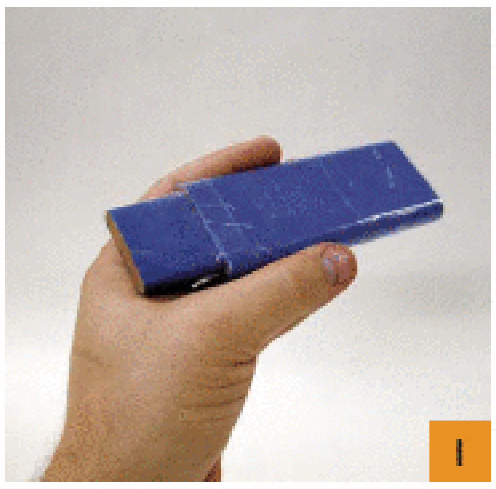
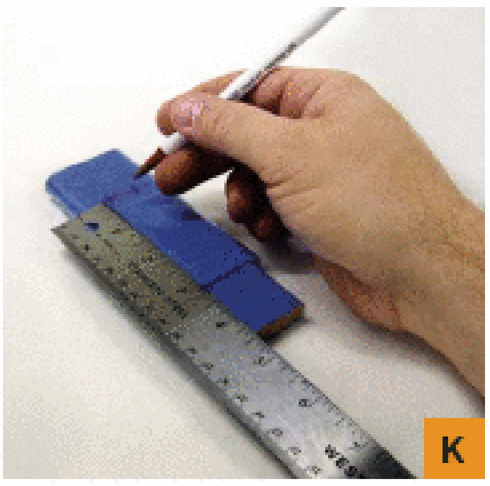


Fig. C: Cut the mandrel.
Fig. D: Replicate the fillets with a router.
Fig. E: Flange cuts.
Fig. F: Vertical flange cuts.
Fig. G: Blue tape wrap.
Fig. H: Clear tape wrap.
Fig. I: The finished plug.
Fig. J: Clamp blocks.
Fig. K: Insert marking.



2. Cut the mandrel to size, making sure that it's very straight along its length, so it will slide out of the hardened composite after curing. You can ensure a straight edge by cutting the MDF using a fence on either a table saw or band saw (Figure C). Then use a router with a ¼" round-over bit to replicate the fillets (rounded edges) along the sides of the iPod (Figure D).

3. In order to form the bottom of the case cleanly, the mandrel needs to have a slight flange for the carbon fibers to wrap around. Create this flange by marking its location 1" from the bottom of the mandrel, then cutting a ⅛" deep groove around the mandrel with a band saw (Figure E). Trim off the excess on the flange with the band saw by using a block to hold it squarely in place (Figure F).

4. Wrap tape over the mandrel if necessary, to build it up to the desired dimensions (Figure G). Be careful to keep out any wrinkles or bubbles.

5. Create a removable sheath for the mandrel by wrapping it with either polyethylene sheeting taped to itself, or with clear packing tape (Figure H). I created a tight, removable sheathing by wrapping the packing tape around the mandrel sticky side up, and then wrapping it again sticky side down (Figure I).

6. Cut 2 clamping blocks out of MDF scrap, making them the same dimensions as the mandrel, without the extra 1" of length. Cover the blocks with packing tape to keep them from adhering to the composite during cure (Figure J).

MAKE THE BELT CLIP

1. If you're adding the belt clip to your case, mark and drill two ⅛" diameter holes on one of the clamping blocks, in the location and spacing that you want for the clip's screw mounts.

2. Mark and drill holes in the mandrel at locations that match the ones drilled in the clamping block (Figure K). These are pilot holes for the set screws that hold the T-nuts during layup and cure, so make them slightly smaller than the screws' diameter.

3. Tighten the set screws into the mandrel so they are exposed at least ¼" above the surface (Figure L).

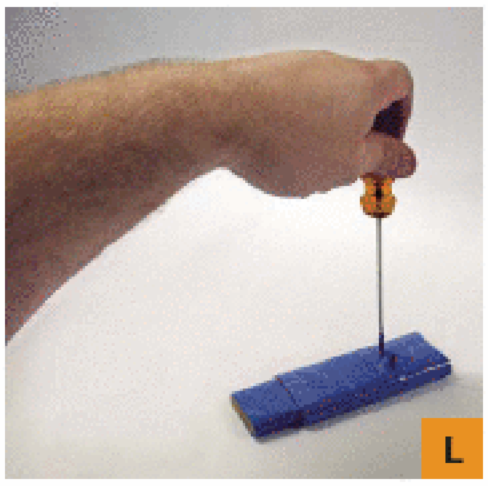


Fig. L: Set screw insertion.
Fig. M: Lubricate inserts.
Fig. N: Nut forming.
Fig. O: Raw carbon trim.
Fig. P: Clay insertion.
Fig. Q: Epoxy spreading.
Fig. R: Clamping.

RESOURCES

Article about current carbon shortage due to increased demand from aerospace and military: fibreglast.com/carbonfibershortage

Soller Composites: sollercomposites.com

4. Apply a very thin coating of petroleum jelly to the set screws to keep the resin from locking them in place during curing (Figure M).

5. Use pliers to flatten the spikes found on the T-nuts (Figure N). The slightly jagged nubs that are left will grab into the composite later and help keep the T-nuts from rotating when you insert the screws.

LAY UP THE COMPOSITE

1. Cut 2 equal lengths of the carbon sleeve, long enough to allow a little extra material to hang over each end of the mandrel (Figure O).

2. Carefully slide one length of sleeving over the mandrel, and wiggle the fibers around the set screws so that they lay flat against the mandrel with the screws poking through. Screw the T-nuts onto the set screws and pack a small amount of modeling clay into the top of each to prevent resin from filling in the hole (Figure P).

3. Mix up the epoxy according to the manufacturer's directions. Wearing latex or nitrile gloves, apply it generously to the sleeve, working it between the fibers with your fingers to ensure total wet-out.

4. Pull the second layer of sleeve over the mandrel, and, as with the first sleeve, work the fibers around the T-nuts so that the nuts poke through and the fabric lays flat. Work more epoxy into this second layer until it is also completely saturated (Figure Q). Tug carefully on either end of the sleeves to straighten any undulations in the fiber weave, and smooth it down as much as possible to ensure clean aesthetic results.

5. Place the clamping blocks on either side of the layup and mandrel with the holes in the drilled clamping block matching the locations of the T-nuts. Apply the C-clamps carefully and tighten them down while trying to minimize shifting in the fiber (Figure R). Wrap a rubber band around the lip of the flange to pull the fiber around the edges. Smooth away any excess resin from the layup with your gloved fingers; this will save surface finishing time later. Allow the layup to cure overnight.

Fig. S: Trimming excess ends with Dremel.
Fig. T: Knocking out the mandrel.
Fig. U: File smoothing.
Fig. V: Final trimming.
Fig. W: Lacquer coating.
Fig. X: Clip forming.
Fig. Y: Finishing the screw tightening.
Fig. Z: Finished clip.

FINISH THE CASE

1. Remove the clamps and pry off the clamping blocks with a flat-blade screwdriver. Use a Dremel with a rotary file bit or cut-off wheel to trim the excess ends from the composite (Figure S). Make sure to use a dust mask; carbon fiber and epoxy produce some nasty dust. Also wear gloves and use caution, because cured carbon fiber slivers are even more heinous than those produced by fiberglass.

2. Unscrew the set screws from the T-nuts. Use a hammer and a small scrap of wood to knock out the mandrel from the flange (Figure T).

3. Pull the plastic sheathing out from inside the case and then trim the case down to size with a Dremel. File and sand the case as needed to create a smooth surface (Figure U). Wet sandpaper works best when smoothing carbon fiber surfaces, and also keeps dust to a minimum. Take care to keep from sanding through one layer into the other, as this will look unsightly and weaken the case.

4. Precisely measure and mark the locations of the screen and buttons on the case (a 1.5" diameter circle template will mark the thumbwheel nearly perfectly). Use the Dremel to cut the holes, and finish the edges with a file and sandpaper (Figure V).

5. Paint the case with several spray coats of clear lacquer to give it a professional finish (Figure W).

FINISH THE BELT CLIP

1. Use sheet metal snips to cut the stainless steel strip down to 3" long, then smooth and round the edges and corners with a file. Then drill holes at one end of the clip with spacing to match the T-nuts.

2. Use a vise to put 2 slight widthwise bends in the strip, one ½" from the end with the screw holes, and the other in the opposite direction, ¼" from the other end (Figure X).

3. Mount the clip to the case with the button-head socket cap screws (Figure Y). Your case is now finished and ready for use (Figure Z)!

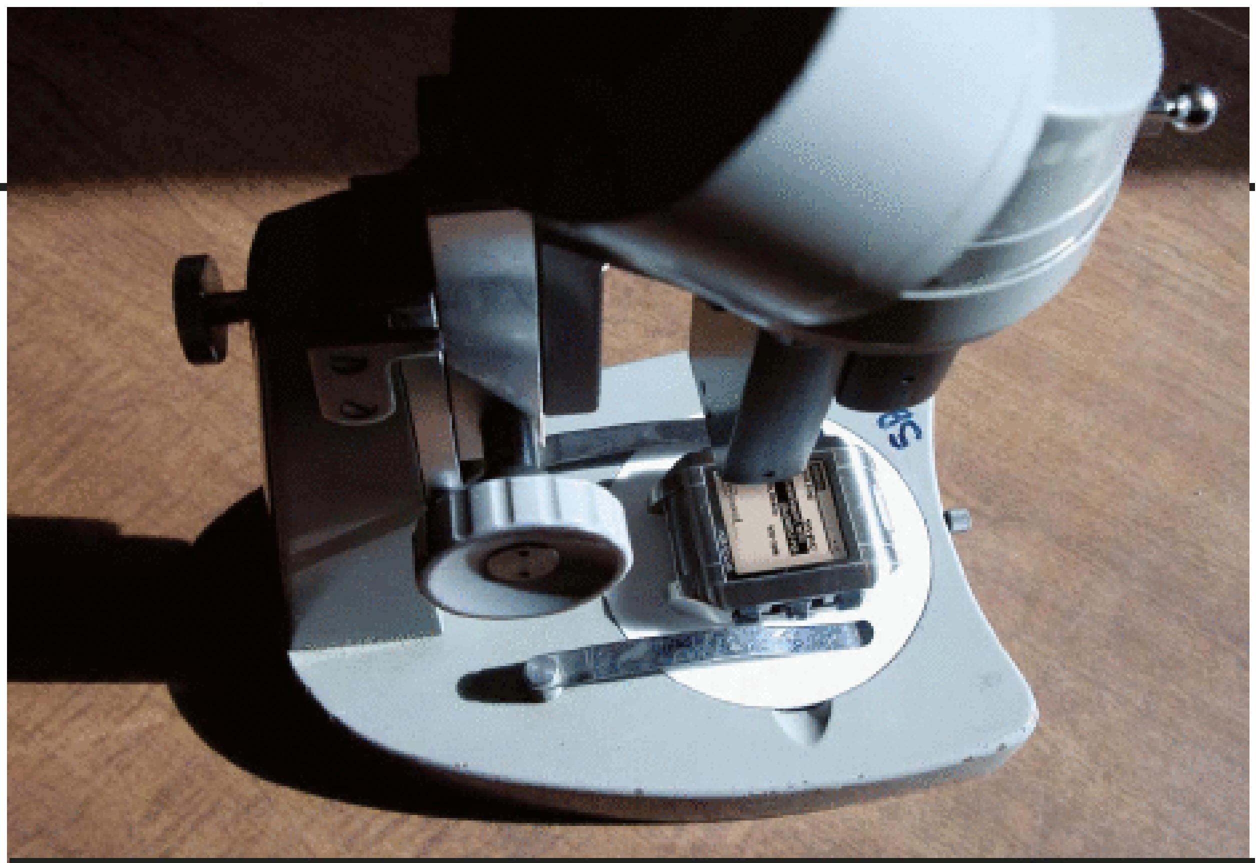
John Wanberg is a professor of Industrial Design at Metropolitan State College of Denver who enjoys researching innovative technologies and designing alternative automobiles.

RETROCOMPUTING

An Apple II in a Wristwatch

By Tom Owad

Emulating a classic Apple computer in the Palm OS.



Zoom in on Zork: When you install the Appalm][emulator on a Palm wristwatch, you might need a microscope to read it.

I've occasionally heard claims, usually as a tribute to our technological advancement, that a modern digital wristwatch has more power than some old mainframe or the space shuttle, or some other system involving early computer technology. The Apollo Lunar Module seems to be the most popular comparison. While it's difficult to compare a watch to a navigation system, I think you'd be hard pressed to find a wristwatch with 4KB of RAM and a real-time multitasking operating system.

On the other hand, it's easy to understand the awe of wearing a computer on your wrist that's more powerful than that used to land on the Moon. One wristwatch that can reasonably make such a claim is the Fossil Abacus Wrist PDA. With a 66MHz Motorola DragonBall based on the 68000 core and 8MB RAM, it's not dissimilar to a personal computer from the early 90s.

The operating system is Palm OS 4.1, which is very well suited for a PDA. What I'm looking for, however, is not a PDA but a general-purpose computer — the technology of yesteryear shrunken to miniature using modern technology.

What I really wanted was a Macintosh on my wrist, but the technology isn't quite there yet (at least not for the $50 an Abacus Wrist PDA costs). I did, however, find an emulator for the Apple II that runs on Palm OS. Appalm][(palmapple.sourceforge.net) is intended for full-sized Palms, but the Wrist PDA does claim it can run most Palm applications, so I decided to give it a try.

I copied the files to the watch and launched Appalm. The screen immediately went black and a line of miniature white text appeared at the top: "Apple //e". I clicked on the Palm menu and loaded the test disk image. The disk successfully booted to the menu screen, full of text. The Apple IIe typically had a 12" to 14" monitor. The Wrist PDA has an LCD that's barely 1" in diameter. The tiny white text on the black background was almost impossible to read. Angling the screen so I could make out the text, I successfully loaded a benchmarking program and ran the Memory Read test. It came in at 168 seconds on the wristwatch, compared to 112 on the real Apple IIe.

Satisfied that this would not be an appealing platform for arcade games, I decided to try something simpler: Zork! Within minutes, I was "standing in an open field west of a white house, with a boarded front door." At least that's what I think it said. By this time I was getting a headache from squinting at the small text, so I removed the wristband with a spring bar remover and placed it under a microscope at 20x magnification.

At this magnification, each pixel was clearly visible, but I had to shift the watch to read the entire screen. My eyes no longer hurt, though, so I decided to stick with the microscope for my game of Zork.

Between the microscope and the pen-based data entry (you write over the top of the Apple II screen using Jot or Graffiti to enter text), the game is tedious but nonetheless fully playable and serves as a curious testament to the advancement of technology. Launch the classic 1970s game Lunar Lander and you can use the 66 MHz DragonBall on your wrist to pretend it's 1969 and you're piloting the Apollo Lunar Module.

Tom Owad (owad@applefritter.com) is a Macintosh consultant in York, Pa., and the editor of applefritter.com. He is the author of *Apple I Replica Creation* (Syngress, 2005).

Photograph by Tom Owad

Read about crop circles, make your own temporary tattoos, and take crystal-clear photos with a circular polarizing filter.

TOOLBOX

Tokyo Time Hackers

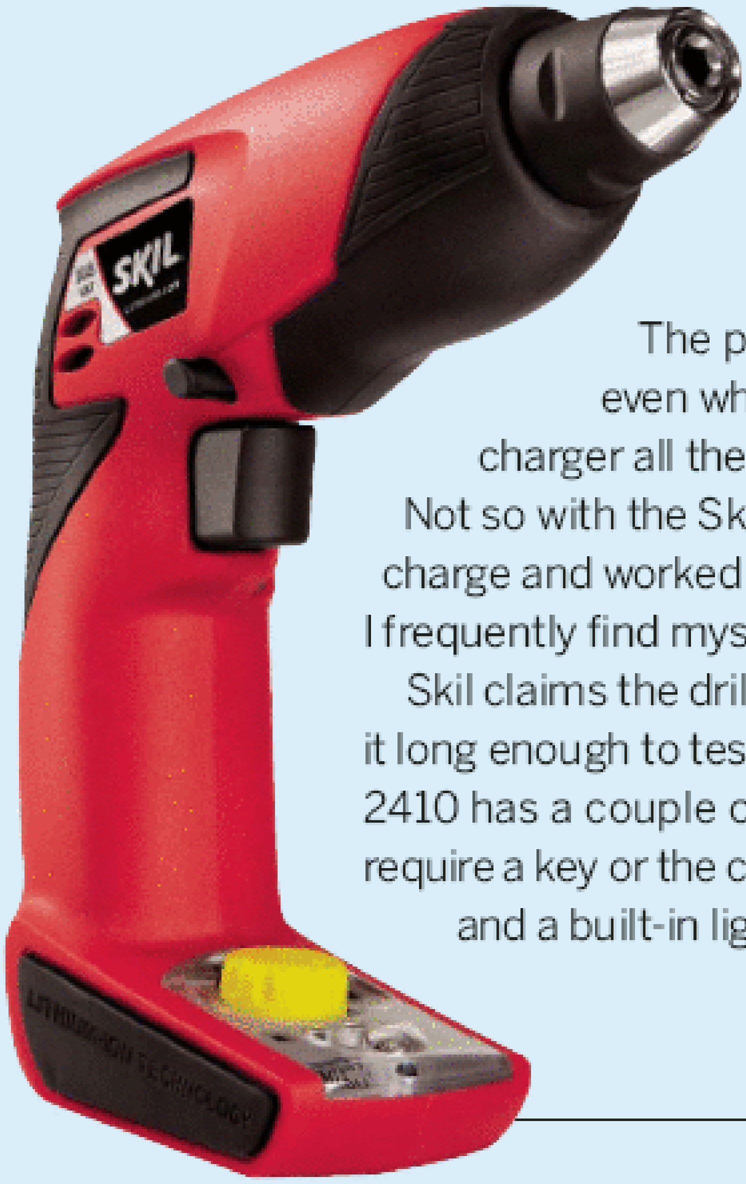
$100 and up tokyoflash.com

We geeks love to hack the wetware (aka our brains) as much as the hardware and software. Puzzles, brainteasers, math problems, games with complex rules and devilish stratagem, anything to keep those neurons sparky. So when a propeller-head chooses a watch, if given the choice between one that tells time via mechanical hands or digital readouts versus one that rewrites the very rules of time-telling, displaying it in some unspeakably nerdy way, you know what the choice will likely be.

For many a high-dome and wired hipster, the choice is TokyoFlash, the Japanese chronograph merchant specializing in unique, and some might say, insanely odd, timepieces. Their Morse Code Watch tells time by sounding it out in Morse code, "refracting the sound through your wrist," as well as displaying the code on the watch's face. The Scope uses X and Y coordinates and a flashing LED scope-like screen to point and flash out the time. One of TokyoFlash's more well-known watches is the B Version by Twelve 5-9. It uses a radar-like display to indicate the hours, a row of five LEDs for the 10s and nine lights for the intervening minutes. The High Frequency PU uses LCD technology to display a dance of brilliant blue (or green) lights that spike and die like a graphic equalizer. Eventually, all the lights fade away except for the ones that indicate the current time (or month/day).

If you really want to play Play-Doh with your thought forms, get several of these watches, ones that use very different methods of time-keeping, and switch off wearing them. Just be prepared to get the snot kicked out of you if somebody asks you for the time on the subway and you shove one of these weirdo watches in his face.

—Gareth Branwyn



Staying Power

Skil 2410 10.8V Li Ion Drill, $80 skil.com

The problem with most cordless drills is the way the batteries drain even when you aren't using them. Unless you keep the battery pack in the charger all the time, you never know if the drill is going to work when you need it. Not so with the Skil 2410 10.8V Li Ion Drill. It sat in my closet for a month without a charge and worked like a champ when I pulled it out, unlike the NiCad-powered tools I frequently find myself cursing.

Skil claims the drill can hold a charge for 18 months of non-use, but I haven't had it long enough to test. (If you don't trust it, you can store the drill on the charger.) The 2410 has a couple of other handy features, like a quick-change chuck that doesn't require a key or the coconut-crushing grip of an orangutan to make sure bits don't slip, and a built-in light to help you see what you're doing.

—Mark Frauenfelder

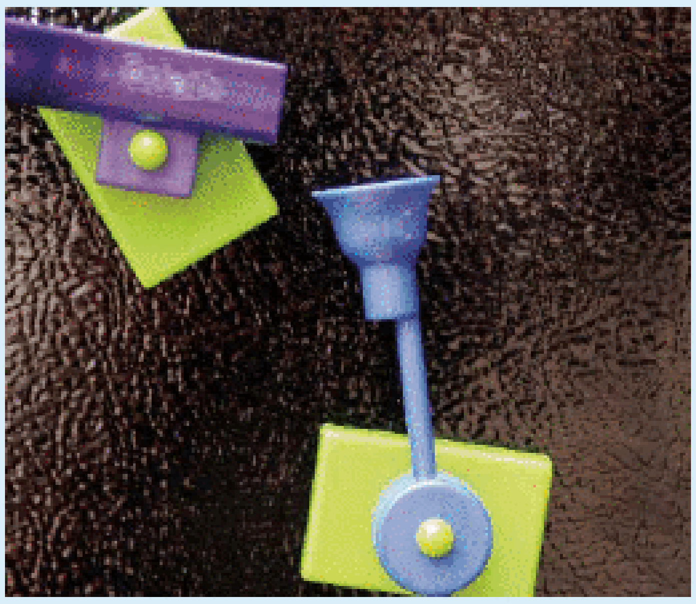
Fun with a Fridge

$14 frigits.com

My mother has collected magnets for her fridge as long as I can remember. Whenever we went on trips, all she wanted was a souvenir magnet. So, you can imagine how surprised we were to see the memory slate wiped clean for a game.

Frigits is a great magnet set that lets you build a marble run right on your fridge. Each piece has swiveling magnets on the back, so you can turn them as you'd like. They send you 12 marbles, and you can buy the "Frigits Extension Launcher" so short folks can send the marbles high enough.

I believe that the only real requirement to use it is to understand gravity; I think most Earth residents are familiar with that. Kids love the clicking, clacking, and spinning as the marble makes its way down. We ended up moving the Frigits to the side of the fridge so we would be ready to play at all times. (See my video of Frigits in action at makezine.com/go/frigits.) ***—Brian Stucki***



The Daily Grail

dailygrail.com

I've savored The Daily Grail for years, and like Boing Boing, its mix is hard to describe except to say that it combines many things I'm interested in — archaeology, anthropology, paranormal phenomena, alternative history, natural science, the occult — and approaches them with the same fascination and skepticism that I have. The links are great, and the comments frequently hilarious. As well as keeping you up-to-date on outlier thought, TDG also follows a pantheon of fringe notables like Graham Hancock and Loren Coleman, and performs due diligence on self-assured authorities such as Egypt's celebrity minister of antiquities Zahi Hawass and career skeptic James Randi.

At the end of 2003, the long-running TDG became the watered-down "TDG News Briefs" behind the home page of the ill-fated *Phenomena* magazine. Thankfully the site came back two years later with even more to share. Now it also hosts The Red Pill, a reference wiki that "grew out of Wikipedia's tendency to avoid 'fringe' issues," and the PDF magazine *Sub Rosa*, which takes a deeper look at fringe topics with historical features, profiles, interviews, and artist spotlights.

It all just makes me want to kidnap the bloggers so that we can drink wine and talk until dawn, while taking turns choosing the music to put on the stereo. I'm sad that I have only one lifetime to explore all the fun things that TDG covers. Or do I?

—Paul Spinrad

Editors Phillip Torrone and Arwen O'Reilly talk about kits from makezine.com/blog.

Snow Bike Kit

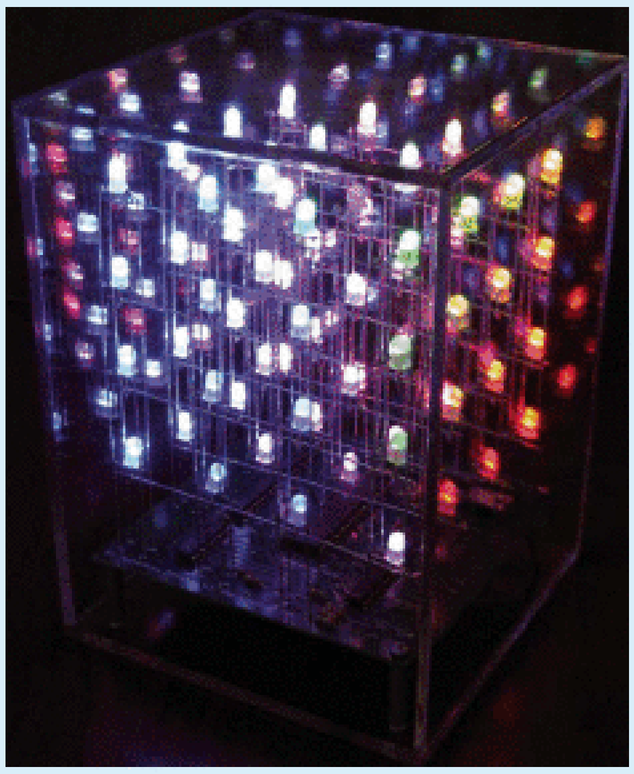
$300 ktrakcycle.com

Add a ski to the front of your mountain bike and a tracked rear drive, and you're set to be James Bond. Not a bad hack either, if you have the time to build it from scratch.

Meet the Beetles!

$50 e-clec-tech.com/gamkitse.html

The flat metal pieces are cool enough, but once assembled you end up with a piece of art: a rhino beetle, scorpion, praying mantis, butterfly, or stag beetle.

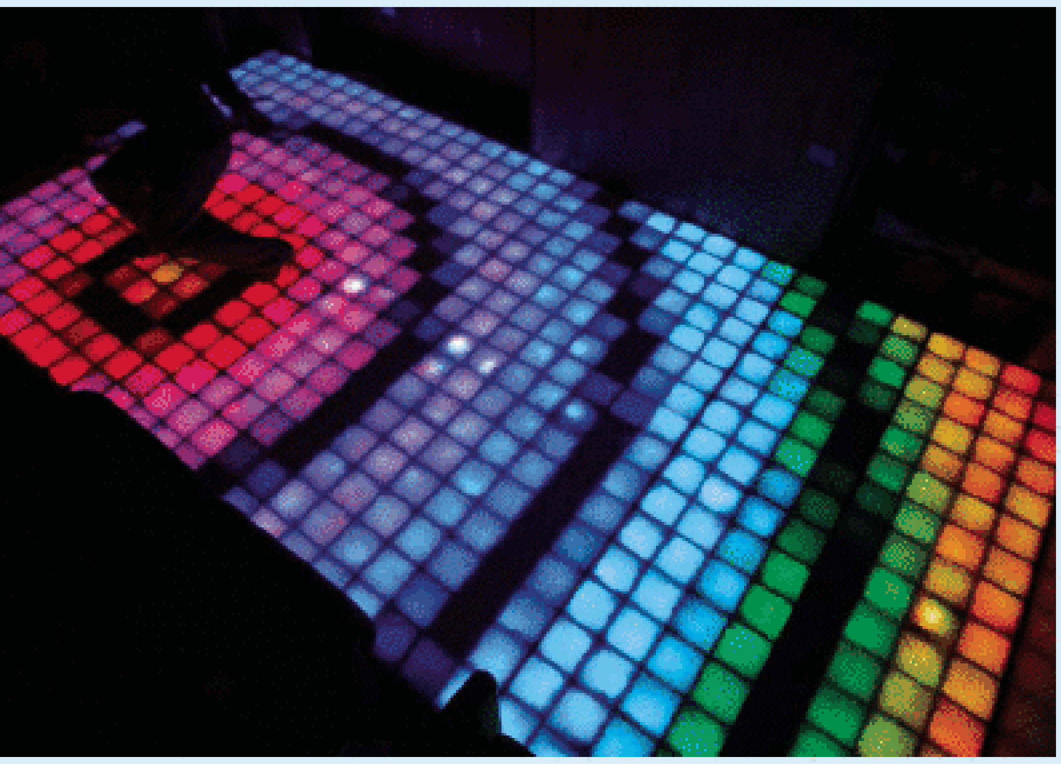


LED Cube Kit

$120 and up

hypnocube.com

Make your own disco with these LED cube kits. Go minimalist with two colors, or go wild with all three!



Disco Dance Floor Kit

dropoutdesign.com

Hey, those craft engineers who did the Disco Dance Floor have a new company and sell kits now. Check 'em out — yay, more 'lectronic kit makers!

Photograph of beetle by Izu Watanabe

Hovercraft Kit

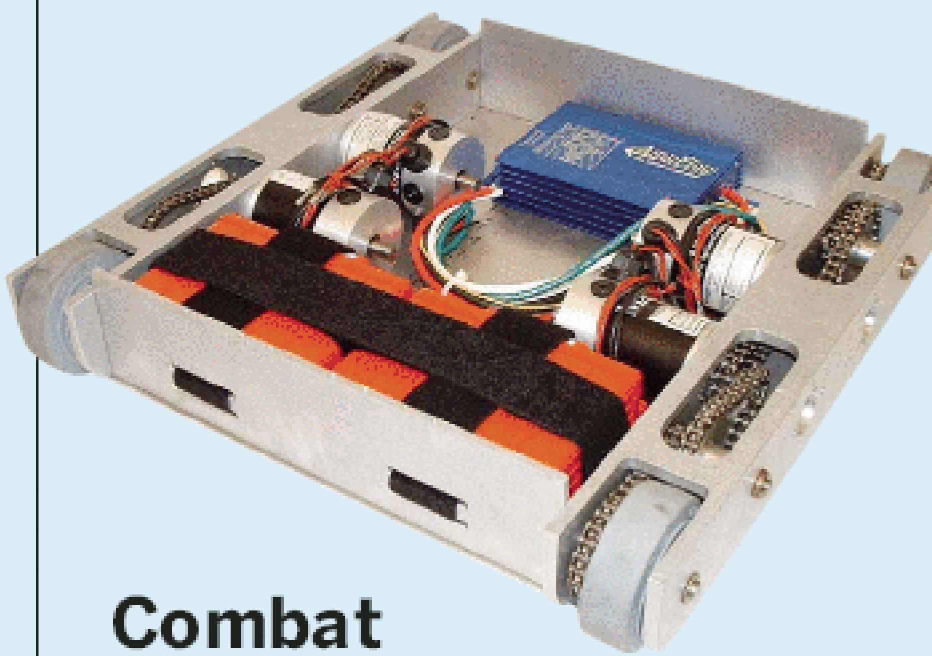
$4,696 (or $112 for the plans) hovercraft.com

Wow, forget those paper plate hovercrafts. This is what you want to make. You know ... for your family.

Power Trips

$50 and up newenergyshop.com

Exergia has a ton of great kits: Stirling engines, steam engines (including a tiny steam-powered trike), fuel cells, photovoltaics — everything "interested individuals" would want to build. A great way to start understanding more about alternative energy technologies.



Combat Robot Kits

$500 battlekits.com

Whoa, BattleKits has combat robot kits ranging from 30 pounds to a massive 340-pounder — all based on the extremely successful "BioHazard" bot.

DIY Temporary Tattoo Kit

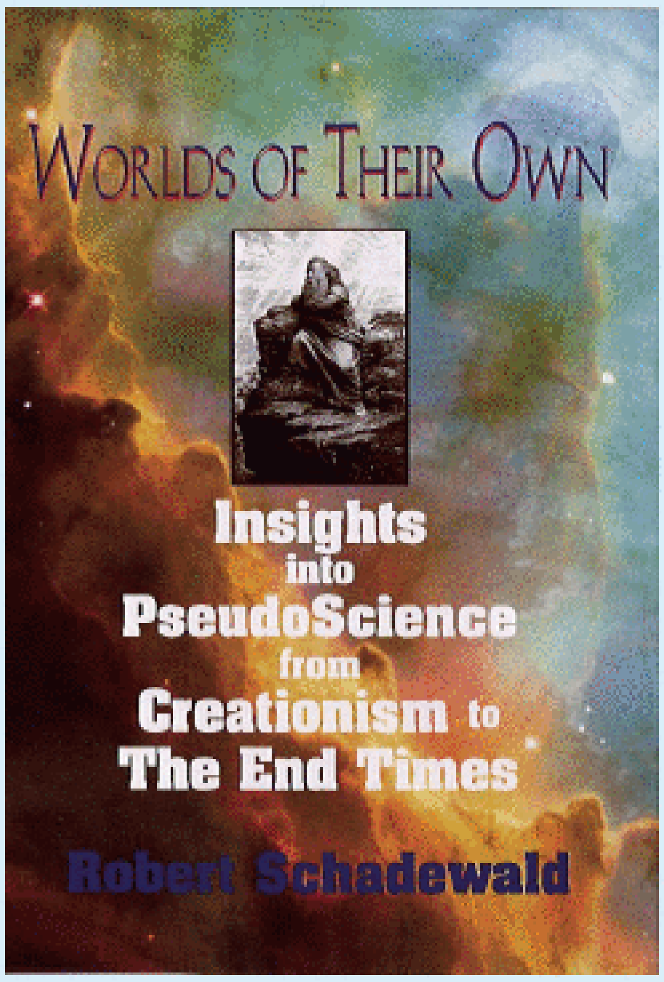
$15 makezine.com/go/tattoo

Temporary tattoos are always a big hit with kids, but the designs usually aren't that great. Here's a temporary tattoo kit for kids so they can make their own (or just use the stencils). It looks like it's a pen with a motor, so you could make your own, too.

Altair 8800

$1,500 altairkit.com

What a great kit — a fully functional Altair! It's not cheap, but the parts are all high-quality, you get free tech support and repair, and you end up with a reproduction of one of the early computers.



« Minds on the Fringe

***Worlds of Their Own* by Robert Schadewald**

$23, SangFroid Press

Bob Schadewald had a lifelong interest in fringe science. This posthumous collection of his published and unpublished materials (skillfully edited by his sister, Lois) is a highly readable account of several varieties of pseudoscience. The unifying theme is "fringe thinkers" who create their own versions of reality, contemptuous of established mainstream science. Bob treats his subjects with respect and even sympathy (he knew many of them personally), but he clearly reveals why their ideas are flawed and misguided.

His chapter on "The Philosophy of Pseudoscience" reveals the common characteristics of these independent thinkers. Here you'll find the stories of historian Immanuel Velikovsky, who rewrote the book on solar system astronomy; John Keely, who claimed he could power a freight train coast-to-coast on a gallon of water; and assorted creationists who freely engaged in "lying for God." This is an informative and entertaining book of continuing relevance, for ideas of this sort never die, perpetually reborn in new clothing.

—Donald Simanek

« Roadside Science

***Pomegranate Roads: A Soviet Botanist's Exile from Eden* by Dr. Gregory M. Levin**

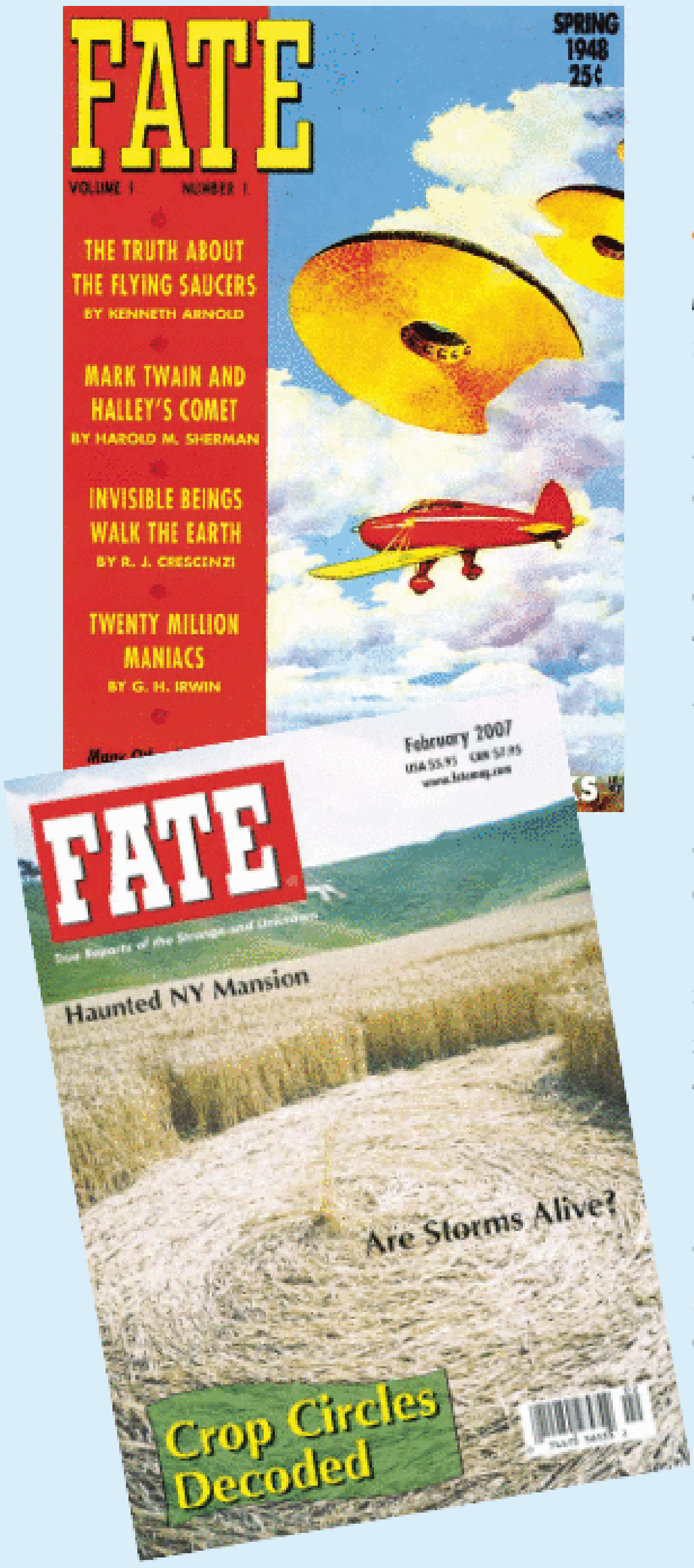
$18, Floreant Press

One tidbit to take away from this book is the word *punicology*, the study of pomegranates. If you were a punicologist, you would call its seeds by the name "arils." There are far more varieties of pomegranate than you can imagine: the author collected 1,117 varieties from 27 countries.

Levin calls this book a "montage" and it truly is: part science, part history, part gardener's guide, part autobiography. It's the life story of a Soviet botanist who left his native Leningrad to work and live at the agricultural station of Garrigala: "I witnessed the prime time and the sunset of this little center of culture at the very edge of Soviet influence." Using Garrigala as his base, he explored the entire region, finding wild varieties of pomegranate growing in subtropical gorges. In 1991, Turkmenistan became an independent country and Levin was cut off from any funding. He ended up in Israel, where there's ongoing research. Levin's life story is about science, not as conducted in a laboratory, but out in the field. "The world should be studied by roaming across it," he writes.

There is also a nice backstory to this book, whose publisher heard about Levin from a BBC broadcast and decided to go find him. She got him to write this book, which you can pick apart to find sadness among its many arils of sweetness.

—Dale Dougherty



« Liberation Psychology

***Fate* magazine**

$32/year (12 issues) fatemag.com

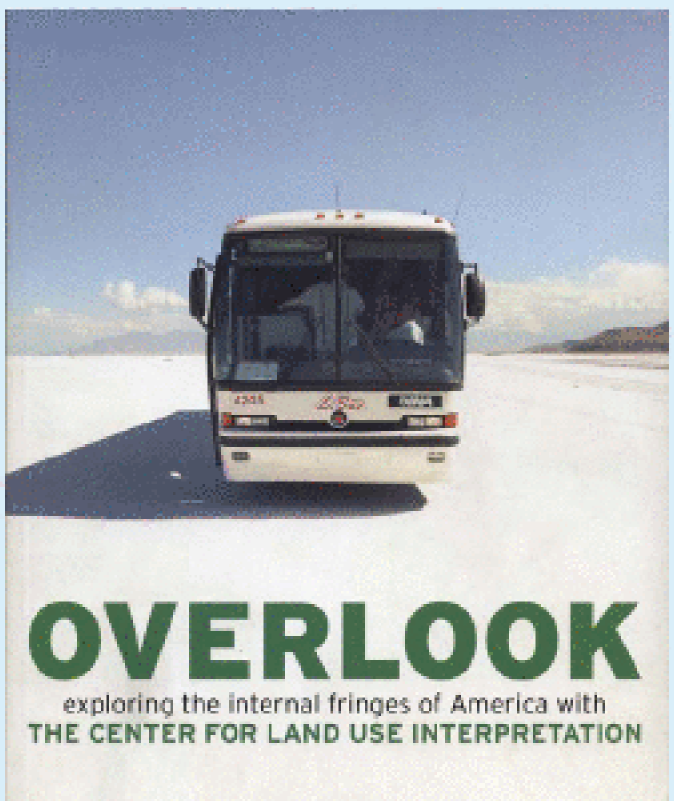
Fate magazine covers UFOs, ghosts, psychic phenomena, and other topics that you'll also see in the *Weekly World News*, but *Fate* takes a more principled approach. Where the *WWN* complicates its voice by mixing real reports (largely from the third world) with funny exaggerations and *Onion*-like fabrications, *Fate* explores with undistanced curiosity.

Fate is run like a fanzine, and the lively community it has created is evident. A long Letters section serves as a miscellaneous forum, and other sections collect readers' first-person accounts of mystical experiences, proof of survival beyond the grave, and other topics.

Features range from local ghost legends, UFO contacts, and speculative history to celebrity stories, like an account of the 1973 séance where Church of Satan founder Anton LaVey summoned the ghost of Marilyn Monroe. Through it all, intriguing ads promote books, psychics, and even messiahs.

If you're more perceiving than judging, and you relish your role as a contributing neuron to the wise hive mind, then you and your pals will have a great time processing *Fate*'s fascinating supply of edge cases and shades of gray.

—Paul Spinrad



« Ground Zero

***Overlook* by the Center for Land Use Interpretation**

$35, Metropolis Books

The Center for Land Use Interpretation occupies a nondescript building along Venice Boulevard in L.A., but its location takes on meaning when you realize that it is next door to, and shares internal walls with, the Museum of Jurassic Technology (read *Mr. Wilson's Cabinet of Wonder*, about the museum's creative take on history and technology, if you haven't already). CLUI, as it is popularly known, is basically a vast database of the ways that humans alter landscape — an "inventory of examples," if you will. They discover the abandoned plutonium dump sites, the covert military installations, the whistle-stop tourist attractions, and the towns flooded by reservoirs (one stunning chapter is devoted to "intentionally drowned" towns). A research institution with a whiff of the art collective about it, CLUI holds exhibitions and runs guided tours, but the book opens our eyes to the spaces we ignore and transforms the way we think about them. A love letter to the outwardly drab outposts of civilization, *Overlook* gives power to the abandoned, the hidden, the unintentionally beautiful, and the just plain weird.

—Arwen O'Reilly

TOOLBOX FAVORITE THINGS

As chosen by John Krewson, an editor at *The Onion*.

Mechanix Gloves Eye protection is great, but *Onion* writers are conscientious about preserving their typing fingers while planning the next heist. We've found comfortable Mechanix gloves deflect impacts, sharp splinters, and hot weld spatter; they also guard against spreading fingerprints around bank vaults. We especially like the Glove Light, with its small but powerful LED flashlight on the back, good for illuminating cramped air ducts or locating loose alarm-panel bolts before they trip the motion sensors.

Dental Tools and Picks You don't have to be a lock-picking enthusiast to love these incredibly sharp, durable, and, we should stress, legal-to-own items — although we're not sure it's ethical to sell them to dentists. We employ them daily in the imprecise fields of "getting gunk off of things" or "cleaning crud out of crannies." People with bad teeth and bad memories will hate the distinctive sound they make, but there's no other downside; they're even cheap.

High-Powered Angle Grinder Anybody can carve their initials in wet cement, but angle grinders let you put your mark on almost anything. Yes, they're perhaps the most dangerous handheld power tool there is: they make showers of sparks, they throw chunks of your material everywhere, and the discs tend to ... well, "explode" is really the only word for worn discs flying apart at 11,000 rpm. Still, nothing's better to have around when you need to get through a barred window or demount a security door, or when some idiot locks their bike to yours. We love the Milwaukee Electric Tools 6155, but anything with enough amps works just as terrifyingly well.

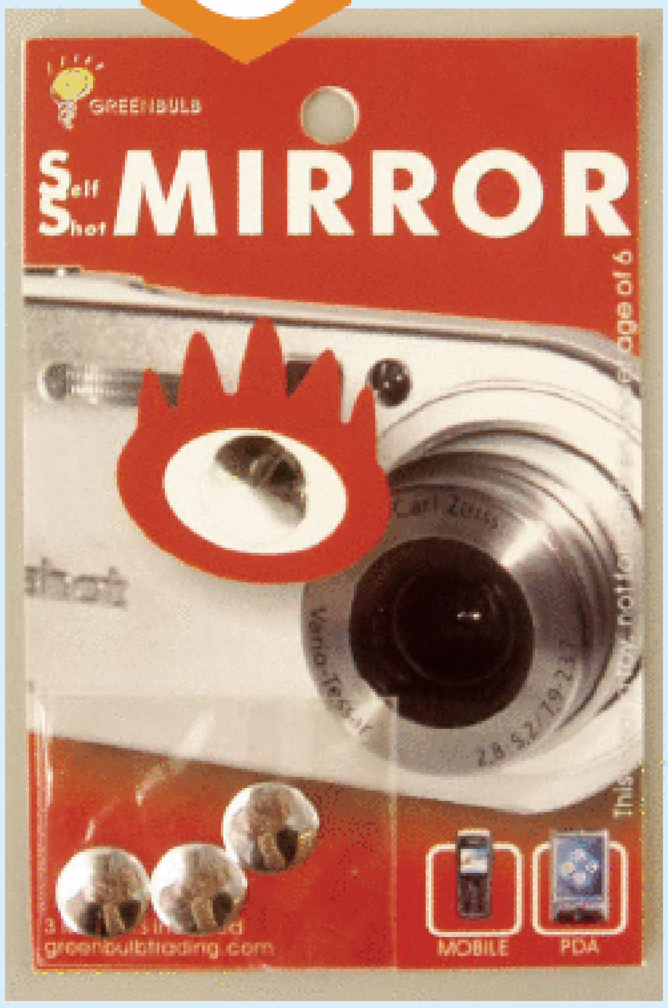
Ready Welder II As MAKE has noted before, one must know welding to be truly capable. And if one wishes to be suave and debonair as well, one must arrive at a moment's notice with one's welder in a ruggedly handsome briefcase, ready to transform an airport shuttle into a fake armored car that's guaranteed to fool sleepy night watchmen. Therefore, one needs the Ready Welder II, a fairly forgiving MIG setup that can run off batteries, welds thin steel even without gas, and packs neatly away in its own ABS case.

CruzTOOLS Tool Kits Most hobbyists neglect to get the good basic pieces you need to work on everyday machinery like counterfeit printing presses, getaway cars, and the trap doors on elevator ceilings. Instead, they get the $20 all-in-one checkout-line kit featuring tools made from an alloy of sawdust, soda cans, and rat droppings. CruzTOOLS RoadTech tools absolutely don't break; every tool in the roll is solid and dependable, from the combination wrenches to the flashlight to the lovely, jewel-like ¼-inch palm-sized ratchet.

The Onion (theonion.com) is a weekly humor magazine and front organization for an intrepid team of international thieves.

I'll Be Your Mirror

SS Mirror $3.45 for 3
greenbulb.com



The SS (Self Shot) Mirror is something I can get behind, er, in front of. It's a little silver button you can stick on the front of your camera to aid in taking self-portraits, and it's a steal at $3.45 for three — and you'll want one for every device.

It's a very easy installation since it's just double-sided sticky, and if it gets scratched or you're bored of it, it's easy to remove. I compulsively take self-portraits, and though I've gotten good at holding the camera at arm's length with some idea of what's in the background, this works like a charm to make sure the camera is at a good angle and everyone's in the photo. *—Andrea Dunlap*

Power Shot

Holga Film Camera $20
makezine.com/go/holga

Holga sounds vaguely Eastern European, but it was created as a budget snapshot camera in China. Then a funny thing happened: a dud at home, it became a hit in the West, for its artfully terrible optics and low-tech approachability.

Yes, it's the Holga, cult favorite of art students and hipsters everywhere. Search Flickr for "Holga" and you'll quickly see how its signature vignetting and erratic focus bring an atmospheric mystery to ordinary photo subjects. The Holga shoots on big 120 roll film, with most fans choosing the 6×6 square-format setting.

It's also a great kid's camera. No pesky shutter speeds to worry about, and if it tumbles down the concrete steps ... hey, it's $20! (It may even work afterwards.) It's also a subtle way to encourage your future hacker. The Holga's technical deficiencies invite (er, require) a certain amount of remedial engineering, like fixing the back latches, plugging light leaks, and finding a use for the non-functional "sunny" setting. But no worries: the net is overflowing with tips, mods, and other users to give advice. See holgamods.com/mods/mods.html for inspiration. *—Ross Orr*

Photograph by Michael Simmons

Circular Logic

Circular Polarizing Filter
$30 and up tiffen.com

A circular polarizing filter is a wonderful tool that gives me an amazing amount of control over my photographs, yet most amateur photographers don't take advantage of one.

It allows me to eliminate or emphasize reflections on a variety of surfaces including glass, water, many plastics, and even skin, just by rotating the filter on the end of my lens. Amazingly, there's even a band of the sky that can be darkened using the filter without affecting the rest of the scene.

Don't think: "I guess I can't get a shot of the circuit board without a distracting reflection." Get a circular polarizer.

They come in particularly handy when you don't have much control over the lighting. They're sold in sizes that will fit on virtually any SLR lens and can be attached to many non-SLR cameras with an adapter.

A circular polarizer will cost two or three times more than a linear polarizer, but linear polarizers have a nasty habit of interfering with the exposure meter and autofocus system in most cameras, so the extra money is well spent.

—Tanner Beck

Tanner Beck is a necessity-loving nerd photographer in Ann Arbor, Mich.

Gareth Branwyn is the cyborg-in-chief of streettech.com.

Andrea Dunlap is a photographer and filmmaker for seedlingproject.org.

Ross Orr keeps the analog alive in Ann Arbor, Mich.

Donald Simanek's "Museum of Unworkable Devices" can be found at lhup.edu/~dsimanek.

Brian Stucki lives in Las Vegas with his family and writes for freemacware.com.

Have you used something worth keeping in your toolbox? Let us know at toolbox@makezine.com.

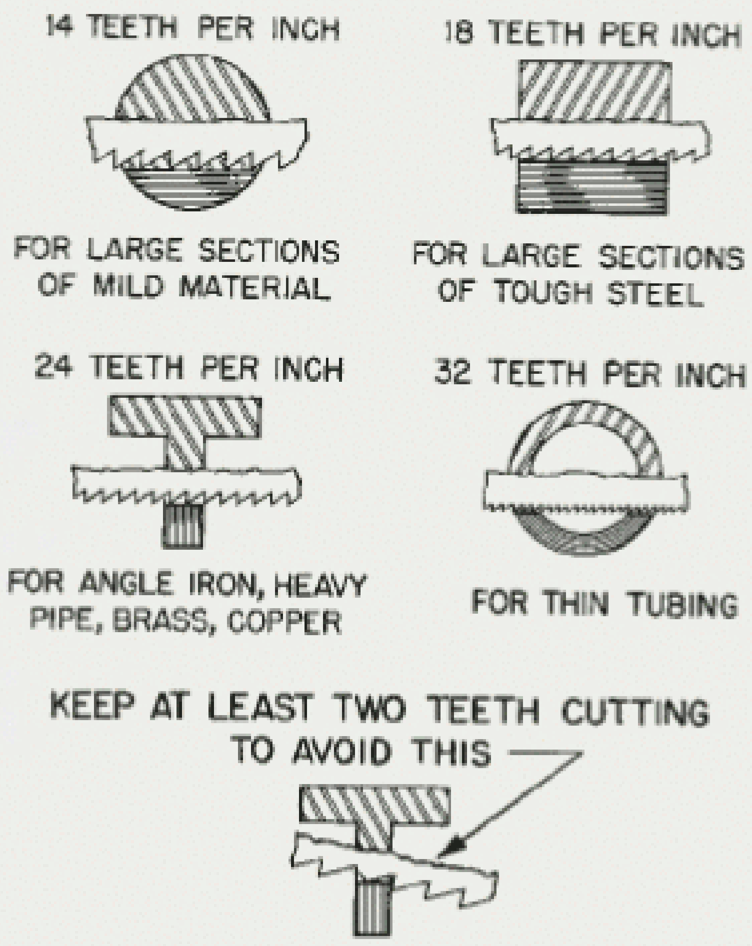
BLAST FROM THE PAST

Old-School Hand Tool Hacks

By Mister Jalopy

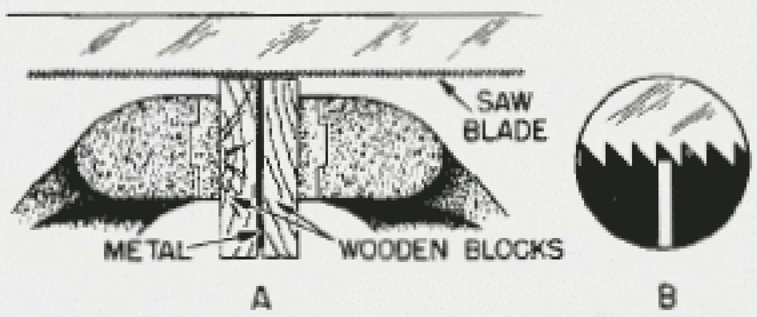
What I learned from the 1963 Bureau of Naval Personnel Training Course.

Hacksaw Hacks

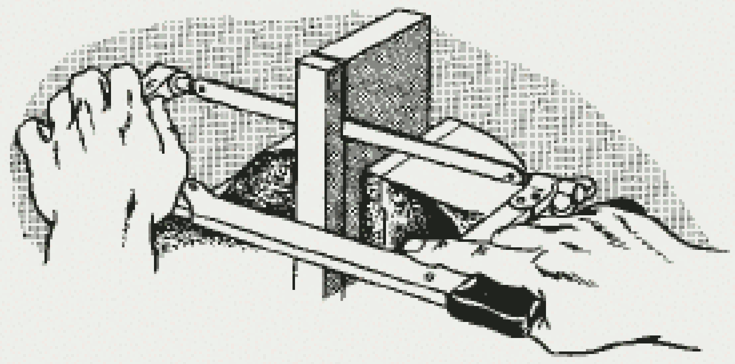


Blade Selection

Select the most aggressive hacksaw blade that's appropriate for the task at hand. For example, a 14 teeth per inch (TPI) blade has much larger teeth than a 24 TPI blade and will comparatively cut much faster. But, if the teeth are too big for thin metal, they will hang up on the edge of the material and the blade will bend, spindle, fold, and mutilate the metal like a postal worker. The rule of thumb is that the targeted material should be thicker than 2 blade teeth.



Avoid bending thin metal by stabilizing between two wood blocks.



Turn Blade in Frame

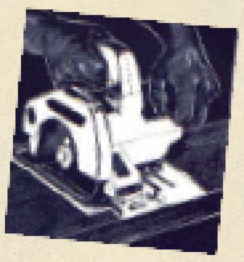
The distance between the blade and the frame is called the throat. The depth of the throat determines how deep you can cut before the work piece bumps into the hacksaw frame. I was awfully embarrassed the first time I saw somebody turn the hacksaw blade at a perpendicular angle to the frame to create an infinite throat. So accustomed to seeing the hacksaw in the traditional manner, I never thought to turn it on edge.

***TIP:** What a pain! Changing blades for every job! Instead, I have a garage-sale hacksaw frame for each type of blade. Four hacksaws on a single pegboard hook scream "progress" from across the room.*

File Hacks

Interior files for expanding holes and clearing corners.

SQUARE: Tapered file used to enlarge rectangular holes.
TRIANGULAR: Open sharp angles and the interior corners of rectangles.
ROUND: The unfortunately (but accurately) named "rattail" for holes and rounded corners.



Despite the lackluster title, the U.S. Navy publication *Basic Hand Tools NAVPERS 10085-A* would create a revolution if it were required high school reading. A nation of graduates would be armed with the basic knowledge to change the world around them. Rather than settling for extended warranties and temporal furnishings, individuals could take control of their lives by being handy. It is the rare machinist, farmyard engineer, or Old World craftsman who claims to know how to do everything, as they recognize it is a lifetime of learning. The Navy's *Basic Hand Tools* is an extremely dense, informative, and generous book, as it can save a year in the handy continuum — one hack at a time.

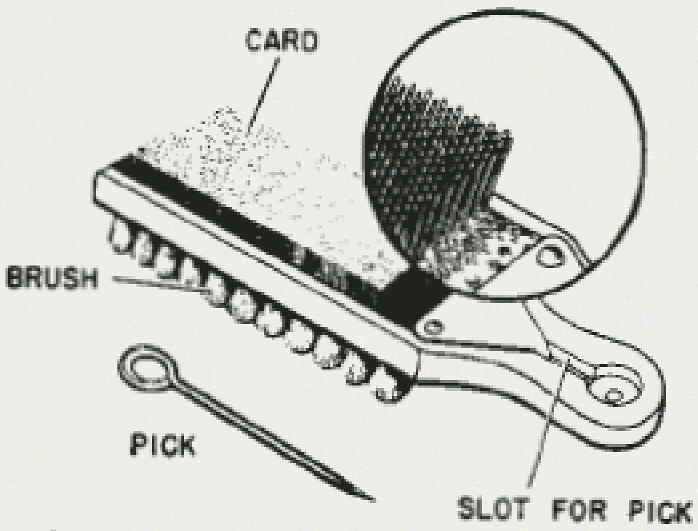
Exterior files for larger, exterior work.

FLAT: General purpose, most often used.
MILL: Thinner, finer, single-cut files for more delicate work.
HALF ROUND: Match the curve radius as closely as possible to the curve of the work.

Cleaning Files

Whether you are using sandpaper or grinding discs, most fine cutting surfaces lose efficacy when they "load up" and fine particles clog the cutting surface.

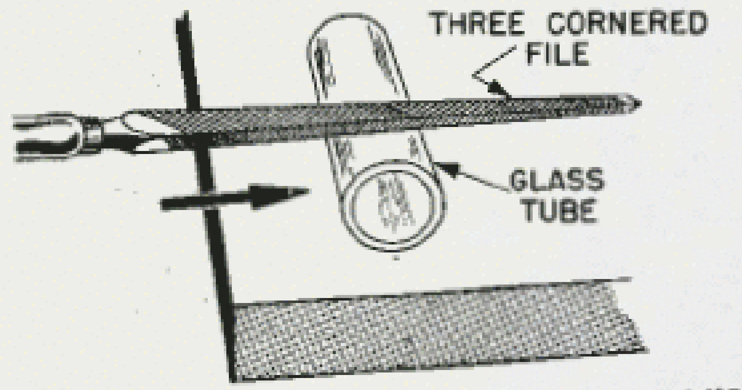
Pick out the bigger chunks, use the card to brush with the grain of the teeth, and then finish with the brush. Resist oiling files as the added lubrication will negatively impact the cutting ability.



File cleaner.

Cutting Glass Tube

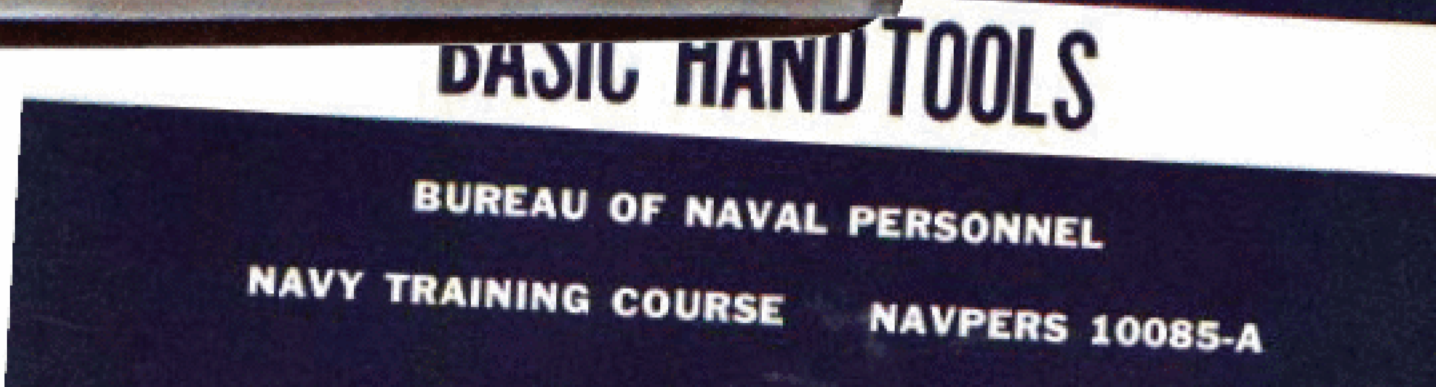
With leather gloves on, use the triangular file to score the glass as you roll the tube. When you have scored the circumference, place a wood matchstick under the glass tube about 1/8" from the scored line. Hold one end securely and press on the other side until it snaps. Clean up the cut with emery cloth wrapped around a file or block of wood. Be careful! Ask to see my gory scar caused by a moment of daydreaming while glass cutting!



Cutting glass tubing with a three-cornered file.

Clean Up Bolt and Pipe Threads

Though technically not a file, I keep my thread restorer with my other files if for no other reason than it looks right in the file drawer! Each face of the thread restorer has teeth for a different thread "pitch." The thread restorer will not perform miracles on heavily damaged bolts, but it does clean up rusty or dirty threads with a little patience. Work slowly and continually check with a nut or female pipe to gauge progress. I will use a smidge of automatic transmission fluid to help matters along when thread-cutting oil is not available.



READER INPUT

Where makers tell their tales and offer praise, brickbats, and swell ideas.

It was great to see the ornithopter project in MAKE 08! For anyone who missed it, an ornithopter is a device that flies like a bird, by flapping wings. I hope MAKE readers find the same fascination and enjoyment I've had from designing and building my own flying bird models over the past 20 years.

Gurstelle's build instructions were great as usual, but the intro focused on the negative. Instead of giving a sense of all the fantastic accomplishments in this field, it was the same rhetoric we've heard so many times before: people can't fly by flapping wings, but you can build a small rubber-band-powered one. The "short history" tells little about what's actually been done. As a result, makers didn't get to hear about all the cool stuff people around the world have been building.

Often the ornithopter concept is judged a failure or impossibility because supposedly no manned ornithopter has flown. This is flawed for two reasons.

First, why should the concept be judged at the manned scale? If we build a device the size of a bird that flies like a bird, then we succeed in imitating bird flight. MAKE readers are smart enough to see where technology is headed. In the future, there will be a lot of unmanned vehicles doing useful work. Moving people around will be far less important than it seems now.

Also, there have been some manned flights. They were dismissed in MAKE out of pure skepticism. The idea that we can't fly is such a deeply internalized myth that people can't accept news of a successful flight after it happens. Of course you can't fly like Daedalus by gluing feathers on your arms, but with the right technology and a powerful-enough engine, we *can* fly by flapping.

Ultimately we can make anything that exists in nature. Even Leonardo understood this, 500 years ago and well before the means were in sight.

—Nathan Chronister

Bill Gurstelle replies: **Mr. Chronister's points are well taken. I, too, look forward to the eventuality of the manned ornithopter.**

Thank you for publishing your magazine! Like many engineers, I got started in engineering by tinkering with ham radio (á là Dilbert), storing static electricity in styrofoam cup capacitors, blowing up power supplies — taking things apart to see how they worked. In short, I got started by engaging in the kind of play you show in each issue of MAKE.

When engineering became a job, somehow the fun got lost. I believe that too much of engineering is treated as an assembly line function — compartmentalized, categorized, commoditized. It's as if creativity can be planned and released in exact, controlled amounts at the exact, appropriate times.

Thanks for bringing back the "messy" human part of engineering. Your magazine should be required reading in every engineering school in the country.

—Jesse Alexander

Editor's Note: **Many readers (and the entire magazine staff) were touched by Colin Berry's memoir (*MAKE, Volume 07, page 36*) about his older brother's soap box derby successes and failures in the 1970s. We also persuaded Colin to record the piece in a quite memorable audio file; you can listen to it at makezine.com/blog/archive/2006/10/the_maker_file_2.html. After listening to the piece, one reader had his own nostalgic tale to add to the soapbox saga.**

Colin,

I just listened to your touching podcast story about your brother and his soap box derby experience. What a compelling story. It took me back to my innocence and youth as I raced in the 1976 soap box derby in Valparaiso, Indiana.

As I listened, I could not believe the race similarities. I too crashed at the end of the race; the brake malfunctioned (pushed too hard and lifted the weight off the wheels), threw my car left, and my rear axle hit the guardrail, and there would be no more racing for me that 4th of July as the axle was bent beyond repair.

My family was there cheering me on amongst the crowd of about 4,000 spectators, and I felt embarrassed and somewhat of a failure at the time to have my dream taken away so quickly and in such a highly public way. But the good news was that everyone remembered me and wanted to look at the damage to the car, and I got interviewed on the radio.

I remember feeling crushed as I thought of all of the hours that I lovingly labored on my passion. The dream was over in a flash, and the only celebration

would be a cake at the house and a party, as I tried to forget the pain that I felt as my dream of making it to Akron was swept away.

As a child growing up, I was obsessed with the race and clearly remember the "Magnet Scandal." How small a world it is to think that this scandal impacted your brother and family's life. Thanks for the great podcast, as it gave me goose bumps to listen to it, and I can't wait to share it with my brother, nieces, nephews, and family. Thanks again.

—Rodney Rumford

I can't believe that nobody has flagged this error in MAKE 07, DIY Circuits, "Hello, World." On page 150, there is a phrase: "the `display 3` routine shows a '3' by turning on all the segments, except for the top-right and bottom-right ones." That will result in an uppercase "E". The phrase should read: "the `display 3` routine shows a '3' by turning on all the segments, except for the top-left and bottom-left ones." Thanks!

—Bruce Cowan

My son and I made the workbench based on the directions I found on makezine.com. First of all, I love the bench, and we had a great time working on it. I came across a neat design enhancement (in my humble opinion) completely by accident. When I was deciding on cutting the legs, I went with 36 inches. This meant that I used an 8-foot 2×4 to make two 36-inch legs, which left a 24-inch piece. I did this twice. When I finished the assembly, I used the leftover 24-inch pieces to further strengthen the top by installing them at 32 inches and 64 inches as braces. Thought you might like that. Now there's no waste (even though I know I could have used the pieces on something else).

Thanks for sharing the design. It made me clean up the garage after.

—Art Trombley

MAKE AMENDS

In the special gift guide section of MAKE, Volume 08, XGameStation programmer Andre Lamothe's name was misspelled.

On page 25 of MAKE, Volume 08, the kinetic sculpture artist Nemo Gould's name was transposed in both the story and the photo credit.

RETROSPECT

String Theory

By George Dyson

High-tensile fastenings stand the test of time.

Lashing and sewing, among the oldest of technologies, remain competitive with the best. String was not invented — it was discovered: as vines hanging in the tropical jungle, sinews exposed when carcasses were scavenged in the savannah, tendons and baleen fibers appropriated by arctic hunters who took sea mammals apart. Net making is even older: witness the highly evolved spider's web.

The puzzle is not why did human beings start lashing things together, but why did they stop? We still sew our clothing, sails, and tents, and our surgeons still sew us, but we no longer sew or lash much else. The few exceptions — like the carbon-fiber skeleton of the *Gossamer Albatross*, Paul MacCready's human-powered aircraft that crossed the English Channel in 1979 — are rare. Ironworkers still assemble the steel backbone of our reinforced-concrete-based civilization with tie-wire, but these temporary lashings are quickly covered by cement. Anything that is lashed together is dismissed as jury-rigged or haywire, makeshift at best. We only tie things together after they break. Lashing survives on the front line of emergency repairs, not because it is primitive, but because it handles loads — especially the sudden loads that break things — so well.

"In pure strength, apart from their flexibility, the lashings, sewings, and bindings used by primitive peoples, and by seamen down to recent times, are more efficient than metal fastenings," argued James E. Gordon in *The New Science of Strong Materials*, the best study ever written on why some things hold together and why other things fall apart.

When Thor Heyerdahl built the *Kon-Tiki* for a voyage across the Pacific, its structure was lashed together, not only to prove a historical point, but because this was the only method of fastening that held any hope of keeping the soft Peruvian balsa logs from falling apart. When Fridjtof Nansen and Hjalmar Johansen left their ship, the *Fram*, frozen in the polar ice at 84°N in March of 1895, to see if they could reach the pole on their own, they took lashed-together sledges and bamboo kayaks, and made it back to Franz Josef Land — 15 months later — alive. Their survival hung by a thread. "When, for instance, a rib had to be re-lashed," explained Nansen, "we could not rip up the old lashing, but had to unwind it carefully in order not to destroy the line."

When I built a treehouse 95 feet up in a Douglas fir on the coast of British Columbia (*see MAKE, Volume 05, page 190*), I used #15 tarred nylon seine twine to tie the framework to 14 different branches, not because I had any objections to pounding nails or driving lag bolts into living wood (working around logging camps had cured me of that), but because I wanted to be sure that house and tree remained attached. The entire structure had to be able to flex wildly in 60-knot winds, and no mechanical fasteners were flexible enough.

The puzzle is not why did human beings start lashing things together, but why did they stop?

Photograph by Beverly Dobbs, ca. 1906, courtesy Baidarka Historical Society

I adopted lashings when I began constructing aluminum-skeleton kayaks, not for historical authenticity — or I would not have used aluminum — but because tensile fasteners made practical sense. When two pieces of high-tempered, thin-wall aluminum tubing are attached with eight turns of 60-pound test twine, you can be sure that it will take something close to $8 \times 4 \times 60$, or 1,800 lbs., to pull them apart. There is no risk of metal fatigue, and the joint will flex elastically (and repeatedly) long before it breaks. Shock absorption is built into every joint.

If you sew two pieces of tempered aluminum plate together, there is no loss of temper as in a weld, and none of the corrosion that affects metal fasteners

Left: Siberian trading party in Nome, Alaska, after crossing Bering Strait in their skin boat.

Right: Joe Ziner and Lou Kelly in the author's kayak-building workshop at Belcarra Park, British Columbia, March 1977. In four months, using miles of braided nylon twine, we lashed together six 28-foot, 3-hatch baidarkas (kayaks), and launched them on a voyage north. The frameworks are 6061-T6 aluminum tubing, 6061-T6 aluminum sheet (from salvaged road signs), and Sitka spruce.

Below: The author lashing the bow assembly for a one-hatch baidarka, 1981, using 60-lb. test nylon twine. The holes in the aluminum are carefully countersunk. If the twine breaks frequently you are applying too much tension; if it never breaks you are not applying enough.

Photograph by George Dyson (above); photograph by Ann E. Yow (below) in the presence of salt. You can safely predict the ultimate strength of the resulting assembly, since the lashings will bear the load equally, and there are no hard stress points to form a weakest link or to propagate cracks. When you sew a seam on a thick nylon kayak skin with four 40 lb. test stitches every centimeter, you can count on the seam taking a load of 200 lbs. per inch without tearing apart.

Not only are lashed fastenings unusually robust and structurally sound, they are pleasant to work with, are forgiving of sloppy craftsmanship, and celebrate the abilities of human hands. If you complete a seam or a lashing and decide it could have been done better, you just undo it and try again. You can stop work at a moment's notice, and resume at any time. You can strive for perfection, but a haphazard-looking lashing will be almost as strong.

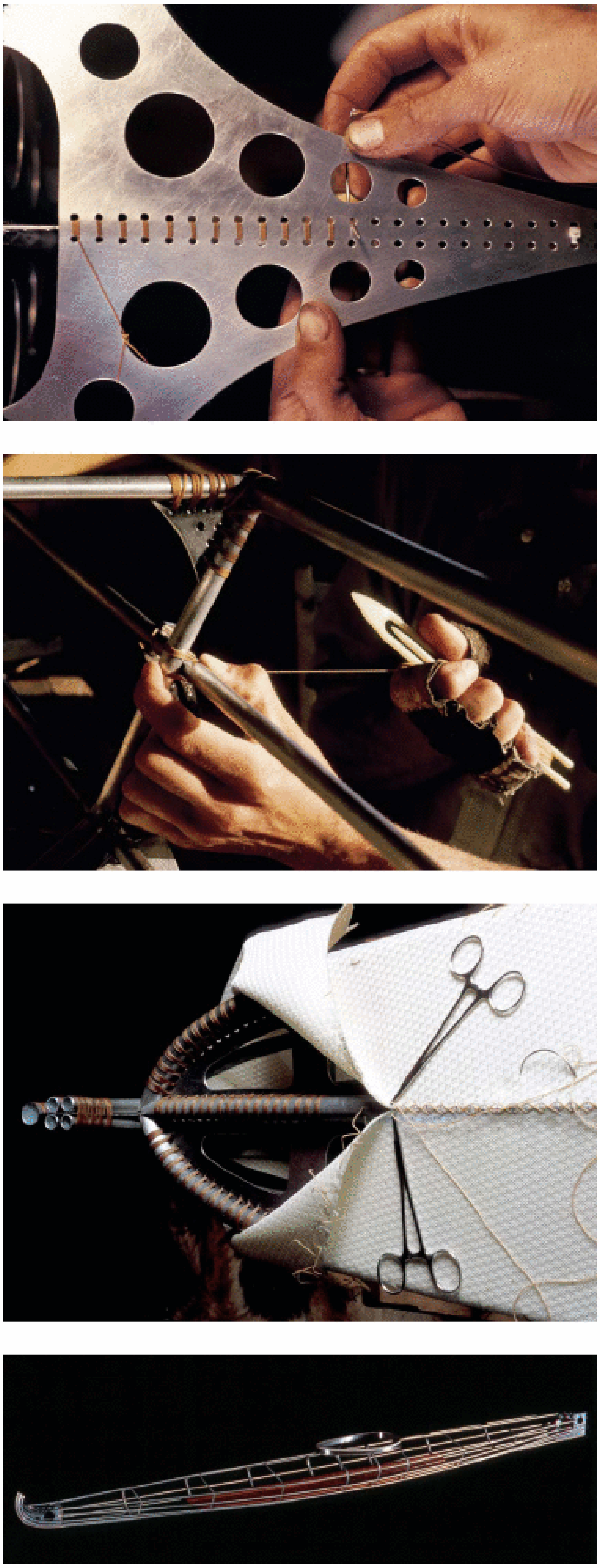
Traveling through heavy seas in a loaded and lashed-together kayak, there is a reassuring creak in the vessel's joints, similar to the old days of loosely fastened wooden sailing ships, designed to work in a seaway for months and years on end. In a modern welded or composite vessel (or aircraft), any sounds emanating from the structure are cause for alarm.

With a load-bearing structure that is sewn or lashed together, what you see is what you get. Finite element analysis (FEA) is now used, in association with computer-assisted design, to predict stress, requisite materials, and required fasteners in a given structure under a given load. The empirical design of lashed structures is the ancestor of FEA. Lashings (and the elements they join together) are finite elements, and can be used to handle stress (and predict strength) in a directly analogous way.

If we examine how nature joins high-strength, high-stress materials — mending a broken bone, joining the plates in a baby's skull, healing a cut in an animal's skin, or attaching a mussel to a rock in the surf — we see lashings at work, on a microscopic scale. In designing and building our own structures, we can do no better than to emulate nature. We have, and we will again.

Approximately 35,000 years ago, a small band of human beings launched into the open Pacific Ocean from Malaysia in lashed-together vehicles. The experiment was a success. Why stop?

George Dyson, a kayak designer and historian of technology, is the author of Baidarka*,* Project Orion*, and* Darwin Among the Machines*.*



Baidarka (kayak) construction, circa 1986. The completed 5-meter (16.4-foot) skeleton, made of 1/16" aluminum sheet and ½" o.d. 6061-T6 aluminum tubing (.049" wall) weighs 18 lbs. The skin material shown here is a 26 oz., (per square yard) double-weave heat-shrinking nylon. The twine is a phenolic-coated nylon obtained at very low cost as remaindered tire cord.

Photography by Ann E. Yow

AHA! Puzzle This

By Michael H. Pryor

MAKE's favorite puzzles. (When you're ready to check your answers, visit makezine.com/09/aha.)

A Matter of Degree

What is the angle between the minute hand and the hour hand at 3:15 on an analog clock? (Hint: It's not 0.) How often does the minute hand pass the hour hand on an analog clock?

Reptilian Repetition

At one point, a tropical island's population of chameleons was divided as follows:

13 red chameleons
15 green chameleons
17 blue chameleons

Each time two different-colored chameleons would meet, they would change their color to the third one. For example, if green meets red, they both change their color to blue. Is it ever possible for all chameleons to become the same color? Why or why not?

100 Lockers

You have 100 lockers in a high school hallway that are all initially closed. You walk down the hallway 100 times starting at the first locker each time. The first time down the hallway, you go to every locker, and if it is open you close it; if it is closed, you open it. The second time you walk down the hallway, you only visit every second locker (lockers #2, #4, #6, etc), reversing the state of each locker you visit. The third time through, you visit every third locker (lockers #3, #6, #9, etc). You continue this until your 100th pass down the hallway when you only visit locker #100. When you are finished, which lockers are open and which are closed?

Illustrations by Roy Doty

Michael Pryor is the co-founder and president of Fog Creek Software. He runs a technical interview site at techinterview.org.

MAKER'S CALENDAR Compiled by William Gurstelle

Our favorite events from around the world March · April · May

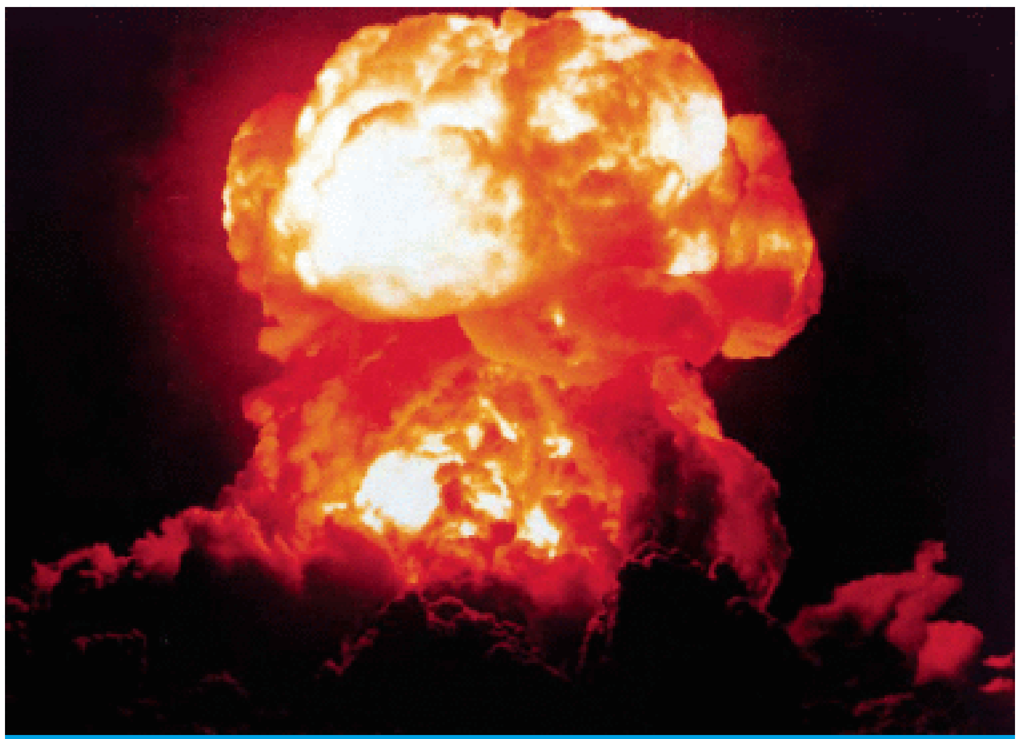
MARCH

»University of Illinois Engineering Open House March 9-10, Champaign, Ill.
The University of Illinois Engineering Open House is one of the best showcases of engineering creativity in the country. This year's theme is "Inspiring Innovation." From crushing cars with huge anvils to crunching numbers with tiny microprocessors, EOH is where you can see what the future engineers of the world have in mind.
eoh.ec.uiuc.edu

»Nevada Test Site Public Access Day
March 20, April 24, May 30, 65 miles NE of Las Vegas
A few times a year, the usually off-limits Nevada Test Site allows a busload of visitors to look around. A 250-mile bus tour begins in Las Vegas and takes visitors to the various nuke-created craters, the town of Mercury, and more. www.nv.doe.gov/nts/tours.htm

»ShmooCon
March 23-25, Washington, D.C.
ShmooCon is a popular East Coast hacker convention. Those attending bear witness to some of the most devious minds, code, and gadgets focused on breaking and remaking the technology the rest of the world simply buys and uses.
shmoocon.org

»The Texas Mile
March 24-25, Goliad, Texas
Land speed racers from around the country meet on the long, long, runway of the Goliad Industrial Air Park to test their fastest machines (motorcycles and automobiles). Some attain speeds of more than 250 mph.
texasmile.com


Have a blast at the Nevada Test Site Public Access Day.

» O'Reilly Emerging Technology Conference March 26-29, San Diego, Calif.
ETech frames the ideas, projects, and technologies lurking just below the mainstream radar. Every year, 1,200 technologists, hackers, researchers, thinkers, strategists, and entrepreneurs meet in San Diego to learn how to make technological magic.
conferences.oreillynet.com/etech

»Rube Goldberg Contest Finals
March 31, West Lafayette, Ind.
A Rube Goldberg device is any exceedingly complex apparatus that performs a very simple task in a very indirect and convoluted way. Inspired by machines drawn by the eponymous cartoonist, the contest inspires college students nationwide to design whimsical machines that require skill and imagination. A series of regional events culminates at the national championship held at Purdue University.
purdue.edu/UNS/rube/rube.index.html

APRIL

»Edinburgh Scotland Science Festival
April 6-15, Edinburgh, Scotland
This festival features hundreds of talks, tours, and exhibitions for children, families, and adults in locations around the city. This is one of the world's largest public celebrations of science and technology.
sciencefestival.co.uk

»NOTACON
April 27-29, Cleveland, Ohio
A favorite of Midwestern hackers, this annual computer enthusiast conference held in Cleveland explores and showcases the technologies, philosophy, and creativity associated with hacker life.
notacon.org

»Toledo R/C Model Show April 13-15, Toledo, Ohio
This is one of the nation's premiere events for radio-controlled vehicle enthusiasts. Modelers and suppliers from across the nation come

Mrs. Ohio's big R/C plane.

to this show to see the latest and greatest in R/C models, electronics, gadgets, and parts. toledoshow.com

MAY

»Interactive Telecommunications Program Show May, New York, N.Y.
Over 100 interesting projects at New York University's annual Interactive Telecommunications Program Show draw thousands of visitors. It's a 2-day exhibition of interactive and unusual sights, sounds, and physical objects from the student artists of ITP. This event is free and open to the public. itp.nyu.edu/show

»The Intel International Science and Engineering Fair May 13-19, Albuquerque, N.M.
The world's largest pre-college science competition, with over $3 million in awards and scholarships, will attract 1,500 top science and technology high school students representing the 50 U.S. states and 40 global countries. sciserv.org/isef

EDITOR'S CHOICE

»Maker Faire May 19-20, San Mateo, Calif.
It's the big kahuna of maker-style events, sponsored by MAKE. Over 20,000 makers come together for a weekend of projects, eye-opening demonstrations, entertainment, and fun at the San Mateo Fairgrounds, near San Francisco. From robotics to electronics to pyrotechnics, it is a celebration of the maker ethos encompassing exhibits, seminars, and many hands-on opportunities. Please introduce yourself to the staff of MAKE, who will be on hand. makerfaire.com

»Andrews Air Force Base Joint Services Open House May 19-20, Washington, D.C.
The JSOH pulls in crowds of nearly 400,000 people. The spectacular aerial demonstrations are the biggest attractions. Typical displays include precision aerial maneuvers by the Air Force's Thunderbirds, aircraft fly-bys, parachute jumping demonstrations, and ground displays. andrews.af.mil

»Jet Propulsion Lab Open House May 19-20, Pasadena, Calif.
This event showcases JPL's accomplishments with exhibits and demonstrations about the laboratory's ongoing research and space exploration. Many JPL scientists and engineers will be on hand to answer questions about the lab's work. www.jpl.nasa.gov/pso/oh.cfm

EDITOR'S CHOICE

»World Championship 39th Annual Kinetic Sculpture Race May 26-28, Arcata, Calif. to Ferndale, Calif.
Art and engineering combine to produce imaginative human-powered racing machines. Thousands of spectators watch as dozens of highly beautiful and cleverly engineered vehicles resembling animals, vegetables, and giant eyeballs pedal 30-plus miles over land and water for the simple glory of winning. kineticsculpturerace.org
(*See page 28 for a story about last year's race.*)

»Atlas V Rocket Launch May 31, Cape Canaveral, Fla.
An Atlas rocket is scheduled to launch ICO North America's geostationary satellite into orbit in late May. The rocket will fly in the powerful 421 vehicle configuration with a 4-meter fairing, two solid rocket boosters, and a single-engine Centaur upper stage. kennedyspacecenter.com/launches/scheduleStatus.asp

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 is 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.

HOMEBREW

Our 6,000-volt Wedding Cake

By Heidi Kumao and Michael Flynn

Our rotating, sparking, 6,000-volt wedding cake was the highlight of our wedding ceremony, because our collaboration on this project represented the way we approach our life together.

Our design began with gear-shaped cakes, symbolizing the way our lives have meshed. We agreed that the cakes should actually rotate, so we mounted plywood gears on large lazy Susan bearings, with one of the gears driven by a 10 rpm electric motor.

We decided the traditional cake-topping figures should be recognizable caricatures of ourselves, and that a spark should jump between the hands of the bride and groom to represent passion. The spark was provided by a 12,000-volt neon-sign transformer, which we hid in the huge "Wed-O-Matic" gift box underneath. The electric current traveled from the transformer to the figures through electric motor brushes that scraped together under the rotating lazy Susan bearings. It was important to avoid arcing the current through the ball bearings themselves, so the sliding electrical contact was made on the uppermost disc of each bearing. Jumper wires ran the current from the top plate of the bearing, through our three cakes, up the figures' legs, and out through their arms.

The completed machine was finally ready for its first test run five days before the wedding. We left the drive motor's frame ungrounded for fear of attracting sparks to the motor, forgetting that the neutral wire inside the motor windings is itself a path directly to ground. When we energized the transformer, sparks sizzled and leaped, destroying the wiring inside our specially ordered, slow-rpm motor.

Luckily, Heidi always orders a spare motor for her art projects. We grounded the new frame so that any stray sparks could be grounded without entering the motor's windings. We ran the transformer at half power, and we found that it still produced sparks adequate to jump between bride and groom. This cake was too dangerous to leave plugged in, so we demonstrated its full function only during the cake-cutting ceremony. We played a fun, cartoon-style tune by Raymond Scott, "Powerhouse," and wore oversized safety goggles for dramatic effect.

You can see the video of Heidi and Michael's 6,000-volt wedding cake performance at heidikumao.net/wed.html.

Photograph courtesy of Heidi Kumao and Michael Flynn

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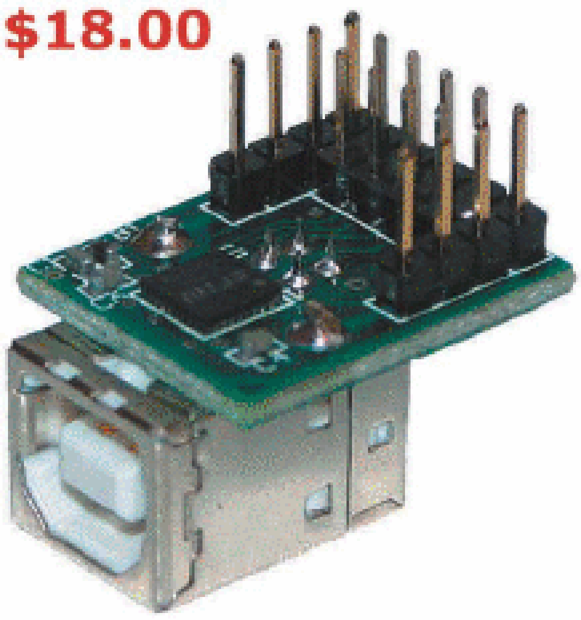

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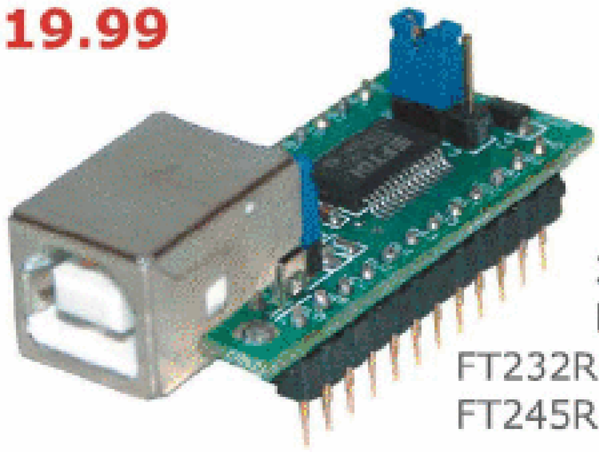

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